The role of organic and free range poultry production systems on the dioxin levels in eggs

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Introduction

Dioxins encompass a large family of polychlorinated dibenzo-p-dioxin and dibenzofuran congeners (Huwe; 2002). They are formed during incomplete natural or industrial combustion processes and a variety of other industrial processes and are considered as the most toxic substances known. Dioxins may cause dermal toxicity, immunotoxicity and reproductive and developmental toxicity. The toxicity of dioxins may differ considerably. The congeners, which are substituted in the 2,3,7,8-position, are most toxic. Therefore, of the many theoretically possible congeners, 17 are considered to be especially important from a toxicological point of view. Analytical results of these 17 congeners are combined into so called toxic equivalents (TEQ). The conversion to TEQ is based on different binding activities of the individual dioxins to the dioxin receptor(s), whereby each dioxin is given a toxic equivalency factor (TEF), calculated from the toxicity of a congener relative to the most toxic compound 2,3,7,8-TCDD, which has been given an arbitrary TEF of 1. The amount of each congener is multiplied by its TEF, giving the TEQ for that congener. All TEQ's of the 17 congeners are added and give the total TEQ for the sample investigated.

Human exposure to dioxins

Approximately 90% of the dioxin uptake by humans is due to food consumption, whereby 90% is caused by animal products. This is due to the lipophilic nature of dioxins and their accumulation in the food chain. Since the 1980's, many countries have implemented measures to reduce dioxin emissions from industrial and waste burning sources. Although this has led to a drastic decrease in dioxin emissions, there is still a heavy environmental historical burden, as many of the congeners are persistent. This is due to the fact that they are not easily degraded and thus have very long half lives.

Based on the daily intake of certain foods and the dioxin levels in this food package, the relative contribution of different foods to the daily dioxin intake can be calculated. Figure 1 shows that almost half of our daily dioxin intake is due to consumption of meat and dairy products. Eggs only contribute 4 % of our total dioxin intake, which is based on dioxin levels present in battery eggs.

According to current health views, the EU has set a goal for a daily tolerable dioxin intake of dioxins that should not exceed 2 pg TEQ per kilogram bodyweight per day. To achieve these aims, regulations have been set up, whereby maximum levels have been assigned to a large number of food products (EU regulation 2375/2001). Table 1 shows the maximal levels of dioxin per gram fat in various food products. The level for eggs has been set to 3 pg TEQ per gram egg fat (one egg contains approximately 6 grams of fat). Eggs from free range or organic chickens, which have an outdoor access, have to comply with the 3 pg level after January 1, 2005. It should be noted that the calculation of these levels has been based on levels that are reasonably achievable in the various food production systems, and not necessarily from a health risk perspective.

Figure 1 Contribution of various foods to the daily dioxin intake in humans. Data are presented as a percentage and are derived from report 639102022 from the National Institute of Public Health and the Environment in The Netherlands.

