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Cost-effective allocation of resources for monitoring dioxins along the pork production chain

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ABSTRACT

The pork chain has been seriously affected by dioxin incidents in recent decades. Hence, monitoring dioxins is crucial for detecting contaminations in the pork chain. This study aims to develop a decision support tool (optimization model) to determine cost-effective monitoring schemes for detecting and tracing a dioxin contamination over multiple control points along the pork production chain.

The optimization model considers four control points (i.e. at the supplier of fatty feed ingredients, the feed mill, the slaughterhouse and the fat melting facility) and a weekly monitoring period. It was applied to several hypothetical contamination scenarios involving contaminated animal fatty feed ingredients.

The cost-effective allocation of resources for detecting and tracing the dioxin contamination from an integrated chain approach (i.e. considering all control points) focuses on monitoring at the feed mill, followed by the supplier of fatty feed ingredients and – to a lesser extent – by the slaughterhouse. The number of contaminated feed mills, the frequency of dioxin contaminations, the required level of effectiveness, and the cost of screening are main factors driving the total monitoring costs.

Sharing the responsibility of monitoring dioxins within control points along the chain largely reduces the total monitoring costs. In each of the evaluated scenarios, the total costs of monitoring dioxins at individual control points are larger than the costs resulting from an optimal allocation of resources among all control points integrated in one overarching chain monitoring scheme. These results elicit the economic benefits of a chain approach to monitoring dioxins over an approach where each chain actor independently monitors dioxins. The developed model can be used by decision makers in the feed and food industry for determining optimal schemes for monitoring dioxins in the pork chain focusing on preventing specific contaminations.

1. Introduction

Polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), from here on termed 'dioxins', are ubiquitous environmental pollutants found in human tissues even in cases where neither occupational nor accidental exposure have been reported (Rose, Thomson, Jensen, Giorgi, & Schulz, 2009). Dioxins are toxic at low levels, with proven effects as endocrine disruptors in animals and humans (Hoogenboom, 2009). They bio-accumulate and bio-magnify along the food chain (Schmid et al., 2002). From all possible human exposure pathways, food ingestion is the major route (Rose et al., 2009) with food products of animal origin as the main contributors (Büchert et al., 2001; Huwe, 2002). Feed ingredients and/or additives used in compound feed for livestock production have been a main cause of such food dioxin incidents in the past decade (Abalos, Parera, Abad, & Rivera, 2008; Bernard et al., 2002; Heres, Hoogenboom, Herbes, Traag, & Urlings, 2010; Hoogenboom, Bovee, et al., 2004; Hoogenboom, Kan, et al., 2004; Huwe & Smith, 2005; Kim et al., 2009; Kim et al., 2011; Llerena, Abad, Caixach, & Rivera, 2003; Malisch, 2000; Sapkota, Lefferts, McKenzie, & Walker, 2007). The pork production chain has been one of the food sectors seriously affected by compound feed contaminated with dioxins (Bernard et al., 2002; Heres et al., 2010; Hoogenboom, Kan, et al., 2004; Kim et al., 2009). Such incidents may result into large financial implications due to recalls and trade disruptions, as was e.g., the case with the Belgian incident of 1999 (Buzby & Chandran, 2003; Lascano Alcoser, Velthuis, Hoogenboom, & van der Fels-Klerx, 2011), the Irish incident of 2008 (Heres et al., 2010; Tlustos, 2009a, 2009b) and the Chilean incident in 2008 (Kim et al., 2009; Kim et al., 2011). Public and private efforts have taken place to manage dioxin contaminations in feed and food aiming to prevent the occurrence of future incidents. The European Commission

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(EC) has set maximum levels for the presence of dioxins in feed and food (EC, 2006, 2011a, 2011b, 2012), enforced the adoption of feed and food safety assurance systems (i.e. Hazard Analysis and Critical Control Points (HACCP) and Good Manufacturing Practice (GMP)) (Domenech, Escriche, & Martorell, 2008; EC, 2004, 2005; Heres et al., 2010), which resulted into the implementation of monitoring schemes. Regular monitoring in the food chain is crucial for detecting accidental or intentional food contaminations (Zach, Doyle, Bier, & Czuprynski, 2012), to verify the well-functioning of the safety management systems (Ropkins & Beck, 2002; Domenech et al., 2008), to identify sources of dioxin contaminations, and to determine weak control points along the food chain (Heres et al., 2010). However, the intensity of monitoring is limited as the required analytical methods for detecting dioxins are costly and time consuming (Ropkins & Beck, 2002; Zach et al., 2012). So far, the challenge to maximize monitoring performance while accounting for resource constraints has received little attention. Quantitative decision support systems that aid in the allocation of resources to the various controls points along the food chain are desired. Lascano-Alcoser et al. (2013) developed an optimization model that statistically determines the optimal sample size necessary to detect a dioxin contamination in bulk milk and a method to quantitatively measure the performance of the monitoring scheme. This study was, however, restricted to a single control point along the chain. Studies to evaluate a cost-effective intensity of monitoring food safety hazards along the entire food chain are seriously lacking. The present study aims to develop a decision support tool to determine cost-effective schemes for monitoring dioxins over multiple control points along the pork production chain aiming at detecting and tracing a dioxin contamination to its origin.

