UPTAKE OF DIOXIN-LIKE COMPOUNDS IN GROWING SWINE: CORRELATION BETWEEN EXPERIMENTAL AND PREDICTED DATA

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Introduction

In 2002 several mineral supplements used in animal feed production were discovered to contain elevated levels of dioxins.[1] These supplements were approved for use in most livestock feeds and had been used by poultry, swine, and dairy producers in the United States. Although the contaminated feeds were recalled, food products were not recalled because no significant health risk was envisioned based on the dilution of the mineral supplements in commercial products and finished feed rations and the estimated uptake and bioconcentration of dioxins from feed into animal fats. The uptake and bioconcentration estimates used in the assessment were based largely on studies in dairy cows[2] and limited studies in beef cattle[3] and chickens.[4] No estimates for uptake or bioconcentration of dioxins into swine tissues were available. In order to provide experimental data on the uptake and bioconcentration of dioxins from feed into swine, we conducted a feeding study in gilts utilizing one of the dioxin-contaminated mineral supplements as the dose. These results are now compared to a model developed to predict concentrations of lipophilic compounds in the tissues of growing swine.[5]

Materials and Methods

Fourteen weaned, one month old, gilts of mixed breed were obtained from the North Dakota State University swine herd. The hogs were randomly divided into three groups: controls (3), dosed (7), and dosed-withdrawn (4). All were raised under the same management conditions with free access to feed and water. The dioxin dose was prepared by homogeneously mixing a dioxin-contaminated copper mineral supplement into the swine feed to a final concentration of 1.8 ppt TEQ (wet feed weight) and 130 ppm copper. The control swine feed was supplemented with copper sulfate to provide the same copper concentration in both control and dosed diets. The hogs were weighed weekly. Individual feed intakes were not recorded, but the total consumption from each group over two time periods was estimated from the amount of feed offered and the amount of feed remaining at the end of the experiment. A corn:soybean grower feed was fed for the first 6 weeks and a corn:soybean finishing feed for the last 10 weeks (publications on swine diet and nutrition can be found at www.asi.ksu.edu).

Hogs were slaughtered at various time points to assess uptake dynamics of the dioxin-like compounds. Control hogs were slaughtered one each at 0, 6, and 16 weeks; dosed hogs were slaughtered one each at 1, 2, 4, 6, 8, 12, and 16 weeks after dosing started; and dosed-withdrawn hogs were slaughtered one each at 6, 8, 12, and 16 weeks. The hogs at the final time point had reached a typical market weight of approximately 110 kg. Adipose tissue samples and other samples were collected at slaughter for analysis. The remaining carcass (with the GI tract removed) was ground and the total fat content was measured. All collected tissue samples, the feeds, and the copper supplement were analyzed by HRGC-HRMS for PCDDs, PCDFs, and three co-planar PCBs (IUPAC # 77, 126, and 169) according to a modification of EPA Method 1613.[6] The only data from the dosed-withdrawn hogs included in this report are the live weights and carcass fat weights.

The experimental data was fitted to the model developed by Fries[5] with the following modifications. The increases in body weight (kg) and carcass fat (kg) with age for the swine were modeled from the experimental data (Figure 1). The new equations for body weight (W) and carcass fat (F) over the ages 30 – 150 days are:

$$W = 0.7716t - 2.9701 \qquad R^2 = 0.9978$$

$$F = 0.0028t^{1.8173} \qquad R^2 = 0.9802$$

where t is the age in days.

Results and Discussion

The model proposed by Fries to estimate the bioconcentration of lipophilic compounds, such as dioxins, from the feed into the tissues of growing animals is based on relatively few input parameters.[5] These parameters are body weight, total amount of fat, feed intake, absorption coefficients, and elimination rate constants. Because the original model used sufficiently old data (from the early 1970s) to generate formulae for weight gain and carcass fat gain, new equations were calculated from the actual experimental data. A comparison of the old and new growth data are shown in Figure 1. Significant changes in weight gain and fat deposition have occurred in the newer breeds of swine with weights of both increasing more rapidly with age. The hogs in our study reached 110 kg body weights at the age of approximately 145 days compared to only 70 kg body weights at 145 days in the earlier calculations. Body weight increased linearly over the time period of this study while the carcass fat increase accelerated over time.

