# Meat Juice Serology and Improved Food Chain Information as Control Tools for Pork-Related Public Health Hazards

Felin, E.

2015-09

Felin , E , Jukola , E , Raulo , S & Fredriksson-Ahomaa , M 2015 , ' Meat Juice Serology and Improved Food Chain Information as Control Tools for Pork-Related Public Health Hazards ' , Zoonoses and Public Health , vol. 62 , no. 6 , pp. 456-464 . https://doi.org/10.1111/zph.12174

http://hdl.handle.net/10138/303398
https://doi.org/10.1111/zph.12174

unspecified
acceptedVersion

# Meat juice serology and improved food chain information (FCI) as control tools for pork-related public health hazards

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## SUMMARY

The seroprevalence of *Salmonella* spp., pathogenic *Yersinia* spp., *Toxoplasma gondii* and *Trichinella* spp. was studied in 1353 finishing pigs from 259 farms that were allocated according to farm types: large fattening farms ( ≥ 1000 pig places), small fattening farms ( < 1000 pig places) and farrow-to-finish farms. The antibodies were analysed with commercial ELISA kits in meat juice samples that were collected at Finnish slaughterhouses. *Salmonella* antibodies were rare (3% of pigs, 14% of farms) when the cutoff optical density (OD) value 0.2 was used. Antibodies to pathogenic *Yersinia* spp. and *T. gondii* were detected in 57% of pigs and on 85% of farms (OD ≥ 0.3) and in 3% of pigs and 9% of farms (OD ≥ 0.15), respectively. No antibodies to *Trichinella* spp. were detected (OD ≥ 0.3). The European Food Safety Authority (EFSA) considers *Salmonella* spp., *Yersinia enterocolitica*, *T. gondii* and *Trichinella*

spp. as the most relevant biological hazards in the context of meat inspection of pigs. The seroprevalence of these important zoonotic pathogens was low in Finland, except that of *Yersinia*. The seroprevalence of *Toxoplasma* was significantly higher in pigs originating from small-scale fattening farms ($p < 0.05$). Strong positive correlation was observed at the animal level between *Salmonella* and *Yersinia* seropositivity and between *Salmonella* and *Toxoplasma* seropositivity ($p < 0.05$). We suggest that these results reflect the level and importance of biosecurity measures applied on the farms. Meat juice serology at slaughter is a useful tool for targeting measures to control these pathogens. The information obtained from analyses should be used as part of the food chain information (FCI).

Keywords: Public health hazards, serology, monitoring, meat safety, pigs, food chain information (FCI), *Salmonella, Yersinia, Toxoplasma, Trichinella*

## IMPACTS

- *Salmonella* spp., *Yersinia enterocolitica*, *Trichinella* spp. and *Toxoplasma gondii* are the most relevant biological hazards in the context of meat inspection of pigs.
- Meat juice serology at slaughter is a useful tool for targeting measures to control zoonotic pathogens.
- In Finland, *Salmonella* and *Toxoplasma* antibodies were rare and *Trichinella* antibodies were not detected in finishing pigs. *Toxoplasma* was more prevalent in pigs originating from small-scale fattening farms.

## 1. INTRODUCTION

The European Food Safety Authority (EFSA) considers *Salmonella* spp., *Yersinia enterocolitica*, *Trichinella* spp. and *Toxoplasma gondii* as the most relevant biological hazards in the context of meat inspection of pigs (EFSA, 2011). Of the zoonotic pathogens causing human illnesses often related to pork consumption (Fosse et al., 2008), only *Trichinella* spp. are detectable within the current *post-mortem* inspection of pig meat. The EFSA (2011) stated that a comprehensive pork carcass safety assurance is the only way to ensure effective control of these zoonotic pathogens. Evaluating the seroprevalences of zoonotic pathogens in pigs entering the slaughterhouse could provide valuable data while targeting national control measures aiming at diminishing carcass contamination with the most relevant foodborne biological hazards, including zoonotic bacteria and parasites, at primary production on farms. Furthermore, sufficient serological data from individual farms would enable intervention at the farm level, while at the slaughterhouse level they would aid in making decisions regarding carcass processing. Considering that routine inspections for *Trichinella* are expected to become less frequent (Anonymous, 2014), new means of monitoring are needed.

