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Cadmium and other heavy metal concentrations in bovine kidneys in the Republic of Ireland

Mary J. Canty [a,b], Aiden Scanlon [c], Daniel M. Collins [a], Guy McGrath [a], Tracy A. Clegg [a], Elizabeth Lane [a,b], Michael K. Sheridan [c], Simon J. More [a,*]

[a] Centre for Veterinary Epidemiology and Risk Analysis (CVERA), UCD School of Veterinary Medicine, University College Dublin, Belfield, Dublin 4, Ireland
[b] Department of Agriculture, Food and the Marine, Backweston Campus, Celbridge, Co. Kildare, Ireland
[c] Department of Agriculture, Food and the Marine, Agriculture House, Kildare St, Dublin 2, Ireland

HIGHLIGHTS

- An estimated 15% of Irish soils exceed the EU Cd threshold limit of 1 mg/kg.
- 11.3% of cattle had kidney Cd concentrations in excess of the EU ML of 1 mg/kg.
- Age, soil Cd concentrations and region were key predictors of elevated kidney Cd.
- Kidneys of most Irish cattle under three years of age will conform with EU requirements.

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ABSTRACT

In Ireland, an estimated 15% of Irish soils exceed the EU threshold limit for soil Cd of 1 mg/kg. The aim was to determine the concentrations of Cd and other heavy metals (As, Hg and Pb) in kidneys collected from cattle at slaughter. Systematic sampling of eligible animals (animals that were born and reared until slaughter in the same Irish county) at the time of slaughter was conducted, until a threshold number of animals from all 26 counties and 6 age categories was reached. A predictive surface of soil Cd was generated, by kriging the Cd values of 1310 previously reported soil samples. A linear regression weighted model was developed to model kidney Cd concentration, using the risk factors of age, sex, breed, province and estimated soil Cd concentration. Kidney Cd ($n = 393$) concentrations varied between 0.040 and 8.630 mg/kg wet weight; while concentrations of As, Hg and Pb were low. The estimated weighted proportion of animals with a high (≥1 mg/kg) kidney Cd concentration was 11.25% (95% CI: 8.63–14.53%). Key predictors for high kidney Cd concentration were soil Cd, animal age and province. At a soil Cd concentration of 1.5 mg/kg, it was predicted that an age threshold to avoid exceeding a kidney Cd concentration of 1 mg/kg in most animals would be ~3 y in Connacht, >4 y in Ulster, and >5 y in Leinster and Munster. In naturally occurring areas of high Cd levels in soils in Ireland, the Cd level in bovine kidneys can exceed the current EU ML of 1 mg/kg in older animals. Kidneys of most cattle under three years of age will conform with EU requirements.

1. Introduction

Cadmium (Cd) is a naturally occurring heavy metal that is also emitted as part of industrial pollution. It has no known biological function in either animals or humans but mimics the actions of other divalent metals that are essential to diverse biological functions (EFSA Panel on Contaminants in the Food Chain, 2009). Cd is an environmental contaminant that is readily taken up by plants and, through feed intake, is further transferred to animals (Waegeneers et al., 2009a). In animals, Cd is not easily cleared by the cells, and the poor efficiency of cellular export systems explains the long residence time of this element in storage tissues such as the intestine, the liver and the kidneys (EFSA Panel on Contaminants in the Food Chain, 2009). It is for this reason that older animals have higher liver and kidney Cd concentrations (Nriagu et al., 2009), even if the concentrations of Cd in their diets and water are low.

The highest concentrations of Cd in topsoil in Europe occurs in Ireland, England, the western Alps and southern France, the Belgian–

* Corresponding author. Tel.: +353 1 716 6071.
E-mail addresses: mary.canty@agriculture.gov.ie (M.J. Canty), aiden.scanlon@agriculture.gov.ie (A. Scanlon), daniel.collins@ucd.ie (D.M. Collins), guy.mcgrath@ucd.ie (G. McGrath), tracy.clegg@ucd.ie (T.A. Clegg), elizabeth.lane@agriculture.gov.ie (E. Lane), michael.sheridan@agriculture.gov.ie (M.K. Sheridan), simon.more@ucd.ie (S.J. More).

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German border, south Sardinia, eastern Italy, Slovenia, Croatia, Albania and Greece. High Cd concentrations in most of these areas are the result of intensive agricultural use of phosphate fertilisers and sewage sludge, except in Ireland, southern Sardinia and Poland and the Goslar district in Germany, where naturally occurring high concentrations are found (Pan et al., 2010).

In Europe, maximum limits (ML) for Cd in foodstuffs are set by Commission Regulation No. 1881/2006 (European Communities, 2006), including bovine muscle, liver and kidneys. The regulatory ML for Cd in bovine muscle, liver and kidneys are 0.05, 0.5 and 1.0 mg/kg wet weight, respectively. Several authors have highlighted high kidney Cd concentrations in cattle in contaminated agricultural areas, both in Europe (including Belgium, Waegeneers et al., 2009a,b; the Netherlands, Spierenburg et al., 1988) and elsewhere (Farmer and Farmer, 2000). However, several studies have also highlighted difficulties in agricultural areas of Europe not exposed to industrial contamination (Andersen and Hansen, 1982; Waegeneers et al., 2009a,b; Bilandžić et al., 2010). As an example, the European maximum concentration for Cd in kidneys was exceeded in 47% of kidneys from Belgian cattle raised in uncontaminated areas (Waegeneers et al., 2009b), leading these authors to conclude that the Cd ML in the EU is realistic in Belgium only for cattle up to 2 years of age (Waegeneers et al., 2009a). Commission Regulation No. 1881/2006 also specifies a ML for lead (Pb) in bovine kidneys (0.5 mg/kg wet weight), but not arsenic (As) or mercury (Hg).

