Prevention and control of contaminants of industrial processes and pesticides in the poultry production chain

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The reduction in levels of organochlorine pesticide residues in food of animal origin in the past 30 years has been achieved especially by controlling entrance via the feed chain. A further reduction was achieved by registration and use of less persistent pesticides both for direct treatment of animals and of plant material.
The remaining problems (*e.g.* dioxins and PCB's) are much harder to tackle. They are either of a ubiquitous nature and their impact might be enlarged by the present welfare trend requiring more contact of the animals with their environment, or they are of a sporadic nature making checking and control quite hard to execute. The present public demand for a farm animal production that is in balance with the animals' needs and a residue free product adds even more complications to the system.

Key words: contaminants; residues; poultry

Introduction

Prevention and control are the two key elements of the **H**(azard) **A**(nalysis) **C**(critical) **C**(ontrol) **P**(oint) approach. Currently in many different industrial processes this approach is favoured in producing safe foods for human consumption. Prevention requires knowledge about the origin of the problem and what to do about it. Control is not just monitoring but also influencing the situation. A nice example is the production of dry egg powder free of Salmonella. On many occasions during the production process one can check the Salmonella content *e.g.* at entrance of the raw material (the eggs), after breaking, at packing the dry powder, during storage or transport or at the shelf of the retailer. However, there is only one point in the process where one can really control it and that is in the drying step, where temperature and duration of stay can diminish or eliminate all Salmonella present.

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Prevention and control of contaminants and pesticides in the poultry production chain, requires:

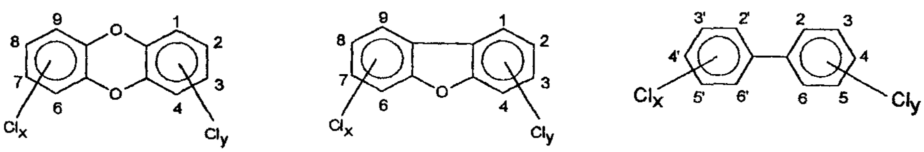
1. Knowledge of the sources of contamination and their consequences and
2. Knowledge of possibilities to exclude these sources from the system or to reduce their effect.

The consequences of contamination in the poultry production chain have been recognised already many years ago and in 1979 at the 2nd European Symposium on Poultry Nutrition attention was already paid to this subject (Kan and Jonker - den Rooyen, 1979).

The ways to reduce uptake of contaminants by poultry or to reduce levels in the final product have been discussed before (Kan, 1994). These ways do not seem to be very (cost) effective and generally measures taken to prevent a problem are preferred over "end of pipe" curative measures.

Possible sources of contaminants and pesticides in the poultry production chain are feed, water, air, soil and environment. The causes can be deliberate use of *e.g.* pesticides on the crops, the animals or the building. Environmental pollution by *e.g.* PCBs, polychlorinated dioxins and dibenzofurans (see *Figure 1*) will have its impact on residue levels in poultry as well. Last but not least, as proven by the Belgian dioxin crisis, accidents in the feed supply chain can have an enormous impact on animal production.

Figure 1 The general structures of the polychlorinated dibenzo-p-dioxins, polychlorinated dibenzofurans, and polychlorinated biphenyls.



Polychlorinated Dibenzo-*p*-Dioxin — **Polychlorinated Dibenzofuran** — **Polychlorinated Biphenyls**

This paper will review firstly the different sources of contamination and the impact they may have on residues in the poultry products. Secondly special attention will be paid especially to the dioxins: their sources and the contribution of poultry products to the average daily intake through the human diet in Europe.

Sources of pesticides and contaminants

Organochlorine containing compounds (pesticides, PCBs, dioxins, dibenzofurans) have proven to be metabolically stable. This property explains their effectiveness when used in a field situation as well as their long lasting and unwanted residues in all environmental compartments.

The main sources, which will be discussed, are:

- Feed and feed ingredients
- Direct application to animals
- Environment, housing, soil, air

First the (organochlorine) pesticides will be discussed and secondly the contaminants.

Organochlorine pesticides in feed

Residues of organochlorine pesticides in poultry and eggs due to their presence in feedstuffs have already been the subject of research for a long time. The available knowledge in 1978 could be summarised as follows (Kan, 1978):

1. Levels in abdominal fat and yolk of some pesticides like HCB, DDT and Dieldrin can considerably exceed levels in feed
2. Considerable differences in persistence exist between pesticides, lindane and methoxychlor being much less persistent than HCB or DDT.

Schenck and co-workers (Schenck and Donoghue, 2000), using more sophisticated methodology, confirmed that methoxychlor did not show residues in egg yolk after dosing hens.