Although the original model also used a rather old formula for estimating feed intake (from 1987), feed consumption is based on body weight, so the new formula for weight gain should compensate with an increase in feed intake. In fact, estimates of feed intake from the model corresponded well with the average intake observed early in the experiment: ages 30-73 days, 1.88 kg/d (calculated) vs. 1.90 kg/d (experimental), but not as well in the later stages: ages 73- 147 days, 3.04 kg/d (calculated) vs. 3.47 kg/d (experimental). Discrepancies between the calculated and experimental amounts could be due to omission of wasted and spilled feed in the experimental intake estimates or an inherent underestimation in the calculated intake. The latter problem could be corrected in the future by incorporating a new equation for feed intake.

Figure 2 shows comparisons between the experimental and calculated levels of a major congener in the dose (2,3,4,7,8-PeCDF). This congener was present at 0.8 ppt in the feed and represented 23% of the TEQ in the dose and in the back fat throughout the experiment. For the model calculations, absorption coefficients and elimination rates were estimated from previous reports, and the fit of each curve was observed. An initial estimate (prediction curve 1) used an absorption coefficient of 20% based on carry over rates for PeCDF into cows' milk from several studies[3,6] and a half-life of 100 days (elimination rate = 0.01) based on a study in beef cattle.[7] This curve clearly underestimates the final concentration of PeCDF in the back fat. Increased absorption (25%) with the same elimination rate (prediction curve 2) comes closer to predicting the actual back fat levels. Finally, increased absorption (25%) with a decreased elimination rate (0.005) (prediction curve 3) shows fairly good correlation (correlation coefficient = 0.926) to the experimental data considering the limitations of the experimental data i.e. each point represents one individual gilt. From the data, it appears that 2,3,4,7,8-PeCDF has a daily carry over rate into the back fat of 20 – 25%, a half-life on the order of 100 – 200 days, and a maximum bioconcentration factor of 3 from the feed into the back fat of swine.

Figure 3 shows a similar comparison for another major congener in the dose, 1,2,3,4,7,8-HxCDF, which accounted for 16% of the TEQ. 1,2,3,4,7,8-HxCDF appears to have a higher absorption coefficient (30%) and longer half-life than 2,3,4,7,8-PeCDF according to the parameters applied in Prediction curve 3 (correlation to experimental data = 0.958). Further predictions can be made for all other congeners and the total TEQ sum in the dose.

When estimated absorption coefficients and elimination rates are available, the model can be used to predict the levels of dioxins and dioxin-like compounds in fat compartments throughout the life of growing animals based on the level of contamination in the feed. Such prediction tools are useful to rapidly estimate and assess contaminations in food products should contaminated feeds or feed ingredients be discovered in the future. The model is simple to use, requires few inputs, and can be modified and improved by updating growth and feed intake equations, as needed, and half-life and carry over rates as they become available from future studies. In this study, the model was applied to growing swine raised under conditions of free access to typical feed; however, restricted diets or energy inputs can alter growth and fat deposition rates in swine such that accumulation of the contaminants may change.[5] Studies showing the effects of such nutritional changes and also the application of this model to other livestock species are areas for future research.

Acknowledgements
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References

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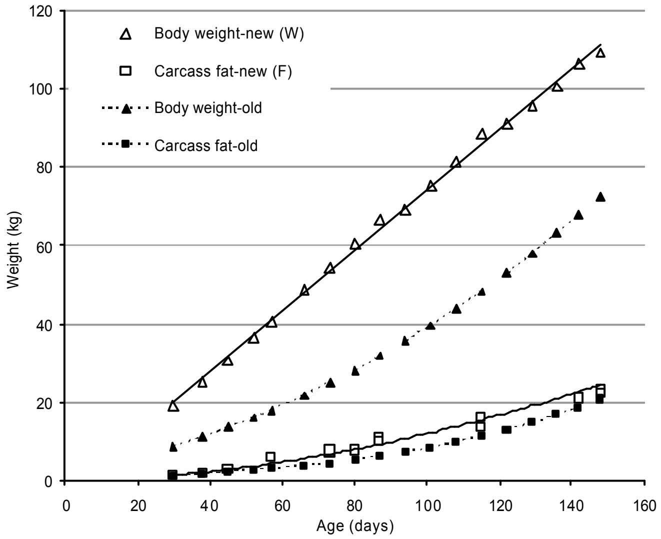

