A STUDY OF THE MASS BALANCE OF DIOXINS AND FURANS IN LACTATING COWS IN BACKGROUND CONDITIONS. PART 2: MASS BALANCE AND BIOCONCENTRATION FACTORS

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Introduction

Consumption of animal fats account for as much as 95%[1] of the human background exposure to compounds with dioxin-like activity. Although it is generally believed that most domestic meat and dairy animals receive most of their exposure from their feed, there is limited data available on levels of dioxin-like compounds in animal feeds. The purpose of this study was to first confirm that feed is the primary source of dioxin exposure for the dairy cattle under study. This was to be accomplished by conducting a mass balance study. A second objective was to use the mass balance data to derive steady-state bioconcentration factors (BCFs, BTFs, and CRs). Future studies will use these bioconcentration factors to look at feed and milk concentration in a number of dairy operations to determine if feed accounts for most of the exposure to dairy animals. This study is described in two parts. The first paper presents the data on levels of dioxin in the feed and makes some conclusions about its variability, and the contribution to overall feed concentration made by the various feed components.[2] This paper summarizes the mass balance results and generates bioconcentration parameters (BCF, BTF, and CR) for the dioxin and furan (CDD/F) congeners. This study did not investigate the dioxin-like coplanar PCBs.

Data Analysis Methods

All Toxic Equivalent, TEQ, results were determined using the 1998 WHO recommendations.[3] Average concentrations of the individual congeners were determined assuming non-detects were equal to one-half the LOD. This was critical mostly for tetra and penta congeners for periods 1 and 3; 2,3,7,8-TCDD, for example, was most often not detected, requiring _ LOD substitution.

The first paper[2] describes the study design and analytical chemistry, which will not be repeated here. A mass balance for each animal/period was comprised of a dioxin intake vector calculated as the product of the average mixed feed concentration (Cmf) times the average daily intake (MF) of the individual cow (Cmf * MF), and a dioxin output vector calculated as the sum of the animal/period feces dioxin output (the animal/period feces concentration times the animal/period average daily feces production (Cf * F)) and the animal/period milk dioxin output (milk concentration times average daily milk production (Cm * M)). The mass balance result for each congener was calculated as the percent of congener input that was excreted in the output: {[Cf * F + Cm * M]/[Cmf * MF]} * 100%. In addition to measurement errors, excretion values greater than 100% can be interpreted as removal from storage in the body while values less than 100% may be attributed to storage in the body or metabolism.

Figure 1 shows the TEQ concentration of the feed, feces, and milk for the three periods. Figure 2 shows the mass balance for TEQs over the three periods, showing the percent of the TEQ intake that was found in the feces and milk. The mass balance results for the 17 CDD/F congeners are shown in Table 1. Table 1 also shows the results for the carryover ratio (CR), bioconcentration factor (BCF), and biotransfer factor (BTF) for the three periods for each CDD/F congener. The three factors were calculated as follows:

CR = [(daily flux in milk, pg/day)/(daily flux in feed, pg/day)] * 100; percent
BCF = (pg/g milk fat)/(pg/g feed dry); unitless
BTF = 1000 * (pg/g whole milk)/(pg/d); 1000 converts the units appropriately to d/kg

Results

1) The feed and feces concentrations ranged from 0.13 to 0.30 ppt TEQ dry weight basis. The temporal trend was the same for these two matrices, with about a doubling of concentration from July to September, and a slight drop for the November testing period. The milk, on the other hand, rose steadily, from 0.53 to 0.65 to 0.96 ppt TEQ lipid-basis. This rise was largely associated with a rise in concentrations of the hexa and hepta furans. The concentrations in the first period were similar to background concentrations in this herd measured in 1996[4]. By comparison, a national survey of CDD/Fs in milk in the United States showed an average of 0.89 ppt TEQ lipid[5].

2) The mass balance of both TEQs and the individual congeners ranged from about 50 to 100%. A noteworthy deviation from expectations is the low mass balance of 40 and 44% for the hepta and octa congeners for the second period; these are generally expected to pass through the dairy cows with little absorption or metabolism, and mass balances for them should be near 100%, as they were for the first and third period, ranging from 80 to 111%. Higher concentrations for these two congeners in feed during the second period may have contributed to a finding of a low mass balance result. Overall, the CDD/F mass balances are consistent with those derived by McLachlan[6] from a single cow study in a background setting. He also showed mass balance results between 50 and 100%, and while there were some individual congener differences (McLachlan showed a 100% balance for 2,3,7,8-TCDD, while this study showed 53%), the overall averages were similar. For the 17 congeners, McLachlan's mass balances averaged 73%, while the average of the 17 congeners in this study (over all 3 periods) was 75%.

