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Short communication

Salmonella risk to consumers via pork is related to the *Salmonella* prevalence in pig feed

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ABSTRACT

Pigs are an important source of human infections with *Salmonella*, one of the most common causes of sporadic gastrointestinal infections and foodborne outbreaks in the European region. Feed has been estimated to be a significant source of *Salmonella* in piggeries in countries of a low *Salmonella* prevalence. To estimate *Salmonella* risk to consumers via the pork production chain, including feed production, a quantitative risk assessment model was constructed. The *Salmonella* prevalence in feeds and in animals was estimated to be generally low in Finland, but the relative importance of feed as a source of *Salmonella* in pigs was estimated as potentially high. Discontinuation of the present strict *Salmonella* control could increase the risk of *Salmonella* in slaughter pigs and consequent infections in consumers. The increased use of low risk and controlled feed ingredients could result in a consistently lower residual contamination in pigs and help the tracing and control of the sources of infections.

1. Introduction

Non-typhoid *Salmonellae*, the second most common cause of sporadic gastrointestinal infections and foodborne outbreaks in the European region in 2014, are mostly zoonotic bacteria found in the intestines of many species of animals and in the environment (EFSA, 2015). Being capable of infecting warm-blooded production animals and contaminating both meat and vegetable products via faecal matter, *Salmonella* is considered as a serious food safety issue. To protect consumers from salmonellosis, the European Union (EU) established the so-called Zoonosis Directive in 1992 and an extended control programme for *Salmonella* in 2003 (Directives 92/117/EEC and 2003/99/EC and Regulation 2160/2003). In Finland, utilizing practices already introduced in the 1950's, an official control programme for *Salmonella* (FSCP) was established before joining the EU in 1995 (European Commission Decisions 94/968/EC and 95/160/EC). Due to the low prevalence of *Salmonella* infections in poultry, beef and pork, Finland was granted so-called additional guarantees by the EU, i.e. the right to demand the same level of *Salmonella* protection as in domestic products in a variety of imported products (European Commission Decisions 95/160/EC and 95/161/EC). The control of feed materials and feeds is not part of the FSCP, but according to the national Feed Act they must not contain *Salmonella* (86/2008 6 §).

A recent study using data from 2007 to 2009 concluded that the pig reservoir as a whole may be the cause of around 2.9–11 (31%) million cases of human *Salmonella* infections in the EU area (de Knegt et al., 2015). Pork products may become contaminated with *Salmonella* at the slaughterhouse level via faeces from infected pigs by cross-contamination during the slaughtering or meat-cutting processes (Arguello et al., 2013). Pigs acquire the infection by ingesting or inhaling viable *Salmonella* bacteria present in feed or in the environment (Fedorka-Gray et al., 2000). Excretion of *Salmonella* may continue from weeks to several months, during which time infected pigs may be transferred from farrowing farms to finishing farms or from finishing farms to the slaughterhouse (Kranker et al., 2003). Most *Salmonella* infections in pigs with the exception of e.g. *S.* Cholerasuis, are so mild that they do not affect growth or production (Fedorka-Gray et al., 2000). These sub-clinically infected pigs may, however, start excreting *Salmonella* when they are exposed to stress for example during transfer to the slaughterhouse (Rostagno, 2009).

Salmonella bacteria can tolerate various environmental

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conditions. They can grow at temperatures from 8 to 45 °C, in a pH range of 4.0–9.0, and at low water activity (0.94; Hanes, 2003). Due to these characteristics, *Salmonella* can persist for long times in the feed mill environment (Alali and Ricke, 2012). Feed ingredients that have a high protein content, such as soy and rapeseed, are the most commonly contaminated raw materials and may introduce *Salmonella* into feed mills and into the feed mixing environment at pig farms. The introduction of *Salmonella* to the farm environment can occur via the purchase of new production animals as well as via contaminated feed and feed materials, infected rodents, birds, insects, pets and even humans working on, or visiting, the farm. The first and the second routes are regarded as the most important ones (EFSA, 2010).

Preventive actions, including testing for *Salmonella*, are mainly used to avoid contamination at feed mills and on farms, especially in countries where the prevalenceof the pathogen is generally low, i.e. less than 5% (2011/432, 2004:2 SJVFS). Eradication of *Salmonella* from pig farms and from the feed chain can be both difficult and costly (EFSA, 2010). Risk assessments should be used as key elements when these preventive actions are planned and executed. In Finland, risk assessments concerning *Salmonella* have been conducted on poultry, pig, cattle, and egg production included in the FSCP (Maijala and Ranta, 2003; Ranta et al., 2004; Tuominen et al., 2007; Maijala et al., 2005; Lievonen et al., 2006). The risk assessment on *Salmonella* in pork production concluded that the currently prevailing magnitude of the *Salmonella* risk to consumers via domestic pork is mainly driven by the prevalence of *Salmonella* in primary production on pig farms (Ranta et al., 2004). The present study addressed the *Salmonella* risk to consumers posed by pigs, focusing on the risk to pigs via their feed. Years 2013–2014 were considered as the baseline situation.

