Assessment of the value of post mortem surveillance of outdoor-reared finishing pigs with focus on bovine tuberculosis and "cost of error"

RK HANSEN[1], LH NIELSEN[1], M ELTHOLTH[2], B HÄSLER[3], L ALBAN[1]*
[1]Danish Agriculture & Food Council, DK-1870 Copenhagen, Denmark;
[2]Department of Economics, School of Arts and Social Sciences, City University of London, London, UK;
[3]Royal Veterinary College, Veterinary Epidemiology Economics and Public Health Group, Hatfield, AL9 7TA, UK

*lia@lf.dk

Abstract
Post mortem surveillance enables monitoring of the status for a specific disease in an animal population, which can be used for documentation of freedom from disease or early warning. The traditional meat inspection (TMI) is associated with a higher probability of detection of bovine tuberculosis (bovTB) but is also more costly than visual-only inspection (VOI). Currently, in Denmark, TMI is performed on outdoor-reared pigs and VOI on indoor reared pigs. To assess if this is the most cost-effective way of surveillance, there is a need for transparency of disease risks and economic costs related to a change in inspection.

The aim of this study was therefore to estimate the cost of error of the two different surveillance systems for bovTB (TMI versus VOI) in outdoor-reared pigs, embracing the probability of introduction, and the monetary consequences related to an undetected outbreak.

To assess the probability for overlooking positive bovTB cases, a scenario tree model was set up and cost of error related to using either VOI or TMI were compared. Input parameters were based on findings from the literature, and knowledge from bovTB free countries that recently had experienced outbreaks, and best guesses. Expert opinions were used to elucidate the economic consequences associated with a bovTB outbreak.

Results showed that bovTB would be overlooked when the within herd prevalence (WHP) was low. In this case, VOI was associated with higher economic consequences compared to TMI. At higher WHP, the probability of overlooking all positive cases in an infected herd was negligible. This implies that although a larger outbreak would be associated with costs, the likelihood of this occurring was minute for both VOI and TMI.

To date, Danish outdoor-reared pigs are exposed to TMI because of trade agreements with important export markets. The outcomes of the present work will form part of coming negotiations with these countries to change the requirement as TMI of Danish finishing pigs does not seem to be necessary from a scientific point of view.

Keywords: *surveillance, outdoor production, early warning, Mycobacterium bovis*

Introduction
In 2014, the new EU meat inspection legislation came into force, allowing post mortem meat inspection to be carried out as visual-only (VOI) as the general approach, and hereby substituting the traditional meat inspection (TMI) (1). A challenge related to VOI is a reduced ability to detect bovine tuberculosis (bovTB), compared to TMI (2, 3). To meet this challenge and requirements set by important trade partners, Denmark has retained TMI on pigs from non-controlled housing.

Cost of error is in this case viewed as an expression of the probability of undetected, positive cases of bovTB times the economic consequences of such case (4).

It is commonly known that different wildlife species can serve as maintenance hosts for *Mycobacterium bovis,* which is the causative agent for bovTB (5). For decades, Denmark has been free from *M. bovis*, including the wildlife population (6), but Denmark is housing wildlife species that serve as hosts for *M. bovis* in other European countries. So, *M. bovis* may be transmitted to pigs (*Sus scrofa*) when infected tissue is ingested (5,7,8). Intra-species disease transfer is rare, as pigs usually serve as end-hosts for *M. bovis*, unless they ingest offal from another infected pig (5,8,9). Pigs housed in non-controlled housing systems – such as outdoor production – are at higher risk of ingesting carcasses or feces from potentially infected wildlife than pigs reared under controlled housing conditions such as indoor productions. This high probability of infection with bovTB among pigs housed in non-controlled housing systems speaks for an unchanged meat inspection. On the other hand, for a country like Denmark, which has been completely free from bovTB for decades, and the fact that TMI is more costly than VOI, there may be a case for a change in the meat inspection to VOI for all slaughtered pigs – irrespective of rearing system.

The potential conflict between the ability of bovTB detection and economic interests indicates a need for higher transparency of potential risks and related economic consequences associated with an overlooked case of bovTB in pigs at the Danish abattoirs. Hereby, a decision of whether

to change the meat inspection or not can be made at an informed basis. Since Denmark is free from bovTB, the meat inspection does not serve as a part of an eradication or disease control program, but may be viewed as an early warning system. So, the question is how valuable it is to have such a system in place. To assess this issue, a hypothetical case has been set up. The case compares cost of error when infected pigs are subjected to VOI and TMI, respectively.

