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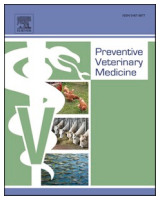

Quarter of pig farmers readily viewed information on *Toxoplasma gondii* infection in pigs provided in a data exchange system of a Dutch slaughter company

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ABSTRACT

Toxoplasma gondii (*T. gondii*) is a food safety hazard causing a substantial human disease burden. Because infected pig meat is estimated to attribute 12 % to this disease burden, it is important to control *T. gondii* infection in pigs. Providing pig farmers with information on *T. gondii* infection in general, and more specific on the status on their farm, could motivate them to take actions. In this study, we analysed the strategy pig farmers used to view specific *T. gondii* information provided for the first time on webpages in an existing data exchange system of a Dutch pig slaughter company. The available information for farmers comprised a webpage displaying the farm-level *T. gondii* seroprevalence and a webpage with information on risk sources and control measures for *T. gondii* infection in pigs and on human health consequences of a *T. gondii* infection.

A total of 1404 owners of pig farms logged in the data exchange system. Of these, a quarter viewed the webpage with information on *T. gondii* seroprevalence, and about of third of them also viewed the webpage with the information on risk sources and control measures. *T. gondii* seroprevalence exceeded 2.0 % at only 0.6 % of these 1404 farms. The seroprevalence level on a particular farm neither influenced the likelihood of the farmer viewing the webpage with the *T. gondii* seroprevalence, nor the likelihood of them continuing to the webpage with the additional information. In the days when the pop-up message was included, the number of views registered on the seroprevalence and the additional information webpages rose nine and two times, respectively.

Since the majority of views was in the period with a pop-up message pointing to this information we conclude that a targeted pop-up might help to transfer needed information to farmers with higher *T. gondii* seroprevalence at farm-level. More general, our study provides valuable insight into pig farmers' viewing strategies of new information on food safety hazards provided in a slaughter data exchange system.

1. Introduction

Toxoplasma gondii (T. gondii) is a food safety hazard which causes a substantial human disease burden (Havelaar et al., 2009; Mangen et al., 2015; Torgerson and Mastroiacovo, 2013). Approximately 12 % of the human disease burden caused by *T. gondii* infection in the Netherlands is estimated to be attributable to pig meat consumption (Suijkerbuijk et al., 2019). Therefore, it is important to control *T. gondii* infection in pigs. Improving farm hygiene management likely contributes to that aim. For this purpose, a research program was conducted in the Netherlands to set up and evaluate strategies to improve farm management. This program included development of a risk-based *T. gondii* serological monitoring program (Swanenburg et al., 2019), assessment of effectiveness of potential control measures (Wisselink et al., 2020), and assessment of awareness, willingness, and ability of pig farmers to control *T. gondii* infection in pigs (van Wagenberg et al., 2020).

A pig farmer can only implement control measures if (s)he is aware of *T. gondii* as a potential food safety risk, of the *T. gondii* infection level on the farm, and is informed on effective control measures, next to being willing to do so. Van Wagenberg et al. (2020) concluded that many

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Dutch pig farmers were aware of key risk sources as well as consequences of *T. gondii* infection in pigs, but less so of the public health impact and risks of *T. gondii* infection in pigs. At the time of their research in 2018 and 2019, key principles of *T. gondii* control in pigs were mainly communicated in the scientific field and Dutch pig farmers were not yet informed officially on on-farm *T. gondii* seroprevalence and the public health impact. Furthermore, generally pigs that carry *T. gondii* cannot visually be discerned from pigs that do not, because *T. gondii* infection in pigs are commonly asymptomatic (Dubey, 2009). Communication on the problem, consequences and solutions is a first step for a motivational change in farmer behavior (Van de Velde et al., 2018). Thus, providing pig farmers with information on on-farm *T. gondii* seroprevalence, potential causes, and control measures could be a first step in better controlling *T. gondii* infection in their pigs.

Pig slaughter companies could provide such information to farmers, because they can measure *T. gondii* seroprevalence in delivered pigs and can add this information to the slaughter information they already communicate to farmers. Connecting slaughterhouse indicators with on-farm data can help to identify the status of biosecurity, health, welfare, and performance in commercial pig farms (Pandolfi et al., 2018). Benchmarking with other farms could aid a farmer to find potential improvement options. However, the value and use of information for health and performance from animal-based monitoring systems, management information systems and decision support systems at farm level is ultimately in the user's hand (Cornou and Kristensen, 2013).