2. Materials and methods

For the aim of this study, it is important to distinguish between a dioxin contamination and a dioxin incident. A dioxin contamination in the pork chain is defined as the presence of dioxins (without considering any referential concentration) in a raw material or processed product at any control point along the pork chain. The detection of a dioxin contamination results in a dioxin incident when the concentration of dioxins in the raw material or processed product, at any control point of a food production chain, is higher than a certain threshold concentration (i.e. maximum limit).

A model was constructed to optimize resource allocations for monitoring dioxins across a hypothetical pork production chain. To simplify the model, only dioxins were considered, excluding dl-PCBs. This section starts by describing the pork chain assumed, the control points for monitoring dioxins and the simulated course of the contamination through the chain. It is followed by a description of the actor related activities to monitor dioxins, a description of the optimization model, and the evaluated contamination scenarios.

2.1. Simulation of a dioxin contamination along the pork chain

Based on statistical data from the year 2011, obtained from the European Feed Manufacturers' Federation (FEFAC), the Agricultural Economics Institute of Wageningen University (LEI) and the Product Boards for Livestock, Meat and Eggs (PVE) in The Netherlands, a hypothetical pork production chain for fattening pigs was designed. This chain represents a western European pork supply chain consisting of five production stages and therefore, five distinct actors: the supplier of fatty feed ingredients, the manufacturer of compound feed for fattening pigs (feed mill), the pig fattening farm, the slaughterhouse, and the pork fat melting processor (see Fig. 1). From the five production stages described, four logical control points for monitoring dioxins are considered. These are located: (1) at the suppliers of fatty feed ingredients to monitor containers with animal fatty feed ingredient before delivery to feed mills, (2) at the feed mills for monitoring batches of manufactured pig feed, (3) at the slaughterhouses for monitoring full carcasses, and (4) at the fat melting facilities for monitoring batches of pure pork fat (Fig. 1).

To simplify the complexity of the real pork production chain, average values of input variables are used to parameterize the production chain. Moreover, all production facilities (including farms) within each stage of the chain are assumed to have the same production capacity (size). The dioxin contamination is followed throughout the production chain from the suppliers of fatty feed ingredients to the fat melting processor. At each control point, the fraction of contaminated material and its concentration of dioxins are estimated. On a weekly basis, a certain number of containers with animal fatty feed ingredients are dispatched by suppliers of fatty feed ingredients to feed mills. A predefined number of those containers is assumed to be contaminated with a specific dioxin concentration, and dispatched to feed mills specialized in producing feed for fattening pigs. At these feed mills, animal fatty ingredients are stored into a silo filled to its maximum capacity before its content is used in the feed production line. In this silo, contaminated animal fatty ingredient can be mixed with non-contaminated material, since feed mills may receive animal fatty ingredients from many suppliers. Thus, a dilution of the initial dioxin concentration in the contaminated animal fatty ingredient is expected. The amount of contaminated pig feed produced in a week at each feed mill is estimated based on the

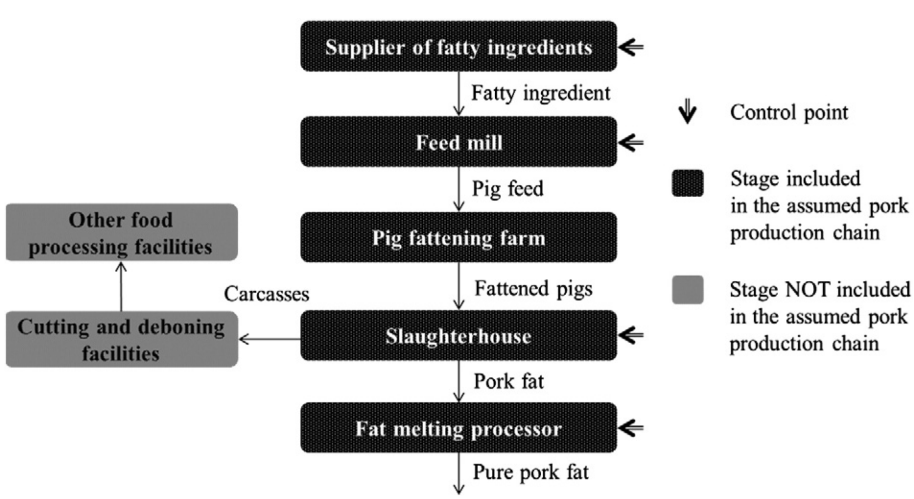

Fig. 1. Description of the assumed pork chain and the dioxin control points.