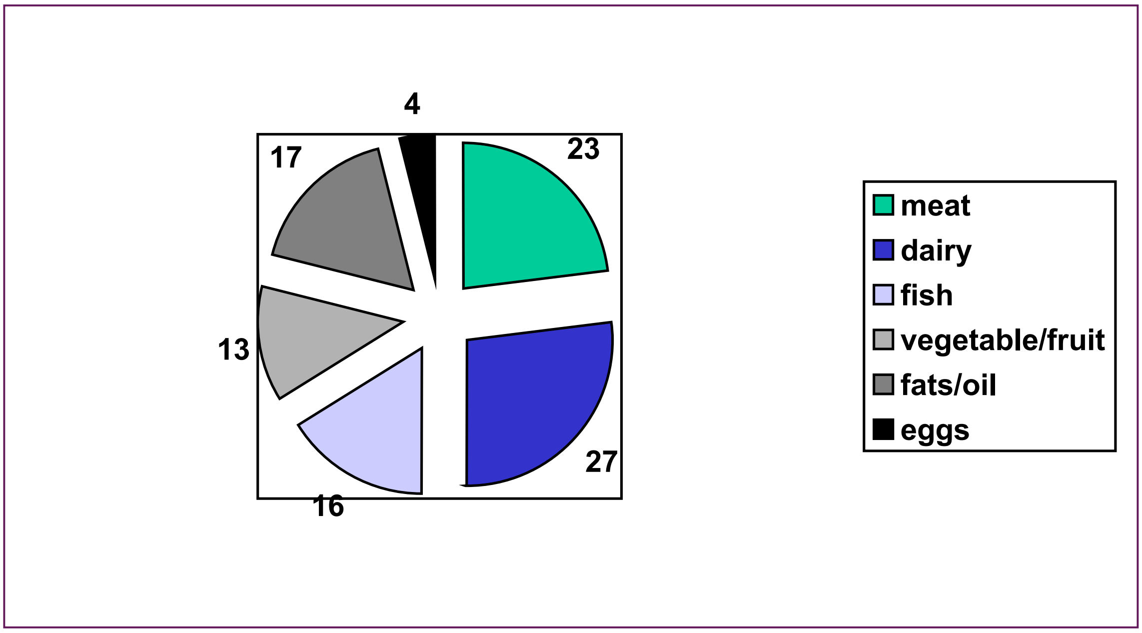

Table 1 Maximal levels of dioxins in food products as dictated by EU regulation 2375/2001.

Product	**Max level (pg TEQ/gr fat)**
Meat (beef, sheep)	3
Meat (poultry)	2
Meat (pig)	1
Livers	6

Fish	4
Dairy products	3
Eggs	3
Oil and fats	0,75 –3 (plant-beef)

Dioxins in eggs

Due to the fact that eggs contain about 10% fat, it is not surprising that dioxins also tend to accumulate into eggs. Stephens *et al* (1995) have shown that chickens exposed to a dioxin source reach a steady state of dioxin transfer after 30-60 days, and that up to 80% of certain dioxin congeners taken up, are distributed over adipose and egg fat. Egg fat may contain up to 30% of the dioxins taken up via food or soil (Stephens *et al* 1995). Modelling studies from the Netherlands have shown that chickens that are continuously exposed to a dioxin source have a gradual increase in the dioxin content of their eggs. Dioxin levels in the eggs build up gradually reaching a plateau after more than 200 days (van Eijkeren *et al*, submitted for publication 2004). The difference with the data obtained by Stephens *et al* (1995) may be due to the different types of contaminated soils used in the two studies. Some soils may release bound dioxins easier than others.

Many studies have already shown that free ranging (not organic) chickens have higher levels of dioxins in their eggs, than chickens kept inside (Table 2). In many countries. the eggs from free foraging animals exceed the proposed dioxin limit of 3 pg. Hardly any studies have, however, been published concerning dioxin levels in the eggs from organic poultry farms. A recent study from Belgium indicated that organic eggs had a similar dioxin content (approximately 1 pg TEQ per gram egg fat) as conventional eggs (Pussemier *et al* 2004). Of interest was the finding from these authors that eggs produced by hobby farmers had very high dioxin levels (10 pg/gram egg fat).

Table 2 Dioxin levels (pg TEQ/gram fat) in battery and free range/organic eggs; data from various European countries

Country	Battery system	Free range/organic	Reference
Netherlands	1-2	0.4-8.1	EC 2000b Kijlstra unpubl.
Belgium	1	1-10	Pussemier 2004
Germany	0.5-2.3	0.4-11.4	Fürst 1993 EC 2000b
Ireland	0.1-0.6	0.5-2.7	FSAI 2004
Sweden	0.6	0.6-3.1	Unpubl. data
Switzerland	1.3	2.3-19	Schüler et al 1997

A small study performed on a few farms in Ireland showed that dioxin levels in organic eggs were approximately 3 fold higher than those seen in conventional eggs, but levels did not exceed the 3 pg level (FSAI, 2004). Similar unpublished results were found in Swedish organic eggs.

Researchers from Wageningen University recently investigated dioxin levels on organic poultry farms (Kijlstra et al; manuscript in preparation). This study, that was performed in the fall of 2003, showed that 25% of the 34 investigated organic poultry farms in The Netherlands produced eggs with a dioxin level that exceeded the upper level proposed by the EU (3 pg TEQ/gram egg fat). Dioxin egg levels on the organic farms ranged between 0.4 and 8.1. When taking the daily egg production figures into account, it was calculated that 14 % of the eggs produced, had dioxin levels exceeding the 3 pg level. These figures were even higher than in data collected earlier in 2001, whereby 6 out of 68 farms tested positive (10 %) (de Vries, 2002).

Due to large media coverage during 2001, Dutch organic poultry farmers have been aware of the fact that outdoor access of chickens can be associated with increased egg levels of dioxins as compared to so called “battery eggs”. Most attention was paid to soil contamination due to local burning practices, and a number of farmers have removed the soil from such areas on their premises. Despite these actions, the dioxin levels in approximately 10% of the eggs remain above the 3 pg level. Possible explanations for these findings are discussed in the following paragraphs.