In the Netherlands, information on *T. gondii* infection in pigs has only recently been provided to pig farmers by a slaughter company operating three pig slaughter locations, which together slaughter around 50 % of all slaughtered pigs in the Netherlands (Swanenburg et al., 2019). The information is provided in the existing slaughter data exchange system. Our study aimed to analyse the strategy pig farmers use to view such new information on *T. gondii* infection in delivered slaughter pigs provided to them through this slaughter data exchange system.

2. Materials and methods

2.1. Provided information on T. gondii in slaughter pigs

Two types of information on *T. gondii* infection in pigs were provided to pig farmers that delivered slaughter pigs to the slaughter company. First, a webpage displayed the *T. gondii* seroprevalence in delivered slaughter pigs at farm-level. Second, a webpage provided an info sheet focusing on risk sources and control measures for *T. gondii* infection in pigs and human health consequences of *T. gondii* infection. This information was provided in the existing web-based slaughter data exchange system the slaughter company uses to provide information to pig farmers on technical (e.g., sex, weight, meat percentage, muscle thickness, fat thickness, lesions) and financial performance (e.g., price effects due to lesions) of delivered slaughter pigs. Provision of *T. gondii* information started on 17 October 2019, also the start date of this study. The study period ended on 30 June 2020. From 5 to 19 December 2019, when logging into the slaughter data exchange system, a pop-up message was posted for all visitors indicating the availability and location of the *T. gondii* information.

Before being able to view the information on *T. gondii*, the pig farmer had to take several steps. First, (s)he had to go to the webpage with the information on the last delivery of pigs, then to click on a link to go to a webpage with 'blood results', followed by clicking on a button for more detailed information on the blood results. On the webpages up to the webpage with 'blood results', no information was provided on *T. gondii*. The webpage with the detailed blood result information showed a dashboard with the estimated average of the within-farm *T. gondii* seroprevalence over the last 12 months (Fig. 1). It was provided qualitatively, with a range from green (low) to red (higher), comparing the *T. gondii* seroprevalence of the individual farm to the average of all farms.

A separate webpage provided a *T. gondii* info sheet which could be viewed by clicking a button left of the *T. gondii* seroprevalence figure (Fig. 1). The button did not mention access to further information. The info sheet described the life cycle of *T. gondii,* risk sources and potential human health consequences. Subsequently, the *T. gondii* sampling scheme and seroprevalence estimation method were shortly described. The info sheet ended with six measures to control *T. gondii* in pigs. Two general control measures elaborated on biosecurity (e.g., clean corridors, clean and disinfect footwear, control birds and insects) and drinking water (e.g., check water quality and clean drinking water system). The other four control measures elaborated on presence of cats, presence of rodents, removal of rodent cadavers, and presence of uncovered feed, because these were identified as key risk sources in literature (Kijlstra et al., 2004; Meerburg et al., 2006; Eppink et al., 2019).

2.2. Pig farmer information viewing data

Pig farmer information viewing data was collected with Google Analytics comprising the login time each time a pig farmer viewed the webpage with the *T. gondii* seroprevalence or the info sheet. Google Analytics data did not include who viewed a webpage. Therefore, we combined the Google Analytics data with login data of the slaughter data exchange system, that included a unique, yet anonymous, farmer identification number and login moment. The moments of view and login were used to merge the data sets. In our study, data comprised the period from 17 October 2019 to 30 June 2020. In the analysis, we included the data of 1404 farmers that logged in the data exchange system in this period.

2.3. T. gondii seroprevalence data

Farmer information viewing strategy was paired with the average within-farm *T. gondii* seroprevalence in slaughter pigs over the last 12 months. The *T. gondii* seroprevalence data were obtained from the risk-

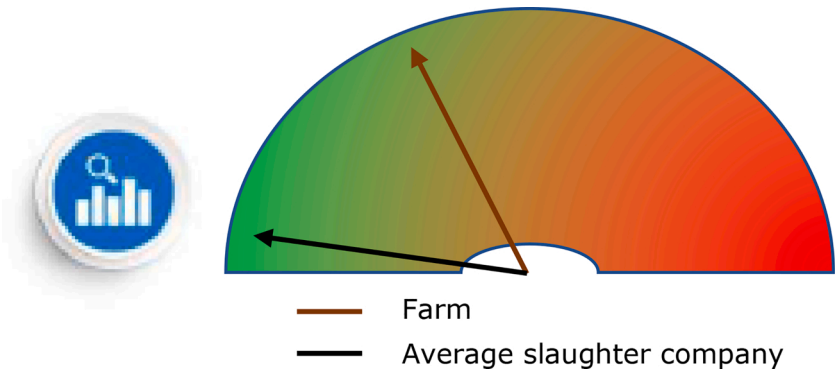

Fig. 1. Information provided on a webpage to pig farmers on the 12-month average. within-farm *T. gondii* seroprevalence in the slaughter pigs delivered to a Dutch slaughter company (from low green to high red, with the maximum based on the highest seroprevalence + 5% points) including a button to view a webpage with a *T. gondii* info sheet, as available in the existing slaughter data exchange system of the slaughter company (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article).

