ESTABLISHING THE RELATIVE CONTRIBUTION OF THE MAJOR SOURCES OF DIOXINS AND PCBS IN ANIMAL PRODUCE

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Abstract

In a series of longitudinal studies, broiler and laying chickens, indoor and outdoor pigs and lowland and highland sheep were reared to market readiness using current animal husbandry practices. In order to control for the many variables involved, closely matched samples (n = 383) of meat, eggs, milk, feed, soil and grass were collected of which 105 were analysed for PCBs and PCDD/Fs. Other potential inputs were also assessed and biotransfer factors (BTFs) were calculated. A slight decline with age in PCB and PCDD/F WHO-TEQ values in meat was evident in the indoor and outdoor pig, lowland and highland sheep and in the broiler chicken rearing programmes. There was no evidence for a general trend for pigs and chickens to accumulate higher levels of PCBs and PCDD/Fs in meat through the ingestion of feed. WHO-TEQ values in meat samples from outdoor pigs tended to be slightly higher than those from comparable ages in the indoor programme. A tendency for WHO-TEQs in eggs to increase as a result of laying chickens being allowed access to free range conditions was also apparent, possibly due to additional intakes from ingested soil. WHO-TEQ values in samples of sheep meat appeared to be slightly higher than those reported for the pig and chicken meat programmes. The meat WHO-TEQs for market ready animals were slightly lower in highland than in lowland sheep.

Introduction

It is well recognised that dioxins, PCBs and other POPs bioaccumulate in fatty tissue and that most human exposure is through the diet. The origin of these contaminants is conjectured as exposure from air pollution, deposits on grazing land, animal feed, as maternal inputs, or from various other routes and contacts that the animals have throughout their lifetime. Several models exist which link the majority of the origin of these dioxins to direct or indirect environmental sources,[1] and there is the possibility that some of the contribution can come from animal feed. The relative contributions from each of these compartments remains uncertain.[2] This work was conducted in order to establish the relative contribution from various ingested sources and also to estimate various biotransfer factors (BTF) involved in the accumulation of these contaminants in different types of animal produce including meat, offal and eggs from various species. The study described in this paper was designed to investigate the transfer and uptake of dioxins and PCBs in 3 of the most common farm animals used for food production – pigs, chicken and sheep.

The knowledge gained from the study was intended to help direct efforts into a risk reduction strategy i.e. to identify the various approaches that would tend to reduce levels of dioxins and PCBs (and possibly other POPs which behave in a similar manner) in animal produce, and hence to reduce human exposure.

Experimental

In a series of longitudinal studies, broiler and laying chickens (indoor and free-range), indoor and outdoor pigs (Figure 1) and lowland and highland sheep were reared to market readiness using current animal husbandry practices. In order to control for the many variables involved, closely matched samples (n=383) of meat, eggs, milk, feed, soil and grass were collected of which 105 were analysed for PCBs and PCDD/Fs. Other potential inputs such as bedding and veterinary supplements were also assessed. All animals were reared according to standard agricultural practice under the control of experienced staff from an agricultural college. The livestock investigated in this study were only exposed to normal – i.e. low – background concentrations of dioxins and PCBs in their environment and diet. There was a decision to rely solely on the high sensitivity of the GC-MS analysis rather than artificially spiking feed or environmental media, which would potentially have led to artefacts such as altered bioavailability from various media. Consequently there is too much data to discuss in depth in this paper, which is intended only as a brief overview of the study, and it is intended to publish more details of the study at a later date.

The method used for the extraction and analysis of samples has been reported previously.[3]