Conventional culture methods for *Salmonella* spp. and enteropathogenic *Yersinia* spp. are slow and laborious, while for *T. gondii* a proper practical method for direct detection does not exist (Basso et al., 2013). Instead, these pathogens can be indirectly detected by the ELISA (enzyme-linked immunosorbent assay) method, which is fast, sensitive and simple to perform. The presence of antibodies to a specific pathogen indicates that the animal has been exposed to the pathogen at some stage of life, although the seropositive animal may no longer be infective (Nielsen et al., 1995, 1996). Serology is considered as a useful tool for population- and herd-level surveillance programmes for all these four main zoonoses in pigs (Nesbakken et al., 2003; Gamble et al., 2004, 2005; Nowak et al., 2007). The aim of the study was to assess the

prevalence of antibodies in meat juice to these important zoonoses and to evaluate the feasibility of the method at the slaughterhouse and the usability of the results as part of the food chain information (FCI).

## 2. MATERIALS AND METHODS

### *2.1 Sampling*

Meat samples from 1353 finishing pigs were collected between November 2012 and April 2013 at slaughter. The pigs originated from 259 conventional farms that were allocated according to farm types: large fattening farms ( ≥ 1000 pig places), small fattening farms ( < 1000 pig places) and farrow-to-finish farms. The samples were collected randomly from two slaughterhouses that receive animals from throughout Finland. Approximately 75 % of finishing pigs in Finland were slaughtered at these two slaughterhouses. A farm was represented by an average of 5 (range 3–15) pigs. Background data on the exact number of pig places, were obtained from 177/179 fattening farms.

For sample size estimation, the seroprevalence of *Yersinia* was assumed to be 60%, *T. gondii* 3% and *Salmonella* 1%. Consequently, the sample size is adequate to detect antibodies to *Salmonella*, *Yersinia* and *Toxoplasma* at the foreseen prevalences (Naing et al., 2006). The seroprevalence of *Trichinella* was assumed to be nearly 0%. However, regarding *Trichinella,* the aim was only to indicate that the seroprevalence was below 1%.

Meat samples (about 10 g of muscle from the diaphragm) were collected in plastic bags and frozen to below -18 °C. To obtain meat juice, the samples were thawed and mechanically squeezed. The meat juice obtained was stored at -70 °C until testing and thawed before analysis,

then frozen again for possible reanalysis. Rastawicki et al. (2012) demonstrated that antibodies are stable even after multiple freeze-thaw cycles.

### *2.2 Serology*

The meat juice samples were examined, using commercial ELISA kits suitable for pig meat juice samples. The reactions were read, using a spectrophotometer (Multiskan Ascent V1.24; Thermo Electron Corporation, Waltham, MA, USA) at 450 nm. All analyses were performed from 10 µl of meat juice (diluted 1:10). Results equal to or above the cutoff value were considered as positive.

The *Salmonella* antibodies were analysed, using the SALMOTYPE Pig Screen test (Labor Diagnostik GmbH, Leipzig, Germany), following the manufacturer's instructions. The test detects antibodies to O-antigens 1, 4, 5, 6, 7 and 12. The results were interpreted according to the manufacturer's instructions with a cutoff optical density (OD) value of 0.2. Following this protocol, the sensitivity of the test was 98.5% and specificity 99.8%, according to the manufacturer.

The *Yersinia* antibodies were determined, using the PIGTYPE® YOPSCREEN test (Labor Diagnostik) according to the manufacturer's instructions (cutoff OD of 0.3). The antigens used in the test are *Yersinia* outer proteins (Yops), which are expressed only by pathogenic *Yersinia* strains carrying the virulence plasmid. According to the manufacturer, the sensitivity and the specificity of the test are near 100%.

The *Trichinella* antibodies were analysed using the PIGTYPE® Trichinella Ab test (Labor Diagnostik) according to the manufacturer's instructions (cutoff OD of 0.3). Pigs harbouring as

few as one larva per 100 g of tissue can be detected by serological methods (Gamble et al., 1983). The sensitivity of the test was 98.9% and the specificity 95.4% (Knoop et al., 2011). Confirming positive results with Western blot analysis enables to achieve almost 100% specificity (Frey et al., 2009).