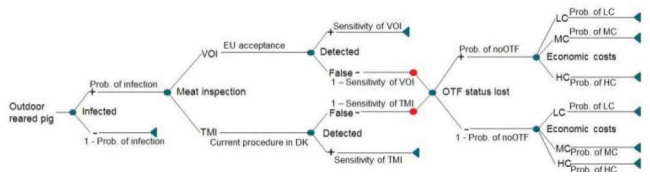
Materials and methods

A scenario tree model was used to assess the probability of a false negative result in Danish, outdoor reared pigs, when subjected to TMI and VOI, respectively. The applied scenario tree is illustrated in Figure 1. Probabilities for positive cases and for detection of bovTB at different meat inspection regimes were based on data from the literature and best guesses.

To estimate the monetary consequences of a false negative result, expert opinions were elucidated via three different interview surveys were carried out. One targeted pig farmers who had experienced bovTB suspicion in 2016/2017. Out of the 40 farmers, 39 were successfully interviewed based on a short questionnaire. The second survey targeted national experts (N=15) with knowledge on trade of animal products. The third survey targeted international experts (N=4) from countries in Europe that had either cases or outbreaks of bovTB. These experts had knowledge on bovTB surveillance, incidents, eradication and consequences of few or several positive cases. To apply the results from the interviews in the estimation, the economic consequences were grouped into three different categories: (i) losses to farmer and slaughterhouse for restrictions and rejected pigs, (ii) outbreak control costs and eradication program and (iii) export losses of pigs, cattle, pork, beef and dairy.

An assumed case consisting of one infected herd of 1,000 outdoor reared pigs was used as an example. Two scenarios for probability of further spread from the first outbreak to other herds, resulting in loss of Officially Tuberculosis Free (OTF) status were set to 20% and 50%, from now on referred to as scenario 1 and scenario 2, respectively. Four different within herd prevalence (WHP) were assumed: very low (0.2%), low (0.5%), medium (2.5%) and high (10%). A low number of incidents were expected if bovTB was introduced by a person feeding one or few pigs with contagious feed materials. A higher number was expected if introduction was by infected feed over a longer period to all animals in an age group.

Figure 1. Scenario tree with economic costs for TMI and VOI of outdoor reared pigs in Denmark



To estimate the economic consequences, three different potential outcomes were included. First, a low-cost outcome, assuming a loss of income for rejected animals and tuberculin test at infected herds, estimated to €1,345. Second, a medium-cost outcome, adding costs for eradication program, was estimated to €134,460. Third, a high-cost outcome, adding costs for lost trade partners, which was estimated to €3,361,480. Economic costs were assumed as weighted average of the three potential outcomes. For Scenario 1, the cost was calculated with the probabilities: 70% for low-cost, 20% for medium-cost and 10% for high-cost outcome. For Scenario 2, the cost was calculated with the probabilities: 10% for low-cost, 70% for medium-cost and 20% for high-cost outcome. The case was calculated with an annual probability of 4%, implying one occurrence in 25 years. This results in Equation 1 (mod. from 10).

$$Cost\ of\ Error = Ann.prob * ((1 - SeMI * WHP)^n * costs) \quad (1)$$

Where *Ann.prob* is the annual probability of the case, *SeMI* is the sensitivity of meat inspection, *WHP* is the within herd prevalence, *n* is the number of tested animals and *costs* is the weighted average for economic costs.

Costs are calculated as follows:

$$Costs = Prob_{OTF} * (ProbLC_{OTF} * LC + ProbMC_{OTF} * MC + ProbHC_{OTF} * HC) + Prob_{noOTF} * (ProbLC_{noOTF} * LC + ProbMC_{noOTF} * MC + ProbHC_{noOTF} * HC) \quad (2)$$

Where *Prob* is probability, "OTF" is a situation where no or limited spreading occurs and OTF status is remained, "noOTF" is a situation where further spreading occurs and OTF status is lost, *LC* is the low-cost outcome, *MC* is medium-cost outcome and *HC* is high-cost outcome.

Results and discussion

The results showed that the probability of overlooking all positive cases of bovTB, at post mortem meat inspection, in an infected herd of 1000 pigs, decreased rapidly, as the number of infected pigs increased. When few pigs were infected, the probability of overlooking all positive cases was higher, if the pigs were subjected to VOI compared to TMI. If more than 20 pigs were infected, the probability of overlooking all positive cases was close to zero for both types of meat inspection, as illustrated in Figure 2.

