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Food Safety and Inspection Service

Protecting Public Health and Preventing Foodborne Illness

Development of a PFOS Plasma Depletion Model in Dairy Cattle

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Introduction

- Perfluoroalkyl substances (PFAS) include perfluorooctanesulfonic acid (PFOS), perfluorooctanoic acid (PFOA), etc.
- In 2018, FDA (U.S. Food and Drug Administration) notified USDA that a dairy herd of approximately 5,000 animals had been exposed to PFAS via drinking water and forage. FDA determined that milk from the herd was adulterated due to PFOS levels.
- USDA/FSIS (responsible for regulating meat, poultry, and egg products) was concerned about the safety of beef from the dairy herd.

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Objective

- This study: to better understand perfluorooctanesulfonic acid (PFOS) plasma depletion dynamics in dairy cattle

- Part of broader project that includes:
  - Developing and validating analytical methods to measure PFAS concentrations in cattle tissues
  - Investigating the relationship between cattle plasma and muscle PFOS concentrations as possible ante-mortem approach to estimate PFOS concentrations in beef

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Preface

- Data, analysis, and results are preliminary.
- Measurements obtained to date are plasma concentrations of the PFOS linear isomer.
- Plasma branched PFOS isomer concentrations are currently being quantified.
- The analysis will be updated based on the total concentration of linear and branched isomers.

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Data

- PFOS (linear isomer) was quantified in plasma from blood samples collected every 2 weeks (0 - 153 days) from 8 animals (3 lactating, 5 young) after removal from exposure to PFOS at a contaminated dairy operation.

- PFOS (linear isomer) plasma depletion model was developed based on 92 PFOS plasma concentrations of the 8 animals.

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Methods

- To account for the lack of independence of repeated measures within cows over time, longitudinal data analysis was performed using generalized estimating equations (GEE).

- Animal class (lactating or young) was identified by an indicator variable (young = 0,1).

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Methods (cont'd)

- A difference in plasma depletion rates between young and lactating animal classes was evaluated by including the young x days interaction term in the models.

- Four depletion model forms were considered: log-linear, log-quadratic, log-cubic, and second- order.

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Log-Linear

- $ln(C_{it}) = ln(C_0) + b_i cow_i + b_1 days + b_2 young_i x days$

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Log-Quadratic

- $ln(C_{it}) = ln(C_0) + b_i cow_i + b_1 days + b_2 days^2 + b_3 young_i \text{x } days$

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Log-Cubic

- $ln(C_{it}) = ln(C_0) + b_i cow_i + b_1 days + b_2 days^2 + b_3 days^3 + b_4 young_i \text{x } days$

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Second-Order

- $\frac{1}{C_{it}} = \frac{1}{C_0} + b_i cow_i + b_1 days + b_2 young_i \text{x } days$

- $\frac{1}{C_t} = \frac{1}{C_0} + b_1 days := ln\left(\frac{C_0 - C_t}{C_o C_t}\right) = \ln(b_1) + \ln(days)$
  - If $C_t > C_0$, $\ln(C_0\text{-}C_t)$ is undefined

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Results

- Based on regression diagnostics and fit criteria, the log-cubic model was selected.

- The limited data provided no evidence that the depletion rate differs between lactating and young dairy cows (interaction term n.s. in all models).

- Preliminary PFOS plasma depletion model:
$$ln(C_{it}) = b_0 + b_i cow_i + b_1 days + b_2 days^2 + b_3 days^3$$