The *T. gondii* antibodies were detected by the PrioCHECK® Toxoplasma Ab Porcine test (Prionics AG, Schlieren-Zurich, Switzerland), according to manufacturer´s instructions (cutoff OD of 0.15). A recent study demonstrated high sensitivity and specificity of the test: 98.9% and 92.7%, respectively (Basso et al., 2013).

### *2.3 Statistical analysis*

An individual animal with a positive sample was considered seropositive. A farm was considered seropositive when at least one of the sampled animals tested positive. The 95% CIs for the seroprevalences were calculated, using the OpenEpi program and the Wilson method (Dean et al., 2013). The serological results were interpreted, using the analytical software package SPSS® Statistics Version 21 (IBM Corporation, Armonk, NY, USA). The Pearson chi-square test was used for cross-tabulated data. Correlations between variables, both on animal and farm level, were analysed using a bivariate Pearson (two-tailed) test. The seropositivity of pigs originating from different farming systems was compared, using one-way analysis of variance (ANOVA) and Tukey honestly significant difference (HSD). P-values $< 0.05$ were considered statistically significant.

## 3. RESULTS

*Salmonella* antibodies were detected in 3% of pigs and in 14% of farms with cutoff ODs of 0.2 (Table 1). When *Salmonella*-seropositive pigs were found, only one pig tested positive for most

150 farms (83%) while on none of the farms did all pigs test positive. Regarding *Salmonella*, no
151 differences were found among farm types. The overall OD values of *Salmonella* were low; in
152 only five samples (0.4%) was the OD > 0.3 (Figure 1).
153
154 In all, 57% of pigs and 85% of farms were seropositive for pathogenic *Yersinia* spp. On 60
155 farms (23%), all pigs tested were positive. *Yersinia* antibodies were more prevalent in pigs
156 originating from large fattening farms than from farrow-to-finish farms: however, the
157 difference between farm types was not statistically significant ($p = 0.09$).
158
159 In all, 3% of pigs originating from 9% of farms were seropositive for *T. gondii*. As an animal
160 group, those pigs originating from small fattening farms showed a significantly higher
161 seroprevalence of *T. gondii* than pigs from other farm types ($p \leq 0.002$). When *Toxoplasma*-
162 seropositive pigs were found on small fattening farms, always more than one pig tested positive
163 and for three of the farms all the pigs tested ($n = 5$) were positive (Figure 2). For the pigs ($n =$
164 918) from fattening farms with known numbers of pig places, a strong negative correlation ($p$
165 $< 0.001$) between the pigs´ seropositivity for *T. gondii* and the number of pig places on the farm
166 of origin was found at the animal level. *Trichinella* antibodies were not detected.
167
168 Most (35/42) of the *Salmonella*-seropositive pigs were also *Yersinia*-seropositive (Table 2).
169 There was a strong positive correlation ($p < 0.001$) at the animal level between the pigs'
170 seropositivity for *Salmonella* and *Yersinia*. No significant association ($p = 0.25$) was found on
171 farm level between *Salmonella* and *Yersinia*. However, for those farms where *Salmonella* was
172 detected the percentage of *Yersinia*-seropositive animals was statistically higher ($p < 0.05$) than
173 for those farms where *Salmonella* was not found. Similar animal-level (but not farm-level)
174 associations were also seen between *Salmonella* and *Toxoplasma* seropositivity ($p < 0.05$).

175

176

TABLE 1. Seroprevalence estimates with 95% confidence intervals (CI) in meat juice samples of finishing pigs in Finland.