Feed for laying hens as a source of dioxins

The composition of organic poultry diets resembles that of conventional feed and contains cereals and legumes, which are mainly of organic origin. In organic poultry farming, 80% of the feed has to come from organic origin. It is not allowed to feed animals with ingredients of animal origin (meat or bone meal), extracted oil meals or synthetic amino acids. Analysis of conventional laying hen feed has shown that dioxin values ranged between 12-232 pg TEQ/kilogram feed (European Commission report 2000). Comparison of dioxin contents, using the CALUX assay, showed that organic feed contains a lower amount of dioxins than conventional feed (Platform Biologica unpublished data, 2002). Although organic laying hens are given approximately 15 grams of feed more per day than regular hens, one may assume that feed is not the main cause of the raised dioxin levels seen in organic eggs. Some organic poultry farmers feed their animals with plant material from their vegetable garden or with unsold organic food (for instance bread). Some vegetable leaves may contain higher dioxin levels due to their wax like surface. It is not yet clear at present how this contributes to the egg dioxin content.

If an organic hen takes up 140 gram of commercial organic feed, containing between 10-200 pg of dioxin per kilogram and 25% of these dioxins are transferred to 6 grams of egg fat, one can calculate that this will lead to an egg dioxin content of 0.05 or 1.25 pg TEQ dioxins per gram of egg fat, respectively (Table 3).

Substances can also be added to feed to decrease bioavailability of dioxins (binders) or stimulate the excretion. Chlorophyll has been shown to stimulate excretion of dioxins in rats (Morita *et al*; 2001). No data are available concerning the role of chlorophyll on dioxin excretion in chickens.

Table 3 Sources of contamination leading to final dioxin levels in organic eggs assuming a 25% transfer of the dioxin intake.

Source	Low estimate	High estimate
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	0.8 pg/gr	5.75 pg/gr

Data represent the contribution of the various sources mentioned to the egg dioxin level per gram fat.

Soil uptake as a source of dioxins

Chickens are known to take up soil, a behaviour known as geophagy. Many reasons for geophagy have been mentioned, including mechanical digestion of feed, mineral supplementation and self-medication against endoparasites. Quantitative data are not available concerning soil uptake by foraging laying hens, but estimates range between 2 and 10 grams per hen per day (Stephens *et al*.; 1995). Soil intake will depend on the amount of time the chickens spend in the outdoor area, the number of animals per free ranging area and the coverage of soil. Hypothetically, the general health status (endoparasites, mineral/vitamin shortage etc) of the animals may also influence the amount of soil taken up. Recent studies from our group, whereby soil dioxin content from organic poultry farms was measured by the GC/MS method, showed that levels varied between 1 and 6 pg TEQ per gram of soil (Kijlstra *et al*. manuscript in preparation). Values in Europe range between 0.5 and 87 pg per gram soil (dry matter). When assuming a 25% transfer, an uptake of 10 grams of soil samples, containing between 1 and 6 pg TEQ/gr, could lead to an egg dioxin content of 0.25-2.5 pg TEQ per gram of egg fat, respectively (Table 3). As mentioned earlier, it is not exactly known how much soil can be taken up daily by a chicken. If a chicken would take up 20 grams per day this would lead to egg dioxin levels between 0.5 and 5 pg TEQ per gram egg fat.

Apart from historical contamination, the farmer on the area where the laying hens forage could pollute soils with dioxins due to waste burnings. In our study, we did not find evidence for highly polluted areas due to these burnings. Dioxin contamination of soil via faeces of chickens has been mentioned but seems unlikely, since most dioxins are extremely lipophilic and will not leave the body via the faeces.

Forage as a source of dioxins

It has been estimated that the daily forage intake of layers may amount to 35 g (grass, legumes, herbs, European Commission report 2000). These 35 grams represent about 7 gram of dry weight material. Grass has been shown to contain between 0.8-1.6 pg TEQ of dioxins per gram dry weight. Assuming a 25 % transfer, an uptake of 35 grams of forage could lead to an egg dioxin content of 0.25-0.5 pg TEQ per gram of egg fat (Table 3).

Insects and worms as a source of dioxins

Approximately 20 grams of worms and insects have been assumed to be daily consumed by foraging laying hens (European Commission report 2000). Quantitative studies have, however, not been published and the true intake of worms and insects by chickens will depend upon many factors, including the actual use of the outdoor area by the chickens and the density of worms/insects. The density of worms /insects may also depend on the density of chickens in the outdoor run (Schuler 1997).

In a recent study, we measured dioxin content by GC/MS in worms obtained from organic poultry farms in The Netherlands (Kijlstra *et al*. manuscript in preparation). In this study, the dioxin content ranged between 0.3-1.9 pg TEQ per gram worm. Assuming a 25 % transfer, an uptake of 20 grams of worms could lead to an egg dioxin content of 0.25-1.5 pg TEQ per gram of egg fat (Table 3).