Toxaphene, an organochlorine containing pesticide made up out of more than 600 individual components, may however remain a problem. Toxaphene has been banned for use from the western world for about 20 years but due to its possible use in other areas of the world and its persistence it still might be (or become) a problem. Schwind and co-workers (Schwind and Kaltenecker, 2000) using modern analytical techniques determined that some components show considerable carry over from feed to eggs. The half life time of these components in eggs was found to be between 25 and 42 days, which is in the same range as some of the organochlorine pesticides (Kan, 1978).

Generally, the prevention and control of organochlorine pesticides via the feed chain is adequate as shown by the considerable reduction in residues in poultry products over the period 1975-1995 (Kan, 1996). Both the ban on and reduction in use of organochlorine pesticides on many crops all over the world and the legislation and control of pesticides in feedstuffs and feeds have contributed to this decline.

Organochlorine pesticides in the environment

Malathion, a well-known ectoparasiticide, could not be recovered (Schenck and Donoghue, 2000) from the egg after dosing laying hens. However, dosing hens with chlorpyriphos-methyl and dimethoate did result in measurable quantities of these substances in the egg. Disappearance from the eggs after dosing was rapidly as could be expected with these substances, which are metabolically much less stable than the traditional organochlorine pesticides. Similarly Barnekow and his group (Barnekow *et al.*, 2001) reported a very high excretion of (metabolites of) 2,4-dichlorophenoxyacetic acid (2,4 D) by laying hens and very low amounts in their tissues. Bargar and his group (Bargar *et al.*, 2001) injected α- or β-endosulfan into laying hens and found a very low excretion of the compounds or endosulfan sulfate via eggs.

Fishwick and co-workers (Fishwick *et al.*, 1980) reported that both continuous and discontinuous operation of vaporisers with lindane in a layers house will lead to quite substantial lindane residue levels in eggs and abdominal fat. Exposure via the air is thus quite possible and should not be neglected as a contamination source of volatile and fat-soluble compounds.

Contaminants in feed and housing

Pentachlorophenol, previously widely used as wood preservative may cause residues in animals both via the oral route (Butler and Frank, 1991) or by absorption through the skin (Qiao *et al.*, 1997). In the past, woodshavings used as bedding material were the main cause of pentachlorophenol residues in broilers and layers. Next to that, there was the microbial metabolism of pentachlorophenol into chlorinated anisoles, which occasionally caused very distinctive musty off-flavours in broiler meat and eggs (Land, 1975); (Steverink and Jansen, 1979). The half-life time of these components, however, is rather short, so if a contamination occurs, the elimination from the body can be a matter of days. Reduction in use of PCP by the timber industry has been the major cause for its declining importance as a contaminant in poultry production in Western Europe.

The present trend towards more contact with "natural" materials, being part of improved welfare for the animals, increases the risk animals getting in contact with wood containing a range of unwanted substances over an extended period of time. Waiting for a washout might not be an option then.

Coatings of concrete silo's, vapour seals or insulation material have proven also to be a possible contamination source for PCB residues in food of animal origin (Willett *et al.*, 1985); (Hansen *et al.*, 1989). These – sporadic – sources might seem to be of less importance than the straightforward feed contamination routes. However, if we succeed in better controlling the concentrated point sources of contamination or accumulation like fats used in animal nutrition, the percentage contribution of sporadic or widespread contaminations will increase.

Grob and his group (Grob *et al.*, 2001) recently draw attention to contamination of eggs and animal fat with olefins and n-alkanes due to the assumed incorporation of mineral oil or paraffin oil into animal feed. This misuse was also brought in conjunction with the Belgian PCB crisis where "oil" was mixed into fat intended for incorporation in animal feed as an energy source. They clearly showed the presence of these non-natural components in food from animal origin.