| Pathogen | Pigs | | | Farms | | |
|---|---|---|---|---|---|---|
| | N* | % | 95% CI | N* | % | 95% CI |
| *Salmonella*[a] | | | | | | |
| Total | 42/1353 | 3.1 | 2.3-4.2 | 35/259 | 13.5 | 9.9-18.2 |
| Large fattening farms | 14/492 | 2.8 | 1.7-4.7 | 12/93 | 12.9 | 7.5-21.1 |
| Small fattening farms | 12/436 | 2.8 | 1.6-4.8 | 9/86 | 10.5 | 5.6-18.7 |
| Farrow-to-finish farms | 16/425 | 3.8 | 2.3-6.0 | 14/80 | 17.5 | 10.7-27.2 |
| *Yersinia*[b] | | | | | | |
| Total | 766/135 | 56.6 | 54.0-59.2 | 220/259 | 84.9 | 80.1- |
| Large fattening farms | 3 | 60.6 | 56.2-64.8 | 83/93 | 89.2 | 88.8 |
| Small fattening farms | 298/492 | 55.0 | 50.4-59.7 | 70/86 | 81.4 | 81.3- |
| Farrow-to-finish farms | 240/436 | 53.6 | 48.9-58.3 | 67/80 | 83.8 | 94.1 |
| | 228/425 | | | | | 71.9-88.2 |
| | | | | | | 74.2-90.3 |
| *Toxoplasma gondii* | | | | | | |
| Total | 43/1353 | 3.2 | 2.4-4.3 | 24/259 | 9.3 | 6.3-13.4 |
| Large fattening farms | 9/492 | 1.8 | 1.0-3.4 | 9/93 | 9.7 | 5.2-17.4 |
| Small fattening farms | 26/436 | 6.0 | 4.1-8.6 | 10/86 | 11.6 | 6.4-20.1 |
| Farrow-to-finish farms | 8/425 | 1.9 | 1.0-3.7 | 5/80 | 6.3 | 2.7-13.8 |
| *Trichinella* | | | | | | |
| Total | 0/1353 | 0.0 | 0.0-0.3 | 0/259 | 0.0 | 0.0-1.5 |
| Large fattening farms | 0/492 | 0.0 | 0.0-0.8 | 0/93 | 0.0 | 0.0-4.0 |
| Small fattening farms | 0/436 | 0.0 | 0.0-0.9 | 0/86 | 0.0 | 0.0-4.3 |
| Farrow-to-finish farms | 0/425 | 0.0 | 0.0-0.9 | 0/80 | 0.0 | 0.0-4.6 |

177 *Pig is considered seropositive when a sample equal to or above the cutoff value. Farm is considered
178 seropositive when at least one sample is positive. In general, five pigs were sampled per farm
179 (variation 3–15).
180 [a] O-serotypes 1, 4, 5, 6, 7 and 12, cutoff OD value of 0.2.
181 [b]Pathogenic (Yop-positive) *Yersinia* spp., cutoff OD value of 0.3.
182

**FIGURE 1.** Distribution of optical density (OD) values of *Salmonella* antibodies in meat juice samples of 1353 finishing pigs at slaughter in Finland.

187 **FIGURE 2.** Percentage of *T. gondii*-seropositive pigs in samples from 177 fattening farms.
188
189

TABLE 2. *Salmonella* and *Yersinia* antibodies in meat juice samples of 1353 finishing pigs at slaughter in Finland.

| *Salmonella* spp. | Pathogenic *Yersinia* spp. | | | | All samples | |
|---|---|---|---|---|---|---|
| | Negative | | Positive[b] | | | |
| Negative | 580 | (44%) | 731 | (56%) | 1311 | (100%) |
| Positive[a] | 7 | (17%) | 35 | (83%) | 42 | (100%) |
| All | 587 | (43%) | 766 | (57%) | 1353 | (100%) |

[a] Antibodies to O-serotypes 1,4,5,6,7 and 12

[b] Antibodies to virulence plasmid encoded Yop proteins

## 4. DISCUSSION

*Salmonella* spp., pathogenic *Yersinia enterocolitica*, *Trichinella* spp. and *Toxoplasma gondii* are the main zoonotic pathogens in pigs and pork (EFSA, 2011). However, none of these pathogens are detectable in the current macroscopic system of *post-mortem* meat inspection, except for the *Trichinella* parasite that is detectable by laboratory analysis. One way of controlling these zoonoses is by performing serological analyses that can be carried out from blood or meat juice at the slaughterhouse. We used meat juice samples to assess the prevalence of antibodies to *Salmonella* spp., pathogenic *Yersinia* spp., *Trichinella* spp. and *Toxoplasma gondii* in finishing pigs in Finland during 2012 and 2013.