In Ireland, it is estimated that 15% of Irish soils exceed the EU threshold limit for soil Cd of 1 mg/kg, particularly in counties Dublin, Meath, Kildare, Westmeath, north Tipperary and Roscommon (Fay et al., 2007), attributable to the chemical composition of limestone in these areas. As yet, however, there is limited understanding of Cd concentrations in Irish cattle at the time of slaughter. The primary objective of this study was to determine the concentration of Cd in kidneys collected from cattle at slaughter in Ireland. In addition, the kidney concentrations of some other important heavy metals (As, Hg and Pb) were investigated.

2. Material and methods

2.1. Animal identification

In Ireland, all bovines are identified at birth in accordance with EU requirements. The Animal Identification and Movement (AIM) system is a centralised database, managed by the Department of Agriculture, Food and the Marine (DAFM), for the identification and movement of all cattle in Ireland. There is significant animal movement within Ireland due to its geography and traditional rearing and trading patterns. Arising from this, many animals will spend their lives on more than one farm and in different geographic regions of Ireland. For this reason, an algorithm was developed for use in AIM to identify cattle eligible for inclusion in the study, being all animals that were born and reared until slaughter in the same county.

Systematic sampling was conducted in participating slaughterhouses, with samples being collected from eligible animals at the time of slaughter, until a predefined number of animals from each county (26 counties) and age category (6 in total) had been reached. The study was undertaken in two phases, focusing on animals >60 months, and on younger cattle (aged 18–60 months). In all counties except Dublin, Kildare and Meath, approximately 12 animals were selected, being approximately 2 animals each in the age categories 18 to <24, 24 to <30, and 30 to <36 months; 1 animal in each in the age categories 36 to <48, and 48 to <60 months, and 4 animals in the age category ≥60 months. In counties Dublin, Kildare and Meath, where a parallel study was being undertaken by DAFM horticulturalists, additional bovine kidney samples were collected, and included in this study. In these three latter counties, a threshold of approximately 40 samples was used, being 8 animals each in the age categories 18 to <24, 24 to <30, and 30 to <36 months; 4 animals in each of the age categories 36 to <48, and 48 to <60 months, and 8 animals in the age category ≥60 months. Samples were collected from 11 participating slaughterhouses in Ireland, from December 2010 to December 2012.

2.2. Sample collection

At each participating slaughterhouse, DAFM personnel notified the Food Business Operator (FBO) when an eligible animal was identified. Both kidneys were removed from each animal with a clean sterile knife and the fat coverings removed. Kidneys were stored in clean plastic bags at −20 °C until sectioning. A laboratory submission form was completed for each animal, and samples were sent to the DAFM Veterinary Public Health Regulatory Laboratory, Backweston Campus, Young's Cross, Celbridge, Co. Kildare, and stored at −20 °C until sectioning.

2.3. Sample analyses

Entire kidneys were allowed to partially thaw. Each kidney was sectioned twice at 90° to the long axis of the kidney, to create a 1 cm wide cross-section of the entire kidney including the renal hilum. The 1 cm wide sections from the left and right kidney from each animal were then combined and sent on ice to the Food and Environmental Research Agency, Sand Hutton, York, United Kingdom for analyses. Samples were homogenised before being digested and analysed using inductively coupled plasma-mass spectrometry (ICP-MS) with collision cell. Reagent blanks and reagent blanks spiked with known amount of each analyte were analysed with test samples for recovery estimate purposes. All results were corrected for reagent blank and spike recovery. The limit of detection was calculated from 3 × standard deviation of reagent blank values adjusted for dilution and sample weight. The limit of quantification was calculated from 10 × standard deviation of reagent blank values adjusted for dilution and sample weight. Heavy metal concentrations are all reported as mg/kg wet weight.

2.4. Data management and analysis

2.4.1. General

Data were managed using Microsoft Excel (Microsoft Corporation, Redmond, WA, USA). Data from the laboratory submission form for each animal was cross-referenced with DAFM's Animal Health Computer System (AHCS) to confirm the animal identity tag, date of slaughter, final herd of residence and that the animal resided within the county boundary throughout its life. Other animal level information was also gathered from AHCS including breed, sex, class, date of birth, herd of origin, number of progeny, number of calving events and movement between herds. Geographic data were generated, managed and analysed using ArcGIS 10.1 (Environmental Systems Research Institute Inc., Redlands, CA, USA).

The location of each animal for mapping and analyses was attributed to the herd in which the animal resided for the longest period in its life, subsequently referred to as the '*max herd*' (n = 357). Herd locations were represented by the centroid of the largest fragment of land associated with each herd according to the Land Parcel Identification System (LPIS) for 2012. The centroid of the herds District Electoral Division (DED) of origin was used to represent the location when LPIS data was unavailable.

Data analyses were conducted using Microsoft Excel and Stata SE version 12.1 (StataCorp, Texas, USA). Where Cd results were below the limit of detection (LOD; 0.01 mg/kg for Cd), we arbitrarily assigned a Cd value of 0.005 mg/kg, being half of the LOD. Maps were created using ArcView GIS 3.2 (Environmental Systems Research Institute, Inc., CA, USA).

2.4.2. Estimating mean soil Cd

Data were available on soil Cd values for 1310 samples throughout Ireland, collected during 1995–96 (295 soil samples) and 2002 (1015 soil samples) by the Environmental Protection Agency (Fay and Zhang,