3) The high milk concentration during the third period led to the highest bioconcentration parameters of the three periods for the furans and for 2,3,7,8-TCDD. These parameters were reasonably comparable over the three periods for the penta through octa dioxin congeners. These same three bioconcentration parameters were derived in a study of cows being fed pentacholophenol-treated wood (although the BTF had different units of [pg/kg]/[ng/d], and hence was different in magnitude as compared to BTFs of this study), and several additional CRs were displayed from other studies.[4] The values derived in this study are similar in trend as those reported on in Fries[4], and reasonably similar in magnitude (mostly within a factor of 2), but the averages from the three periods are somewhat higher than those in Fries[4] , mainly because of the high factors determined for Period 3 in November. The use of half LOD for the non-detected furan congeners that are not substituted in the 4 and 6 positions probably overestimates the transfer coefficients because these congeners are metabolized in mammalian systems.

Observations

Since mass balance results were near to and less than 100%, one can conclude that feed was providing the dioxins to the dairy cattle in this study. Like the variability in dioxin concentrations found in the feed of this study (as described in the first paper[2]), variability was also found in the mass balance results and the bioconcentration factors. While the feed and feces concentrations decreased in the third period, the milk concentrations rose in the third period. As noted, a primary goal of this study was to develop confidence in the bioconcentration factors such that they can be used to look at feed and milk concentration in a number of dairy operations to determine if feed can account for most of the exposure to dairy animals. Given the variability found, this goal may not have been met. Alternately, one can consider that such variability is likely to be inherent in background studies of the dioxin-like compounds - due to variability in feed concentrations, laboratory measurements, and so on. More study may be needed to fully understand the nature of this variability. It may be most reasonable to consider that BCFs for individual congeners fall in a range - 0.2 to 2.0 for 1,2,3,4,6,7,8-HpCDD, for example. If that is the case, then one can still find important uses for the bioconcentration factors derived here and elsewhere. Such uses include use of average BCFs in risk assessments, identifying significant perturbations in field studies or commercial operations, studying the sources of dioxins in the food chain, and similar uses.

References

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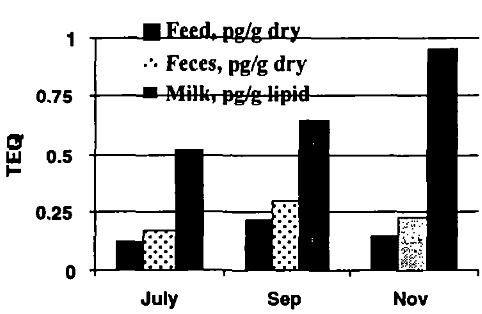

Figure 1. Time trend of TEQ concentrations.

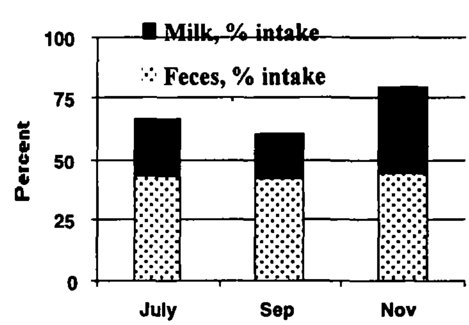

Figure 2. Time trend of TEQ mass balance

Table 1. Mass balances (MB), Carryover ratios (CR), Bioconcentration factors (BCF), and the Biotransfer factors (BTF).

Congener	MB, %			CR, %			BCF, unitless			BTF, d/kg		
	Jul	Sep	Nov	Jul	Sep	Nov	July	Sep	Nov	Jul	Sep	Nov
2378-D	44	45	71	17	13	41	2.83	2.08	7.32	0.004	0.004	0.013
12378-D	54	59	61	25	31	31	4.40	4.82	5.55	0.006	0.008	0.010
123478-D	66	83	76	30	30	34	5.13	4.63	6.01	0.007	0.008	0.011
123678-D	145	57	85	64	18	34	11.18	2.82	6.06	0.015	0.005	0.011
123789-D	76	64	72	28	18	25	4.76	2.95	4.47	0.007	0.005	0.008
1234678-D	111	40	92	11	1	7	1.96	0.23	1.30	0.003	<0.001	0.002
OCDD	100	44	81	1	<1	1	0.19	0.03	0.16	<0.001	<0.001	<0.001
2378-F	39	41	67	9	4	37	1.57	0.58	6.63	0.002	0.001	0.012
12378-F	50	60	62	18	19	34	3.07	3.01	5.93	0.004	0.005	0.010
23478-F	71	64	86	31	31	57	5.30	4.80	10.07	0.007	0.008	0.018
123478-F	77	84	138	24	23	61	4.20	3.67	10.70	0.006	0.006	0.019
123678-F	76	78	121	27	24	50	4.67	3.73	8.82	0.006	0.006	0.016
234689-F	47	85	68	18	25	43	3.05	3.90	7.62	0.004	0.007	0.013
123789-F	64	98	110	15	29	28	2.54	4.62	4.94	0.003	0.008	0.009
1234678-F	109	79	80	8	4	5	1.45	0.61	0.92	0.002	0.001	0.002
1234789-F	52	82	79	15	7	14	2.54	1.10	2.49	0.003	0.002	0.004
OCDF	95	66	74	5	1	2	0.80	0.21	0.38	0.001	<0.001	0.001