A Risk and Benefit Assessment for Visual-Only Meat Inspection of UK Indoor and Outdoor Pigs

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Summary

The current system of post-mortem inspection using the typical macroscopic inspection techniques is ineffective in identifying the most common foodborne illness risks, e.g. *Salmonella* and *Campylobacter*. Therefore, there is a need to adopt a more appropriate, risk-based approach to meat inspection. One specific example of modifying traditional inspection techniques to represent a more cost-effective approach to meat inspection is the allowance in EC Regulation 854/2004 for only visual inspection of pigs that have been reared under controlled housing conditions since weaning. However, the definition of controlled housing excludes outdoor pig production from visual-only meat inspection, and hence so far the UK has yet to introduce this method of meat inspection into abattoirs because of the associated complications of having a large outdoor pig herd. We have therefore conducted a qualitative risk assessment to assess the comparative risks to public and animal health from allowing visual-only inspection of both indoor and outdoor pigs.

In order for visual-only inspection to be of higher risk than traditional meat inspection, the sensitivity of detection of a condition must significantly decrease for visual-only inspection. In addition, in order for outdoor pigs to pose a greater risk than indoor pigs, then the condition must be more prevalent in the former than the latter. From a large number of diseases/conditions originally identified as worthy of investigation, only two (porcine tuberculosis (pTB, primarily *M. bovis*/*M. avium*) and endocarditis) were considered to be of public or animal health risk and would be less likely to be spotted through visual-only inspection. Despite higher rates of pTB in outdoor pigs than indoor pigs, the relatively small number of additional heads/carcasses that would be missed by including outdoor pigs in visual-only meat inspection (compared to traditional meat inspection) would pose a negligible risk to public health and a negligible-very low risk to animal health/welfare. The prevalence of endocarditis was higher in indoor pigs than outdoor pigs; hence the risk to public and animal health, regardless of inspection system, should be lower for outdoor pigs than indoor pigs. The risk to both public and animal health by transferring to a visual-only inspection method was assessed as negligible for all pigs, and hence was also
assessed as negligible should outdoor pigs be included in the regulations for visual-only meat inspection.
Official meat controls play an important role for the production of safe food, and are also required to ensure access to international trade. Therefore, the aims of the current system of official meat controls in the UK are to: 1) protect public health by ensuring that meat is safe to eat, 2) protect animal health and welfare, 3) maintain consumer confidence, and 4) to facilitate national and international trade. According to current EU legislation (Regulation (EC) 854/2004), particular attention during ante and post-mortem inspection should be paid to the detection of zoonotic and listed diseases by the World Organisation for Animal Health (OIE, 2004). However, the current post-mortem meat inspection was designed primarily to detect lesions typical for classical zoonotic diseases that are now rare in humans (e.g. brucellosis, trichinelllosis). Furthermore, some of the suspected lesions can also be caused by agents of relatively low public health importance (e.g. M. avium). The current system of post-mortem inspection using the typical macroscopic inspection techniques (visual examination, palpation and incision) cannot currently detect the most important foodborne hazards, e.g. Salmonella, Campylobacter and E. coli O157 (EFSA, 2009b). Therefore, there is a need to develop a more appropriate, risk-based approach to meat inspection which would improve efficiency in detecting important public and/or animal health issues. This had been recognized by the European Community (EC) (EC, 2000), and subsequently the Food Hygiene Package regulations (EC 852-854/2004) provided an opportunity to implement, under certain criteria, different approaches to post-mortem inspection of pigs, calves and lambs provided a sound risk assessment is made. These regulations also include the requirements to supply so-called Food Chain Information (epidemiological data, heard health data, production data) for animals (including pigs) before arrival at the slaughterhouse and the post-mortem inspection requirements.

One important aspect of modifying traditional post-mortem inspection is laid down in EC Regulation 854/2004. Specifically, this regulation allows for fattening pigs, housed under controlled housing conditions since weaning, to undergo only visual meat inspection, rather than the mandatory palpation of major organs and incisions in the heart and lymph nodes. The main reason for this option is to avoid palpation-
and/or incision-mediated microbial cross-contamination of meat. The definition of controlled housing conditions includes the criterion that none of the animals had access to outdoor facilities. Such a criterion that prevents the inclusion of outdoor pigs within the provision for visual-only inspection appears to be logical - as it is evident that implementation of some important measures for disease control are harder in such systems - but we are unaware of any published objective assessment of risk on this issue. The UK pig industry have expressed concern over the logistics of implementing visual-only inspection given the larger ratio of outdoor to indoor pigs in the UK compared to other countries that have implemented visual-only inspection. Therefore, in this paper we present a qualitative assessment for the risks and benefits of including pigs raised outdoors since weaning in a visual-only meat inspection system.