A recently developed model (Välttilä et al., in this issue) utilizing both production chain information and *Salmonella* typing data from pigs, feed and the environment, was combined with a point-estimate of the share of human cases attributable to the domestic pig reservoir as a whole. The point-estimate was based on typing data from human salmonellosis cases from 2012 to 2014 (Finnish National Infectious Diseases Register, 2016). This typing data was compared to the typing data from salmonella-positive animals and products of animal origin (pigs vs other sources, Evira). Based on the feed risk assessment model, different scenarios were simulated in order to study the influence of different preventive actions on *Salmonella* prevalence.

2. Methods

To estimate the *Salmonella* risk for consumers via the pork production chain including feed production, a quantitative risk assessment was developed to quantify Salmonella prevalence from raw feed materials to pigs and to consumers (Fig. 1). The assessment combined a recently developed model (Välttilä et al., in this issue) with a source attribution estimate. It was implemented with OpenBugs software using Finnish data on farm-to-fork flow-chain structures and available sampling data.

The model combined two approaches. A bottom-up approach was used to estimate the *Salmonella* risk to pigs from feed ingredients and feeds. Top-down approaches, which started from subtyping data, were used to estimate the relative proportions of pig infections due to feed or the environment and also to estimate the relative proportion of human salmonellosis cases attributable to pork. The data from the feed production chain were collected in 2013 and 2014 (data from 2015 were not yet available), whereas the typing results from contaminated pigs, feed, and environment were from 2008 to 2015 and the human isolate data from 2012 to 2014. Several year time-series were exploited due to scarce *Salmonella* findings.

The feed model was used to estimate the true *Salmonella* prevalence in feed ingredients, feed types and feeds, as well as the concentration and changes in concentration of the pathogen in *Salmonella*-positive batches in the overall total production (Välttilä et al., in this issue). Two preventive actions aimed at reducing the levels of *Salmonella* in feed were included in the model: 1. heating of feed and 2. chemical treatment of contaminated feed raw materials. The relative commonness of different feeding practices, such as using complete feeds or component feeds and liquid or dry feeds, was also taken into account.

Additionally, the probability of a pig consuming *Salmonella*-contaminated feed and the probability of infection after a one-day consumption was evaluated, as well as over consumption period of a single batch of feed. In Finland, the primary observation of any *Salmonella* type on a pig farm or in a slaughter pig leads to trace-back activities and eradication measures of *Salmonella* from the *Salmonella* positive farm. Therefore, we focused on the point of entry of *Salmonella* to farms, and the within-herd spread was not studied. Lymph node sample prevalence data acquired from Finnish slaughterhouses and the test sensitivity (Enøe et al., 2001) were used to estimate the true prevalence of *Salmonella* in pigs. The proportional risks of feed and the environment (i.e. remaining other sources), given that the infection occurred for one or the other reason, were evaluated from the ratio of overall probability of feed-borne infection and probability of infection due to either reasons. In addition, serotype -data on the *Salmonella*-positive findings from pigs and the environment were also used to evaluate the proportional risks of the sources of infections.

The human salmonellosis cases attributable to pork were calculated by comparing the *Salmonella* subtypes isolated from human cases with those isolated from various sources, including pigs. The data was composed of 58 *Salmonella* subtypes isolated from 191 live production animal samples (pigs, cattle, broiler, turkey) combined with 4 subtypes (5 samples) from domestic products originating from the same animal species, as well as from 64 subtypes (231 samples) from imported products of animal origin (pigs, cattle, broiler, turkey) isolated in 2008–2015, and 86 subtypes isolated from 750 domestic human cases in 2012–2014. Four subtypes isolated from eight human cases were unique to domestic pig reservoir. 424 human cases were caused by 70 *Salmonella* subtypes which had never been isolated from the pig reservoir. The 318 human cases representing 12 subtypes isolated from both pig reservoir and some other sources were attributed to the eight different sources according to the relative share of the subtypes within the reservoir in the estimation. Finally, the point-estimate of the proportion of human cases attributed to pork via live pigs was combined with the estimation of the proportion of pig infections attributable to feed in order to estimate the proportion of human salmonellosis cases attributable to pork via pig feed.

The information and data needed for the risk assessment were gathered from several sources, including the scientific literature and statistics, reports of the Finnish Food Safety Authority Evira, the customs office, the Finnish Farm Registry and Finnish National Infectious Diseases Register. The data used in the dose response model for pigs were adopted from Loynachan and Harris (2004). More specific information on feed production practices in feed mills and on farms was collected by carrying out an inquiry targeted at feed mills producing pig feed, pig farms producing their own feeds and mobile mixers mixing pig feed in Finland. The data have been described in more detail by Välttilä et al. (in this issue). As the feed

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