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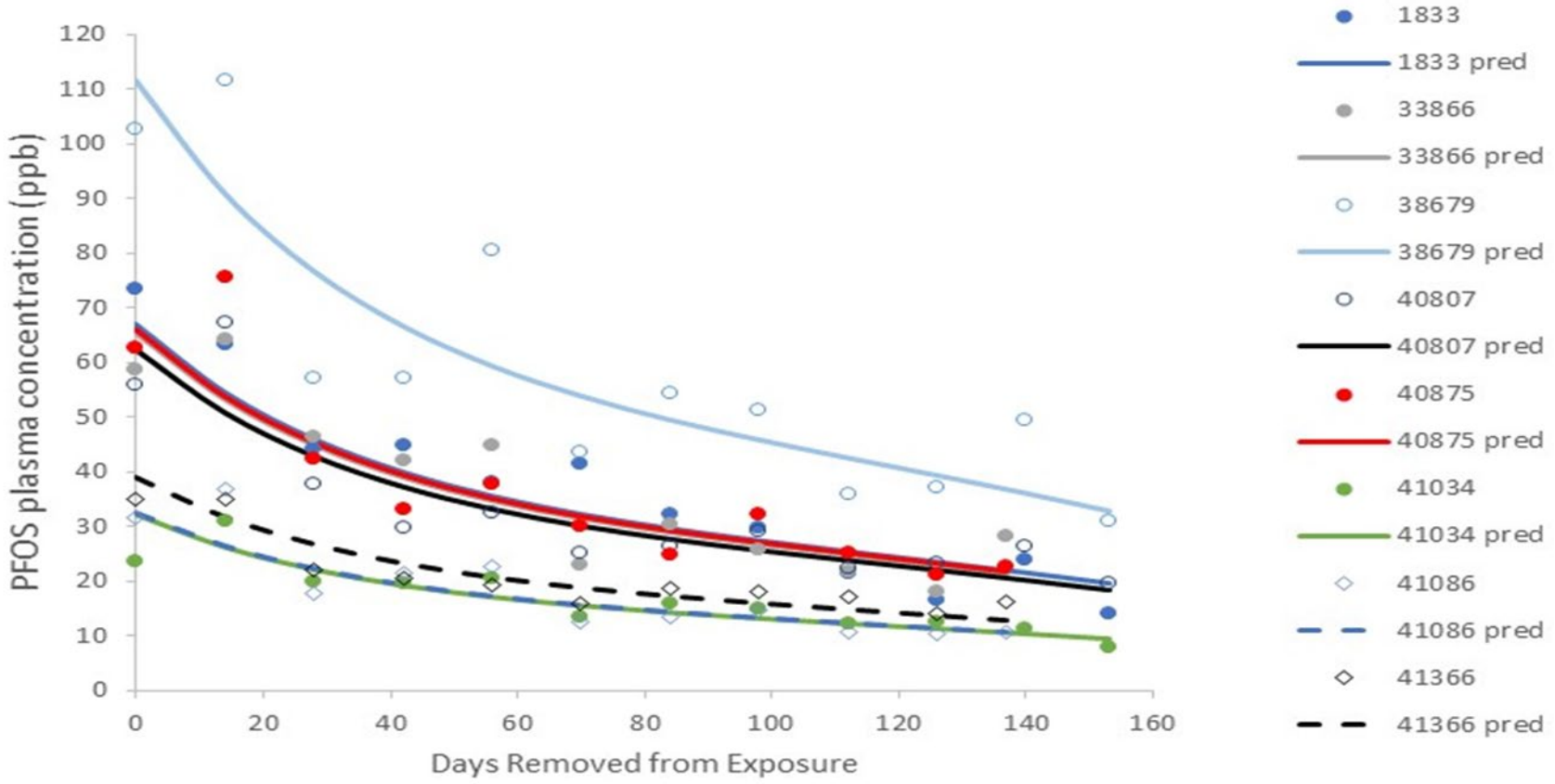
Results

Comparison of Plasma PFOS (linear isomer) Concentrations Observed and Predicted by the Log-Cubic Depletion Model



Out-of-Sample Performance

- Independent of the data used to estimate the depletion model, paired PFOS (linear isomer) plasma concentration data for 19 animals were collected on-farm and at necropsy after 14 days post-exposure.

- An out-of-sample prediction under the depletion model was accurate for the 14-day post-exposure withdrawal period.

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Discussion

- The preliminary results suggest that PFOS plasma depletion dynamics in dairy cattle are complex: first- and second-order kinetics fail to describe the observed data.

- Potential applications of this model include development of risk management strategies to permit the recovery of unadulterated beef from PFOS exposed cattle

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Questions