PCB from feed to product

Fries and his group in Beltsville (Fries *et al.*, 1977) gave feed with Arochlor 1221, 1232, 1242, 1248, 1254 or 1268 to laying hens during 9 weeks and determined with (at that time) standard packed column GLC the residues in egg, body fat and excreta. The higher the chlorination rate to the biphenyls was (thus the higher the Arochlor number) the higher the PCB residues in eggs. The maximal transfer to body fat seemed to be at 54% chlorination (thus Arochlor 1254). The amount in excreta was about 10% of intake for all mixtures tested. The methodology used did not allow making a distinction between the individual components of the PCB mixtures in the Arochlor. Hansen and co-workers (Hansen *et al.*, 1983) gave a feed with Arochlor 1254 either directly or after passage through pigs to broilers for about 20 days. They assessed the concentrations of 18 individual chlorobiphenyls in liver and body fat. Highest accumulation in body fat was found for the congeners 118, 128, 138, 153 and 180. Levels in liver followed a similar trend but there were some differences between isomers. Brunn (Brunn, 1984) gave radioactive congener 49 to laying hens and measured excretion of radioactivity in both eggs and excreta. About 42% of the dose was excreted as a metabolite in eggs and faeces. The rate of metabolism of the tetrachlorobiphenyl congener 49 is in the same order as metabolism of a number of organochlorine pesticides (Kan, 1977). Ueberschär and Vogt (Ueberschär and Vogt, 1986) determined the accumulation ratios of the congeners 28, 52, 101, 135, 153 and 180 in broilers and layers. Congeners 52 and 101 showed much less persistence than the other four. Very recently Bargar and his group (Bargar *et al.*, 2001) injected a pentachlorobiphenyl (congener 105), and hexachlorobiphenyl (congener 156) and a heptachlorobiphenyl (congener 189) into laying hens and measured residues in eggs. Transfer to egg was inversely correlated to chlorination rate but were all around 0.5% of the injected dose. Co-administration of other chemicals somewhat influenced excretion rate into eggs. Hoogenboom *et al.* (unpublished results, 2001) fed diluted feed originating from the Belgian dioxin crisis for one week to laying hens and broilers and followed residue patterns in egg and abdominal fat during several weeks, both with a biological (CALUX) test and with GC/MS. The PCB pattern in this feed is quite alike a 50/50 mixture of Aroclors 1254 and 1260 (van Larebeke *et al.*, 2001). The results are not yet completely available, but of the seven marker components congener 101 proved to be much more metabolised than congeners 118, 138, 153 and 180. Congeners 28 and 52 were also metabolised quite extensively as can be expected for these lower chlorinated congeners. These results concur with the comparison of congener patterns in feed and eggs from Belgium in 1999 (van Larebeke *et al.*, 2001).

Dioxins and dibenzofurans from feed to product

Zabik and her group (Zabik *et al.*, 1998) fed a low level of 2,3,7,8- tetrachlorodibenzo-p-dioxin (TCDD) to male leghorn chicks for 14 days. Residues of the dioxin were not found in brain, heart, fat, plasma, muscle kidney and skin. Residues were only found in liver samples even 21 days after the administration had stopped. Inclusion of mineral oil in the diet did not fasten the excretion of the TCDD. One can however wonder how the results would have been in much faster growing broiler type chickens. Hoogenboom et al (unpublished results 2001) found that 2,3,7,8 TCDD was only a minor component (about 1.5% of total dioxins and dibenzofurans) in the feed originating from the Belgian dioxin crisis. The major contributor to the TEQ-level by far (ca. 68%) was 2,3,4,7,8-Pentachlorodibenzofuran (PeCDF); other major components (> 5%) were 2,3,7,8-TCDF, 1,2,3,4,7,8-HxCDF and 1,2,3,7,8-PeCDD. Similar results from other feed analyses have very recently published (van Larebeke *et al.*, 2001). The levels in eggs and fat after cessation of administration naturally decreased due to excretion with the eggs, but the 4 above-mentioned congeners were about equally stable. The percentage contribution to the total residue slightly increased during the washout period. The overall picture from these studies is, that the higher chlorinated congeners are metabolically more stable and accumulate to a higher extent. However, also between congeners with the same chlorination rate there are considerable differences.

Dioxins and dibenzofurans in the environment and the product

Dibenzofurans and dioxins are ubiquitously present in our environment, but point sources due to fires involving chlorinated compounds occur. The resulting contamination of soil, water and air with dibenzofurans and dioxins often results in increased levels of these compounds in poultry products as well as in other fatty products. Chang and co-workers (Chang *et al.*, 1989) *e.g.* showed that in after a fire involving a pentachlorophenol wood treatment plant in the Oroville Ca, USA, eggs and chicken fat raised in that neighbourhood showed increased dibenzofuran and dioxin levels. A more detailed study on the situation in the area was published recently (Harnly *et al.*, 2000). The absolute levels in soil and eggs did not change over a six-year period. Differences in residue level between sites of investigation were large. The major contributors to the TEQ amount were pentachlorophenol (PCP), octachlorodioxin (OCDD) and 1,2,3,4,6,7,8 HpCDD. A similar study in the UK – The Pantegg project – was published some years ago (Lovett *et al.*, 1998a; Lovett *et al.*, 1998b). Controlled exposure studies using contaminated soil incorporated in poultry diets were also carried out in relation to the US contamination findings (Stephens *et al.*, 1990); (Petreas *et al.*, 1991); (Stephens *et al.*, 1995). Schuler and co-workers (Schuler *et al.*, 1997) carried out a similar study in Switzerland. Both studies showed that intake of contaminated soil will increase the levels of contaminants in eggs or body fat although the bioavailability of the bound residues in soil is quite low. Pentachlorophenol treated wood in itself has also proven to be a source of dioxins and dibenzofurans in products of animal origin, especially milk and body fat of calves. (Fries *et al.*, 1999); (Feil *et al.*, 2000). Poultry that is provided with wood to increase their welfare might therefore pick up traces of dioxins or dibenzofurans, if this wood happens to be treated with chlorine containing compounds. Exclusion of these types of compounds for wood treatment is the main preventive action possible.