The overall estimate for *Salmonella* seroprevalence in pigs in Finland was 3%, which is clearly lower than that previously reported for other countries in Europe and that derived from the serological *Salmonella* surveillance programme in Denmark (Hautekiet et al., 2008; Fosse et al., 2009; Sisák et al., 2011; Alban et al., 2012; Wacheck et al., 2012; Meemken et al., 2014).

The seroprevalence detected reflects the fact that the health status of pig herds with respect to *Salmonella* in Finland, Sweden and Norway is favourable (EFSA and ECDC, 2014). The positive results were sporadic and the OD values generally low. Only two samples (0.2%) showed OD values over 0.4, which is a cutoff value widely used in Europe. The low prevalence is consistent with the results from the Finnish national *Salmonella* control programme, in which *Salmonella* has been isolated from 0.2% or less of the yearly tested intestinal lymph nodes of pigs since 1997 (The Zoonosis Centre team, 2012). The situation is favourable, although there are still indications of rare exposure of pigs to *Salmonella* in Finland. The seroprevalence of *Salmonella* was similar in pigs originating from different types of farms. Interpretation of the true seroprevalence for these different farm types was limited; mostly only five pigs per farm were sampled and often the samples represented only one batch of pigs rather than the entire herd. However, Nollet et al. (2005) demonstrated that in analysing five serum samples per herd, the probability of classifying a *Salmonella* culture-positive herd as seropositive is 98.9% for a cutoff value of 0.2. Regardless of the results, it is still important to follow good hygienic practice (including feed hygiene, bird and rodent control and proper protective clothing) at every level in the food chain to maintain adequate protection against *Salmonella*.

The seroprevalence of pathogenic *Yersinia* spp. was the highest of the pathogens studied, although it was similar to or slightly lower than in previous studies from Germany and Belgium (von Altrock et al., 2011; Meemken et al., 2014; Van Damme et al., 2014). Higher seroprevalence was expected, based on previous studies in which the isolation rates of pathogenic *Y. enterocolitica* in slaughter pig tonsils were 52% in Finland and 29–93% in other parts of Europe (Korte et al., 2004; Fredriksson-Ahomaa et al., 2007; Ortiz Martinez et al., 2009, 2011; Vanantwerpen et al., 2014; Van Damme et al., 2014). Usually, pigs are infected during the fattening period and the antibodies typically remain detectable until slaughter (Nesbakken

et al., 2006). The high number of *Yersinia*-seropositive farms was not surprising, considering the results of previous studies (von Altrock et al., 2011; Meemken et al., 2014; Van Damme et al., 2014). However, in only a quarter of the farms did all the pigs studied here show antibodies to *Yersinia*, possibly because the pigs may have originated from different compartments of the same farm. Virtanen et al. (2012, 2014) demonstrated that piglets from *Yersinia*-positive breeding farms transmit *Y. enterocolitica* strains to fattening farms and spread the pathogen throughout the unit and that pigs purchased from infected herds transmit *Y. enterocolitica* infection between farms of all production types. In the present study, seropositive pigs were detected more often from large fattening farms than from farrow-to-finish farms, but the difference was not statistically significant ($p = 0.09$). This is in accordance with previous studies (Skjerve et al., 1998; Nesbakken et al., 2003) possibly because the piglets in farrow-to-finish farms may not have originated from other farms. In previous studies (Skjerve et al., 1998; Nowak et al., 2006), the prevalence of *Y. enterocolitica* has been lower in production systems with limited numbers of piglet suppliers. On 39 farms (15%), none of the pigs sampled (4–10 pigs per farm) showed *Yersinia* antibodies. In Germany, von Altrock et al. (2011) reported similar results when they studied 30 pigs/farm: 16% (13/80) of farms were seronegative, indicating that it is possible to produce pigs with low *Y. enterocolitica* risk in other production systems than specific pathogen free (SPF) systems. Nevertheless, the prevalence of pathogenic *Yersinia* in finishing pigs is so high that slaughter hygiene still remains as an important control measure to reduce carcass contamination.

The test applied cannot distinguish between infections with pathogenic *Yersinia* species: *Y. pestis*, *Y. pseudotuberculosis* and *Y. enterocolitica*. *Yersinia pestis* is not currently found in Europe (Raoult et al., 2013), while *Y. pseudotuberculosis* has been isolated in 4% and *Y. enterocolitica* in 52% of slaughter pig tonsils in Finland (Niskanen et al., 2002; Korte et al.,

2004). We assume that the serological reactions detected were mainly due to infection with *Y. enterocolitica*, although the presence of *Y. pseudotuberculosis* should not be excluded.