Time spent outside as a factor determining egg dioxin level

Most of the dioxin sources mentioned above are found in the outdoor area, and uptake of these sources will directly depend upon the time spent outside. This may vary, to a large degree, because, although birds are given access to a large outside area, many of them will not go outside at all or will stay within the immediate environment of the houses (Dawkins *et al*; 2003). This depends, amongst others, on the habitat of the outside area (tree coverage), presence of predator birds and the scale of the flock size (large flocks tend to remain close to the houses). The way the animals have been reared will also influence the use of the outdoor area. Animals that have been given the opportunity to use the outdoor area as young as possible will show a different “outdoor” behaviour compared to animals given an outdoor access at the time they start laying eggs.

The time spent outdoors may also differ between free range and organic production systems, whereby free range animals are only allowed to be outdoors for a few hours per day, whereas EU regulations dictate that an organic chicken should spend at least 30% of it’s lifetime outside.

How to lower dioxin levels in organic eggs?

A number of different factors may lead to the accumulation of dioxins in eggs, of which only a few can be manipulated. From the currently available knowledge, the following list of possible interventions can be tried. It is clear that some of the proposed actions counteract conditions, which have been implemented in organic farming to ensure animal welfare.

- Decrease the soil uptake by assuring complete coverage either via grass, shredded wood, etc. or shielding bare areas from the chickens.
- Decrease uptake of soil/earthworms/insects by diverting the behaviour of the laying hens.
- Stimulate excretion of dioxins via administration of chlorophyll (for instance via Chlorella, which is a unicellular green algae) or by adding dioxin binders to food.
- Do not feed laying hens with feeding stuffs with unknown dioxin content. The commercial feed suppliers should provide data concerning dioxin content. Do not feed hens with scraps or leftovers.

- Eliminate possible point sources (old burning sites) in the barn or outdoor area.
- Replace soil of the outdoor area with soil containing a lower dioxin content.
- Limit the time the chickens spend outside.
- Limit the outdoor area per chicken.

Proving the assumptions and future questions

Behaviour of the laying hens

The effect of the use of the outdoor area in time and space on egg dioxin levels is a parameter that needs to be investigated further. This behaviour may be influenced by 1) the actual time the barns are opened and closed by the farmer 2) the size of the flock (large flocks tend to spend less time outside 3) the way chicks were raised in the past 4) the presence of roosters in the flock 5) the shielding of the outdoor area against predators (presence of trees and bushes) 6) race of the laying hens.

Worms and insects

It is not exactly known how many worms and insects are actually eaten by free-range chickens. Nor is it known what the biomass of earthworms and insects is in the outdoor area used by the laying hens. If earthworms and insects play an important role as a source of dioxins then a gradual drop in dioxin levels would be expected in wintertime. Earthworms tend to reside deeper as soon as temperature drops, and levels of insects also decrease dramatically in the fall.

Herbs and grass

The amount of herbs and grass consumed by chickens on organic poultry farms is not exactly known nor is it known how this affects the dioxin content in eggs.

Soil uptake

It is not exactly known how much soil free-range chickens take up and how this uptake can be influenced. Methods to exactly quantify soil uptake by laying hens should be devised. How is soil uptake influenced by the health status of the chickens, grass coverage of the outdoor area etc.?

Conclusions

Only limited data has been published in the literature concerning dioxin levels in organic eggs. Analysis of dioxin levels in organic eggs among various European countries shows marked differences. An explanation for these differences may be found in the historical dioxin emissions, which may be lower in countries such as Sweden and Ireland, when compared to a densely populated country, such as The Netherlands. On the other hand, differences between the behaviour of the chickens amongst farms in different countries may also explain the observed difference. In some countries, the actual number of chickens going outside may be quite low as well as the total time spent outside. In some countries, the weather conditions in winter may be such that chickens stay inside most of the time, and even if they go outside they will not have access to soil under a heavy snow.

The most likely source of dioxins leading to higher levels in the eggs is directly (soil uptake) or indirectly (uptake worms/insects) related to the soil dioxin levels.

Deficiencies in the amount of minerals or vitamins in the organic feed preparations may influence the soil uptake behaviour (geophagy) of the chickens. The outdoor area per chicken may influence the amount of worms and insects that are available. Higher stocking densities may lead to a low insect/worm population but on the other hand may lead to disruption of the grass coverage and a possible higher uptake of soil from a bare outdoor area. Many of the explanations described above are theoretical and should be investigated under well-defined conditions.

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