Biotransfer rates or accumulation ratios of organochlorine containing compounds in poultry products have still to be determined experimentally. The predictions made for transfer of these compounds into beef and milk using the molecular connectivity index (Dowdy *et al.*, 1996) have to my knowledge not been tested yet for other farm animal species. The bio-availability of dioxins and dibenzofurans from "Kieselrot" has been compared in several *in vitro* systems (Wittsiepe *et al.*, 2001). Unfortunately, the different systems gave quite different results, so a good predictor for *in vivo* data was not obtained.

Dioxins and dibenzofurans in feedstuffs in the EU

In November 2000, the Scientific Committee on Animal Nutrition of the EU has published an extensive report, summarising and evaluating all available data (Nutrition, 2000). Important conclusions were:

- Fish meal and fish oil of European origin are the most heavily contaminated feedstuffs
- Fish meal from the South Pacific is much less contaminated
- Animal fat is next in the order of dioxin concentration
- Other plant feed material is generally not heavily contaminated
- Levels in roughages and soil very much depend on local pollution and can vary enormously
- Bioavailability of dioxins and dibenzofurans in soil is generally low, so their contribution to residues in products of animal origin will be limited.

Dioxins and dibenzofurans in food of animal origin

Dioxin, dibenzofuran and pentachlorophenol levels in food of animal origin have been determined long ago. The data on Canadian samples of chicken and pork (Ryan *et al.*, 1985) might not pass the 2001 standards for analytical methodology, but they indicated quite a substantial (background) contamination of about 50% of the chicken fat samples containing detectable amounts of dioxins and PCP. Goldman and co-workers (Goldman *et al.*, 1989) measured in the earlier mentioned Oroville area dioxin levels in food and levels in plasma of residents from that area. Dioxin levels were increased in both types of samples as compared to a non-exposed control area. Fries reviewed some years ago (Fries, 1995) the significance of animal food products as potential pathways for human exposure to dioxins from an American perspective. He concluded the following: "*The potential for public concern over exposure to dioxins is high and regulatory actions to reduce emission of dioxins into the environment and food chains can be expected. Alterations in production practices or recommendations for dietary change do not seem realistic because of the diversity and uncertainties of the exposure pathways. Changes in animal production practices to reduce dioxin transmission to animal food products would require increased confinement of animals and greater use of concentrates. These practices are antithetical* *to the current emphasis on animal welfare and sustainable agriculture*". Hecht has more recently (Hecht, 2000) tried to quantify the real contribution of meat and meat products to the dioxin intake of the German population. He estimates that the contribution is "only" 13% as opposed to the earlier assumption of a contribution of 30%. There were however clear regional differences in residue levels, the western part of the country having the highest levels and the southern part showing the lowest levels.

The messages from these two papers seem – at first – contradictory; part of the difference may be due to the different situation of animal farming in the USA as opposed to Germany and the different approach taken by the authors. Part of the difference might also be due to a further decrease in dioxin levels in food of animal origin in the last few years. This decrease might both be real due to reduction in levels or perceived due to better – unbiased – sampling and improved analytical techniques.

The next difficult task is however to translate residue levels of the different components found into health hazards for the human population. The SCAN paper (Nutrition, 2000) has given a lot of attention to that for dioxins and dibenzofurans as well as *e.g.* Hansen in two papers (Hansen, 1987), (Hansen, 1998) did for toxicity assessment of PCB congeners.

A last point is the possible reduction in the levels of dioxins and dibenzofurans in meat and meat products, when found (too) high. Petroske and co-workers (Petroske *et al.*, 1998) showed that these fat soluble compounds during frying end up in the pan fats and juices. So only if these are discarded, a reduction in residue levels can be obtained. Kan some years earlier (Kan, 1994) formulated a similar conclusion for organochlorine pesticides in poultry meat and eggs.

Conclusion

Prevention and control of organochlorine pesticides in feedstuffs and feeds has considerably reduced the levels in both feed and products in the past 30 years. The present challenge is to achieve a similar success on the environmental contaminants, where on one hand occurrence is quite ubiquitous – so hardly controllable - and on the other hand quite sporadic so also hard to control. To make life even more complicated, public opinion does not longer accept residues as "unavoidable" in the product. Consumers demand no residues and no risks on those issues where they themselves have apparently no control.

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