based serological monitoring program of the slaughter company. Below, we provide its most important aspects, for more information see Hiller et al. (2013) and Swanenburg et al. (2019). From every delivery of pigs, a minimum of one and a maximum of six serum samples were taken at slaughter. The PrioCHECK™ Toxoplasma Antibody ELISA was used with a cut-off of 20 percentage positivity (PP) to classify a serum sample as positive. The performance of this ELISA test was determined in two different studies (Basso et al., 2013; Steinparzer et al., 2015). Misclassification due to false-positive or false-negative results were accounted for through a Bayesian approach as described in Branscum et al. (2004). The seroprevalence data used in this study were based on sera collected from August 2018 up to and including July 2019.

2.4. Statistical analysis

We used descriptive statistics to analyse the *T. gondii* seroprevalence and webpage viewing data. To analyse the effect of *T. gondii* seroprevalence on viewing strategies we used Poisson regression analysis:

$$Y_i = C + \beta_1 X_i + \beta_2 L_i + e_i$$

Y_i is a count variable on number of views on a webpage with *T. gondii* information by farm i, C is a constant, X_i is the 12-month average within-farm *T. gondii* seroprevalence, L_i is the total number of logins in the slaughter data exchange system, and e_i is the error term. L_i was included to control for farmers with more frequent deliveries and, therefore, are more likely to have logged in the data exchange system as well as viewing the *T. gondii* information webpages more often. The model was estimated separately for the webpage with *T. gondii* seroprevalence and with the *T. gondii* info sheet.

3. Results

3.1. T. gondii seroprevalence

The estimated seroprevalence on the 1404 farms whose owners logged in the slaughter data exchange system in the study period was 0.1 % (standard deviation 1.0 %). Table 1 shows that *T. gondii* seroprevalence exceeded the 2.0 % level at only 0.6 % of the farms.

3.2. Pig farmer viewing strategy of information on T. gondii infection in pigs

From 17 October 2019 to 30 June 2020, the owners of 1404 pig farms viewed the webpage with *T. gondii* seroprevalence and the info sheet 571 and 115 times, respectively. This is 0.74 % and 0.15 % of the 77,219 logins of these farmers in the slaughter data exchange system recorded in that period. Approximately 24.4 % and 7.3 % of the pig farmers viewed the webpage with *T. gondii* seroprevalence or the info sheet at least once (Table 2). About a third of the pig farmers that viewed the webpage with *T. gondii* seroprevalence at least once (N = 343) also viewed the webpage with the info sheet at least once (N = 103).

Webpage views peaked in mid-December 2019 when a pop-up message was posted indicating the availability and location of the *T. gondii* information (Fig. 2). The number of views per day increased by nine and two times for the webpage with *T. gondii* seroprevalence and with the *T. gondii* info sheet, respectively.

Poisson regression analysis revealed that the *T. gondii* seroprevalence levels in pigs neither significantly influenced the likelihood of a farmer viewing the webpage with the *T. gondii* seroprevalence at least once, nor the likelihood of viewing the webpage with the info sheet at least once (Table 3). However, farmers with more logins in the slaughter data exchange system were more likely to view either webpage ($p < 0.001$).

Table 1
Frequency distribution of the 12-month average within-farm *Toxoplasma gondii* seroprevalence in slaughter pigs measured in a serological monitoring system of a Dutch slaughter company (from August 2018 up to and including July 2019).

Toxoplasma gondii seroprevalence (categorized)	Number of farms	% of farms	Cumulative % of farms
0.0 %	1353	96.4	96.4
>0.0 % - ≤1.0 %	34	2.4	98.8
>1.0 % - ≤2.0 %	8	0.6	99.4
>2.0 %	9	0.6	100.0

Table 2
Frequency distribution of number of views by 1404 Dutch pig farmers on two webpages with information on *Toxoplasma gondii* in pigs available in the slaughter data exchange system of a Dutch pig slaughter company (from 17 October 2019 to 30 June 2020).