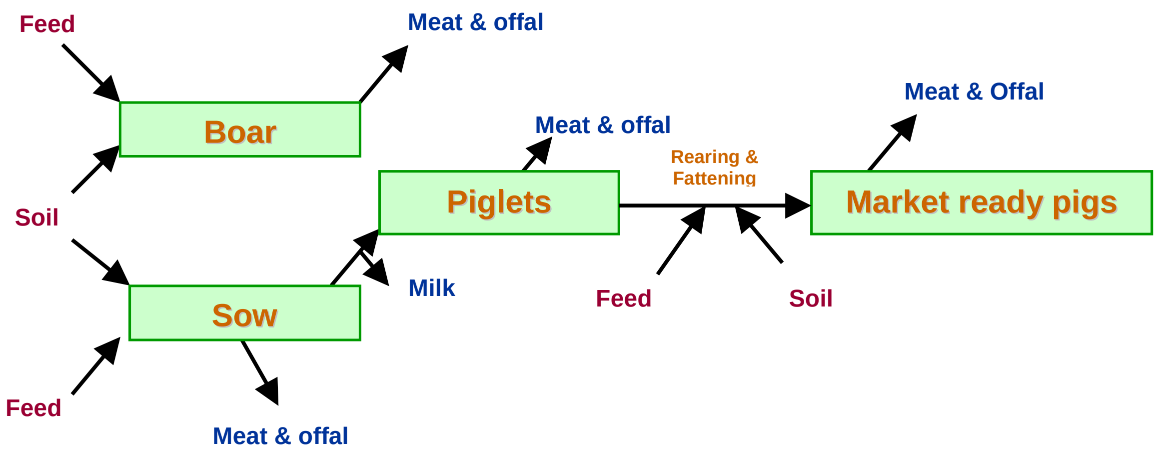

Figure 1: Schematic showing possible inputs and outputs of dioxins and PCBs in production of animal produce; in this example for pigs (outdoor)

Results and Discussion

The analytical data obtained from the six rearing programmes were generally in agreement with the results of previous studies and appear consistent with the PCB and PCDD/F levels to be expected in rural background locations. A slight decline with age in PCB and PCDD/F WHO-TEQ values in meat was evident in the indoor and outdoor pig, lowland and highland sheep and in the broiler chicken rearing programmes. WHO-TEQ values in meat samples from outdoor pigs tended to be slightly higher than those from comparable ages in the indoor programme. A tendency for WHO-TEQs in eggs to increase as a result of laying chickens being allowed access to free range conditions was also apparent. In both cases, it is possible that these differences might be attributable to additional PCB and PCDD/F intakes from ingested soil. WHO-TEQ values in samples of sheep meat appeared to be slightly higher than those reported for the pig and chicken meat programmes. Although the results of the two sheep programmes were generally similar, the meat WHO-TEQs for market ready animals were slightly lower in highland than in lowland sheep.

The transfer of PCDD/Fs and PCBs from dietary sources to eggs, meat, liver and kidney were investigated through the calculation of biotransfer factors (BTFs) for four representative congeners - 2,3,7,8-TCDD, 2,3,4,7,8-PeCDF, PCB 153 and PCB 169. The BTF approach[4] was used since it was decided that this was more versatile than either the bioconcentration factor (BCF) or carry-over rate (COR) since total intake of dioxins and PCBs from all dietary sources can be calculated as a daily input flux and in turn could be related to the contaminant concentration in the produce. It was then possible to estimate the relative importance of sources at different stages of the animal-rearing programme.

BTF was defined as:

$$\text{BTF} = \frac{\text{contaminant concentration in foodstuff (ng/kg fat)}}{\text{daily contaminant input flux (ng/d)}}$$

The absolute magnitude of BTFs tended to be higher in chickens than in sheep or pigs at comparable stages of the rearing programmes. This situation confirmed the potential usefulness of chickens as a biomarker for potential human exposure to PCBs and PCDD/Fs. There was also evidence in all of the rearing programmes that meat BTFs decline in magnitude as the animals get older and larger. Within meat samples, the relative ranking of BTFs for the four selected congeners showed considerable consistency, with the order (highest first) usually being PCB 153, PCB 169, 2,3,4,7,8–PeCDF and 2,3,7,8-TCDD. This suggested that the highly chlorinated congeners accumulate more readily in meat tissues than their less chlorinated counterparts. Variations in BTFs for specific PCDD/F or PCB congeners were found to be associated with several types of variables. These included changes in dietary composition during a rearing programme, differences between foodstuffs, and contrasts between animal species. Particularly prominent examples were:

- Increases in the BTF for PCB 169 in the pig rearing programmes when the diet changed from being dominated by sow’s milk to feed.
- Much higher transfer factors for many PCDD/Fs congeners (e.g. 2,3,4,7,8–PeCDF) in liver than in meat or kidney samples from the same animals.
- BTFs for non-ortho PCBs 126 and 169 were appreciably higher, relative to other PCDD/F and PCB congeners, in meat from sheep than in comparable samples from pigs or chickens.

Particular dietary constituents also varied in their importance as contributors to the input flux of individual congeners. One example is that soil consistently accounted for at least 30% of input for many hexa- or more chlorinated PCDD/Fs, while rarely representing more than 10% of the total WHO-TEQ intake during a rearing period.

For both sheep and pigs, the difference in concentrations, expressed on a fat weight basis, between liver, kidney and muscle/meat was of interest. It was clear that animals fed under normal conditions with standard animal feed, which did not exceed the EU statutory limits for dioxins in animal feed that were subsequently introduced, resulted in meat and kidney tissues well below the EU MRL for dioxins. However, the WHO-TEQ concentrations for dioxins in liver from the same animals, was typically up to around an order of magnitude higher in concentration and would easily exceed the MRL. It was also apparent that the congener profiles for dioxins in liver were distinct from those in meat and kidney.

Acknowledgement

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