*Toxoplasma gondii* seroprevalence (3%) was low and similar to that in the previous Finnish study (1984) and Swedish study (1999) (Hirvelä-Koski, 1992; Lunden et al., 2002). The seroprevalence in finishing pigs from different farming systems varies between 0% and 45% in Europe, and the highest prevalences are detected in pigs with access to the outdoors (Kijlstra et al., 2004; Klun et al., 2006; van der Giessen et al., 2007; Dubey, 2009; Villari et al., 2009; Deksne and Kirjusina, 2013). In Latvia and the Netherlands, the seroprevalence in intensively farmed pigs has been 0.4% (van der Giessen et al., 2007; Deksne and Kirjusina, 2013). In the present study, information of the access to outdoors from all of the pigs sampled was not available. Nevertheless fattening pigs in conventional farms in Finland are raised almost exclusively indoors (Finnish Food Safety Authority Evira, 2011). Considering that in this study fattening pigs apparently raised indoors were tested, the number of positives was surprisingly high. In all, 9% of farms were *Toxoplasma*-seropositive, which is higher than in intensively operated farms in the Netherlands (Kijlstra et al., 2004; van der Giessen et al., 2007). Interestingly, on three small-scale fattening farms, all samples (five per farm) were positive, indicating that on these farms biosecurity measures have failed. Pigs in these three farms have no access to outdoors. The seroprevalence of *Toxoplasma* was significantly higher in pigs originating from small-scale fattening farms. A recent study in Finland reported that increasing farm size seems to predict better biosecurity in all production types (Sahlström et al., 2014). The most probable sources of infection in indoor pigs are cat faeces or rodents (Kijlstra et al., 2008; Dubey, 2009). The control of rodents and cats is crucial to reducing pigs´ exposure to the parasite.

285 Regarding *Trichinella* spp., we found not a single seropositive individual in our sample of 1353
286 fattening pigs, suggesting that the prevalence of *Trichinella* antibodies was less than 0.3% with
287 95% confidence. This was expected, based on the results from digestion analyses performed at
288 meat inspection: since 2004 only one positive pig has been detected while over 20 million pigs
289 have been tested (The Zoonosis Centre team, 2012; The Zoonosis Centre, 2014). However, the
290 parasite is abundant in wildlife in Finland (Airas et al., 2010; The Zoonosis Centre team, 2012).
291 The predominant *Trichinella* species in wildlife in Finland is *T. nativa*, which has low
292 infectivity in pigs, but *T. spiralis* is also commonly found in wild animals in Finland (Kapel
293 and Gamble, 2000; Airas et al., 2010). In this study, no antibodies to *Trichinella* were detected,
294 which can be considered as an indication of good control of farming conditions regarding
295 *Trichinella* exposure (e.g. rodents and feed).
296
297 Considering that these two parasites have some similar sources of infection to pigs (e.g rodents),
298 it is interesting that antibodies to *Trichinella* were not detected, while antibodies to *Toxoplasma*
299 were more common than expected. According to the results of a recent questionnaire study, 97 %
300 of fattening farms and 90 % of farrow-to-finish farms in Finland practice control of rodents and
301 birds (Sahlström et al., 2014). Unlike *Trichinella*, *Toxoplasma* can be acquired also from cat
302 feaces. Farmers traditionally have cats for rodent control and they might not be aware of the
303 role of a cat in spread of toxoplasmosis. Cats at farms can be the most significant reason for the
304 unexpected high seroprevalence of *Toxoplasma* in pigs in Finland.
305
306 There was a very strong positive correlation between seroprevalence of *Salmonella* and
307 *Yersinia* at the animal level. This contrasts with previous findings in Germany, where herds
308 with low *Yersinia* seroprevalence were significantly more often classified as moderate or
309 unsatisfactory *Salmonella* status (von Altrock et al., 2011). The authors speculated on the

possible change in competitive exclusion, but concluded that there were no references to this in the literature and commented on the possibility of misleading results due to small sample size. The positive correlations found in the present study appear to contradict the presence of competitive exclusion between these pathogens. The association found at the animal and farm level can be partly explained by the similarity in the infection route. The antigens used in tests are specific and no cross-reactivity is suspected between *Yersinia* and *Salmonella* (Heesemann et al., 1987; Nielsen et al., 1995; Anonymous, 2007).