Figure 1. Plots of new and old growth data for swine ages 30-150 days. New data (open symbols) are average body weights of gilts measured weekly during this study and carcass fat weights of individual gilts measured at the time of slaughter. Old data (filled symbols) are calculated from the growth equations used by Fries.[5]

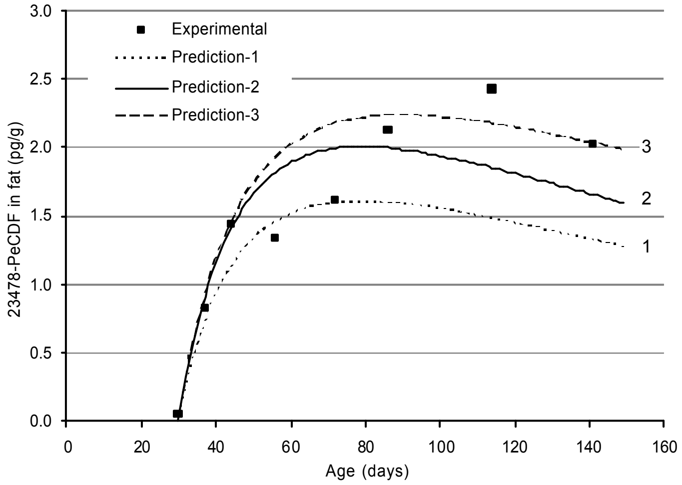

Figure 2. A comparison of experimentally measured concentrations of 2,3,4,7,8-PeCDF in the back fat of gilts fed a dioxin-contaminated feed and three calculated uptake curves for 2,3,4,7,8-PeCDF. Prediction 1 applied an absorption coefficient of 20% and an elimination rate of 0.01 (100 day half-life). Prediction 2 applied an absorption coefficient of 25% and an elimination rate of 0.01 (100 day half-life). Prediction 3 applied an absorption coefficient of 25% and an elimination rate of 0.005 (200 day half-life).

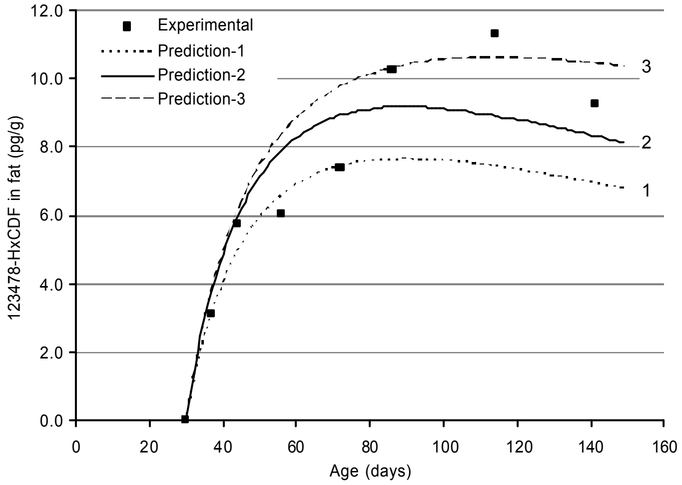

Figure 3. A comparison of experimentally measured concentrations of 1,2,3,4,7,8-HxCDF in the back fat of gilts fed a dioxin-contaminated feed and three calculated uptake curves for 1,2,3,4,7,8-HxCDF. Prediction 1 applied an absorption coefficient of 25% and an elimination rate of 0.005 (200 day half-life). Prediction 2 applied an absorption coefficient of 30% and an elimination rate of 0.005 (200 day half-life). Prediction 3 applied an absorption coefficient of 30% and an elimination rate of 0 (4 half-life).