Webpage views (categorized)	Number of farms	% of farms	Cumulative % of farms
Webpage with *Toxoplasma gondii* seroprevalence			
0 views	1061	75.6	75.6
1 view	221	15.7	91.3
>1 views	122	8.7	100
Webpage with *Toxoplasma gondii* info sheet			
0 views	1301	92.7	92.7
1 view	87	6.2	98.9
>1 views	16	1.1	100

4. Discussion and conclusion

In the current study, pig farmers were informed for the first time on *T. gondii* seroprevalence levels and potential causes and control measures through the existing online slaughter data exchange system of a Dutch pig slaughter company. About a quarter of the pig farmers viewed the webpages with *T. gondii* information at least once. In the period with a pop-up pointing to this information, the number of views was substantially higher. Although not all pig farmers reached out to the information in the current system, part of them did view the information, which is a first step for a motivational change in their behavior (Van de Velde et al., 2018).

In our study, most pig farmers (99.4 %) had an estimated *T. gondii* seroprevalence in their pigs of 1.0 % or less (including absence). The pig farmers, whose farms had higher *T. gondii* seroprevalence were not more inclined to view the webpage with *T. gondii* seroprevalence levels than those with farms with lower seroprevalence. This might be caused by the fact that pig farmers could only notice their *T. gondii* seroprevalence when viewing the webpage with these data and not before, and by the fact that these data were provided for the first time. Only one third of the pig farmers viewing the seroprevalence data continued to the webpage with more detailed information. The 17 pig farmers with a *T. gondii* seroprevalence >1% were not more inclined to view the webpage with the more detailed information than the other farmers. Possibly, the information on the new seroprevalence data or the way of providing *T. gondii* seroprevalence data did not provide sufficient sense of urgency to continue to the other webpage, the button to continue to the info sheet was insufficiently clear, or they were indifferent. Furthermore, the *T. gondii* seroprevalence was not updated during the study period, so there was limited need for the farmers to revisit these websites more frequently. Finally, all farmers with high *T. gondii* seroprevalence levels (above 2.0 %) were contacted through the extension service of the slaughter company as part of the Dutch *T. gondii* research program to analyze and evaluate intervention strategies on pig farms. They might have found it unnecessary to visit the websites, because they received information through the extension service.

Whether the pig farmers used the provided *T. gondii* information cannot be deduced from the data available in this study. The analyzed time period (17 October 2019 to 30 June 2020) is too short to see an