There was a positive correlation ($p < 0.05$) at the animal level between pigs´ seropositivity for *Salmonella* and *Toxoplasma*. This finding may reflect the level of biosecurity measures on a farm, particularly because both infections are relatively rare in pigs in Finland and wild rodents may serve as vectors for both pathogens. Future studies will include visits to *Salmonella*- and *Toxoplasma*-seropositive farrow-to-finish farms to investigate the level of biosecurity measures.

In this study, we used commercial ELISA kits and meat juice matrix, due to the ready availability of commercial kits and their usage in previous studies (von Altrock et al., 2011; Virtanen et al., 2012; Basso et al., 2013; Meemken et al., 2014). Collection of meat samples at slaughter was easy and practical and handling and sending of samples simple. There was no problem with haemolysis, as in serum samples. Sufficient amounts of meat juice can be obtained from a 10-g piece of muscle and frozen for later use, e.g. in animal disease surveys. Novel automated technologies may even further facilitate the future use of serological tests (Wutz et al., 2013).

Serological monitoring systems for *Salmonella* are established in some European countries. In Denmark, meat juice samples are taken at slaughter on monthly basis, herds are categorized to

different risk levels according to the results and there is a penalty scheme to motivate farmers to improve herd´s *Salmonella* status (Alban et al., 2012). However, this applies only to *Salmonella* and monitoring programmes for other important zoonotic pathogens in pigs is missing or to be diminished (*Trichinella*). Meemken et al. (2014) recently carried out a study in Germany, concluding that serological risk categorization of pig herds regarding zoonoses is meaningful if used for risk-based decisions in the framework of new meat inspection concepts and as part of the herd health management system. The present study further supports the use of meat juice serology to control meat safety in the pork production chain. Differences between herds were shown and continuous data can be used to create serological herd profiles. These profiles should be used as part of the food chain information (FCI) to make decisions regarding additional carcass processing or sampling at the slaughterhouse. Meat juice serology enables to detect farms where improvement in biosecurity measures may be needed and to monitor the national situation of these zoonoses in pigs. For example, the carcasses from herds with high prevalence of *Toxoplasma* antibodies could be directed to freezing. Interventions at farm level could be encouraged when needed for any pathogen tested. Testing of intestinal lymph nodes for *Salmonella* could be targeted to pigs from herds with suspicious *Salmonella* status. Farms with low *Yersinia* prevalence could be found and supported to maintain the situation. Data of *Trichinella* antibodies could be used for monitoring of holdings officially recognised as applying controlled housing conditions (Anonymous, 2014). In this study, about five pigs per farm were sampled; thus, for further testing larger sample sizes should be used for more accurate estimation of intraherd prevalence and risk categorization of the herds.

This study shows that *Salmonella* and *Toxoplasma* are rare in fattening pigs in Finland. *Salmonella*-seropositive samples were sporadically detected from all types of farms. *Toxoplasma* was more prevalent in pigs originating from small-scale fattening farms, probably

resulting from ineffective biosecurity measures on these farms. *Yersinia* antibodies were common and most prevalent in pigs originating from large fattening farms; however, 15% of the farms were seronegative for *Yersinia*. *Trichinella* antibodies were not detected. Meat juice serology at slaughter is a useful tool for targeting measures to control these pathogens. The information obtained from analyses should be used as part of the food chain information (FCI).

## 5. ACKNOWLEDGEMENTS

This study was supported by research funding from the Ministry of Agriculture and Forestry, Finland (1933/312/2011). The official veterinarians, auxiliaries and slaughterhouses are gratefully acknowledged for their cooperation. We also thank Maria Stark for the technical assistance.

## 6. DECLARATION OF INTEREST

Elias Jukola is a Manager of Corporate Responsibility in HKScan Corporation.

Saara Raulo is the head of The Finnish Zoonosis Centre at the Finnish Food Safety Authority Evira.

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