Figure 2. Probability of false negative result by VOI and TMI

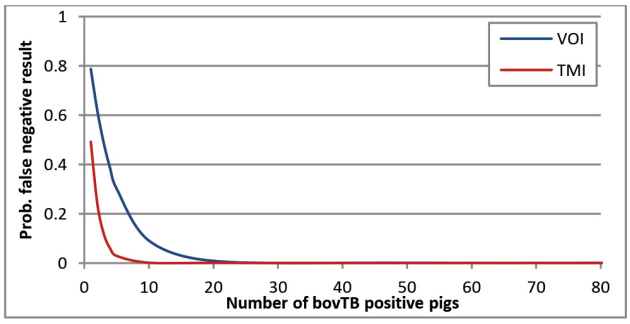


Table 1 shows the average yearly cost for VOI and TMI in the two scenarios for economic outcome. It appears that estimated costs related to overlooking positive cases were higher when pigs were subjected to VOI, due to the lower sensitivity of meat inspection. The more infected pigs, the lower are the costs to overlooked cases, no matter if the pigs were subjected to TMI or VOI, or if the infection resulted in a spreading of the infection or not.

Table 1. Yearly costs (€) to false negative results for Scenario 1 and 2.

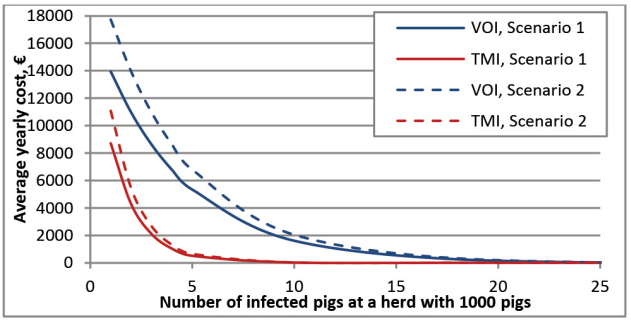
Average cost, €/year				
	Scenario 1		Scenario 2	
No. positive pigs	VOI	TMI	VOI	TMI
2	10.963	4.279	13.942	5.441
5	5.333	506	6.782	643
25	43	0	55	0
100	0	0	0	0

The difference in cost of error for VOI and TMI, when few pigs were infected, made it interesting to investigate these situations. There were three different outcomes of an overlooked positive case: the infection died out, the infection remained in one or few herds or the infection spread to several other herds. The first outcome was not relevant in this relation, as it had no economic costs.

It could be argued that the most likely outcome of a few positive, overlooked cases, in Denmark was limited spreading and a remained OTF status. This situation is illustrated as Scenario 1. Because pigs serves as end-hosts for bovTB (5,8,9), it was expected that infected pigs were moved from the bovTB-positive herd to bovTB-negative herds, for the disease to spread between herds. If the infection was introduced to a finisher unit, the probability of spreading was considered low as finisher pigs were only moved from the herd for the purpose of slaughter. Between herd movements of infected pig assumed to presuppose that the infection was introduced to piglets or weaner pigs. Danish pig farmers have mainly fixed agreements for trade of pigs. Movements of infected pigs would therefore only target a limited number of bovTB-negative herds.

On the other hand, a situation where only a few number of pigs were infected, decreased the ability of detection of at least one positive case, which increased the time to detection. In addition, bovTB evolves slowly which could further expand the time from introduction to detection. This allowed movements of infected pigs for a longer time span, and increased the probability of further spreading and a lost OTF status, illustrated by Scenario 2. The economic consequences of Scenario 2 were larger than of scenario 1, illustrated in Figure 3. For both scenarios, the economic impact was larger when pigs were subjected to VOI, compared to TMI, due to a lower sensitivity of the early warning system.

Figure 3. Cost of error for Scenario 1 and 2



In conclusion, VOI inspection would lower the probability of bovTB detection if a low number of pigs in same herd were infected, compared to TMI. If a medium to high number of pigs were infected within a herd, the infected herd would be identified, independent of type of meat inspection. A low prevalence of bovTB infected pigs would potentially have higher economic consequences, if the infected pigs were subjected to VOI compared to TMI.

TMI of Danish outdoor-reared pigs will continue because of trade agreements with important export markets. The present work will form part of coming negotiations with these countries to change the requirement as TMI of outdoor-reared finishing pigs does not seem to be necessary from a scientific point of view.

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