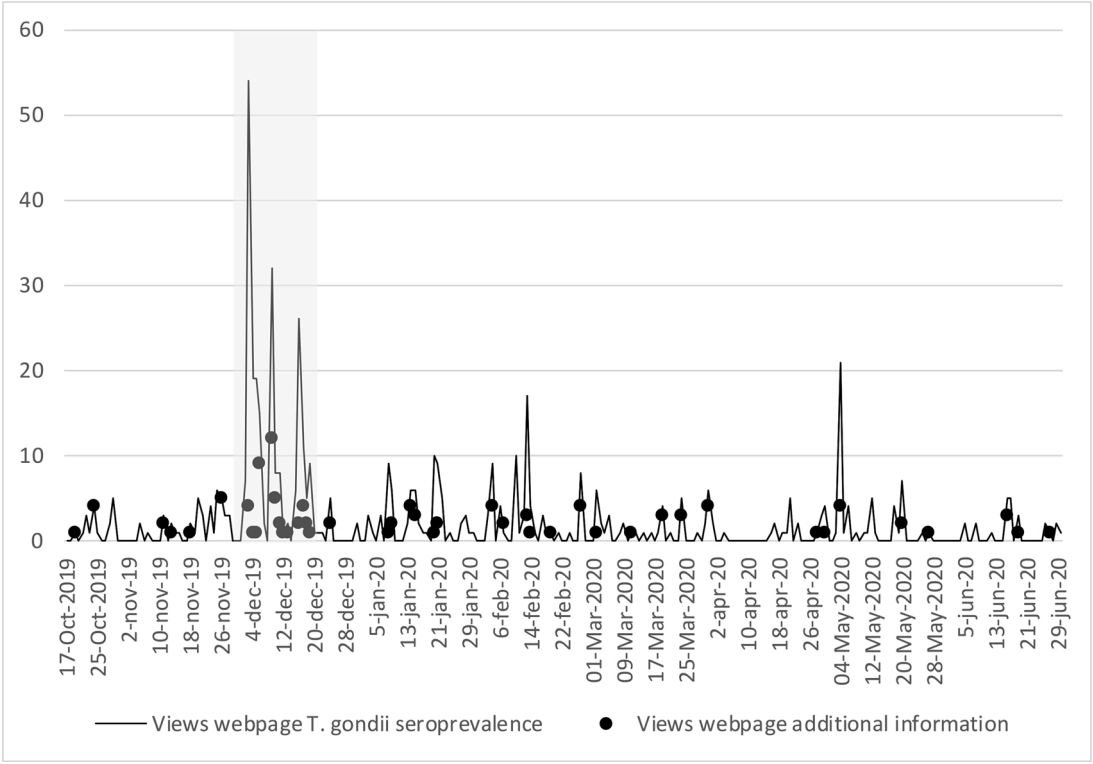

Fig. 2. Number of daily views by 1404 Dutch pig farmers of the webpage with *Toxoplasma. gondii* seroprevalence and the webpage with the *Toxoplasma gondii* info sheet available in the slaughter data exchange system of a Dutch pig slaughter company (from 17 October 2019 to 30 June 2020 and pop-up message from 5 to 19 December 2019 in the grey area).

Table 3
Poisson regression analyses of number of views by 1404 Dutch pig farmers on two webpages with information on *Toxoplasma gondii* in pigs available in the slaughter data exchange system of a Dutch pig slaughter company (from 17 October 2019 to 30 June 2020).

	Webpage with *Toxoplasma gondii* seroprevalence			Webpage with *Toxoplasma gondii* info sheet		
	Estimate	Standard error	p	Estimate	Standard error	p
Constant	−1.600	0.111	<0.001	−3.257	0.128	<0.001
Toxoplasma gondi seroprevalence in pigs	0.024	0.040	0.546	0.019	0.095	0.841
Number of logins	0.008	0.001	<0.001	0.008	0.001	<0.001
Log likelihood	−1,063			−359		

impact on on-farm *T. gondii* seroprevalence (i.e., efficacy of the intervention). Moreover, whether farmers implemented measures to control *T. gondii* infection in their pigs based on the provided information and costs of implemented control measures are unknown. This hampers comparison of the cost-effectiveness of information provision with that of other control measures analysed in studies such as Mangen et al. (2015) and Van Asseldonk et al. (2017).

In our study, the information was provided to all pig farmers from farms delivering slaughter pigs to the slaughter company. However, only 0.6 % of the 1404 pig farms in our study had a *T. gondii* seroprevalence in the pigs exceeding 2.0 %. Only farmers with a higher seroprevalence will need to implement extra control measures. We did not see a difference in likelihood of viewing the *T. gondii* information between farmers with higher and lower seroprevalence. Pig farmers with higher seroprevalence might need to be given additional attention, compared to the other pig farmers, to induce them to view the *T. gondii* information. A pop-up message specifically targeting pig farmers with higher seroprevalence could be one option for this, since the pop-up message applied in the current study revealed higher number of views during this period.

Information provision via the slaughter data exchange system could be extended to other food safety hazards related to pig meat for which serological monitoring systems are already in place at slaughterhouses. Our study provides insight into pig farmers' viewing strategies of new information on food safety hazards provided in a slaughter data exchange system. Furthermore, processors in other agricultural value chains use similar data exchange systems with their supplying farmers and the results of this study can be used to design information sharing arrangements.

The current study provides valuable insight into pig farmers readily viewing new information on *T. gondii* infection in pigs provided in a slaughter data exchange system. About a quarter of the pig farmers accessed the information on *T. gondii* infection in the pigs on their farm, with the majority of views in a period with a pop-up message pointing to this information. Additional efforts, such as targeted pop-ups or slaughterhouse outreach to pig farmers with higher *T. gondii* seroprevalence in their pigs, might be needed to further raise the awareness of the availability of the *T. gondii* seroprevalence data in the slaughter data exchange system in all pig farmers as well as to incentivize them to take *T. gondii* control measures.

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Declaration of Competing Interest

This work was part of the project “Toxoplasma infections in pigs: a system for risk-based monitoring in the pork production chain” which was co-funded by the Dutch Ministry of Agriculture, Nature and Food Quality and Vion within the public-private partnership “One Health for Food” in The Netherlands. All authors declare that there was not an inappropriate influence bias affecting the submitted manuscript by the private business providing the data.

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