2 Risk and benefit assessment framework

For clarity, we first define relevant terminology, concordant with the relevant EU legislation and risk analysis frameworks. The scope of the risk and benefit assessments applies only to pigs raised specifically for slaughter. We therefore define “pig” as a pig raised specifically for slaughter. All mention of other categories of pigs, e.g. sows and boars, is explicitly defined as sow, boar etc. Pigs that are raised under controlled conditions since weaning may be visually-only inspected post-mortem under current regulations; among other criteria the two major, relevant conditions that define “controlled” are whether the pigs were raised indoors and in an integrated system (EC 854/2004). An integrated system is defined as “one that operates in an integrated manner from birth through the rearing phase to slaughter. An integrated system therefore requires information to be transferred backwards and forwards between the farm and the abattoir. The good functioning of an integrated system requires full accountability, and transparency in all parts” (EFSA, 2004). Expert opinion from the UK pig industry (Andrew Knowles, BPEx, personal communication) suggests that all quality-assured farms, regardless of indoor or outdoor production type, would meet the criteria for a fully integrated system given the traceability between farm and abattoir provided by Food Chain Information (FCI)
and the Animal Movement Licence Systems (AMLS). Therefore, for the purpose of this document and the UK situation, we define indoor and outdoor respectively:

Indoor: Pigs raised indoors since weaning on a quality-assured farm.
Outdoor: Pigs raised outdoors since weaning on a quality-assured farm.

A qualitative assessment of risk is typically expressed in categories varying from negligible to very high. In this risk assessment we define the following categories, as modified from (EFSA, 2006).

**Negligible** – Risk or frequency/consequence is so low as to not merit consideration.
**Very Low** - Risk or frequency/consequence is almost negligible, but due to uncertainty or other extenuating circumstances cannot be excluded from consideration.
**Low** – Risk or frequency/consequence is small/infrequent, but still worth considering intervention/mitigation.
**Medium** – Occurs frequently, or event associated with a modest consequence.
**High** – Event occurs often, and/or is associated with a significant consequence.
**Very High** - Event occurs almost certainly, and/or is associated with a serious consequence.

These definitions are to be used from now on unless explicitly stated otherwise.

Given that pigs reared indoors since weaning (with appropriate Food Chain Information and from integrated production systems) are allowed to be visually inspected, then it would be reasonable to assume that these pigs pose an acceptable risk to public health, animal health and animal welfare. Should outdoor pigs be assessed to pose the same level of risk as indoor pigs in respect of specified hazards, then visual inspection of outdoor pigs must also be considered as an acceptable risk. We are therefore interested in whether there is any increased risk, relative to indoor pigs, from visual-only inspection of outdoor pigs, and subsequently what this change in risk means to the absolute risk to public and/or animal health. Therefore, there are two objectives of this risk assessment: to identify the change in public health/animal health/animal welfare risk that would occur (above the relative risk from visual-only inspection of indoor pigs) from allowing outdoor pigs to undergo visual-only inspection, and to assess the absolute risks posed by visual-only inspection of outdoor pigs. There are two main criteria that determine whether the risk will change. One, whether the sensitivity of detecting a condition is affected by switching from
traditional to visual-only inspection (if not, there is no change in risk). Two, whether a condition of concern is more prevalent in outdoor pigs than indoor pigs (if not, then outdoor pigs pose no greater risk than indoor pigs). The absolute risk to public health is determined by the relationship between the burden of contaminated meat entering the food chain and the rates of human illness attributable to that contaminated pig meat. The absolute risk to animal health is assessed according to whether a potential decrease in the feedback of meat inspection information to indoor or outdoor farmers occurs.

In addition to the risk assessment, we also consider, the benefits (if any) of switching to the proposed visual inspection method. Risk-benefit methods are still under development, and the vast majority within the field of food safety have been on the subject of chemical contaminants versus nutritional quality (e.g. the benefits of Omega 3 in oily fish versus potential mercury contamination risks) (Gochfeld and Burger, 2005; Hoekstra et al., 2008; Ponce et al., 2000). We have applied, as far as practically possible, the methods proposed in two recent publications, taking a tiered approach to the risk and benefit assessments, where diseases that do not fit the criteria laid down are not taken forward in the rest of the assessment (Hoekstra and Verhagen, in press; Hoekstra et al., 2008). However, as all present methods for combining risk and benefit are quantitative and still in their infancy, we do not combine the qualitative risk and benefit assessments into one risk-benefit measure; rather we expect the risk manager to make a judgment based on both risk and benefit assessments as to when the benefit outweighs risk and when the risk outweighs the benefit.

The two frameworks for risk and benefit assessment are shown in detail in Figure 1. As stated above, an iterative, tiered approach was taken in ascending order of rigor, where a number of conditions were eliminated at each stage based on whether or not the risk they posed to public or animal health would be affected by two main criteria stated above. In Tier 1 a brief literature review and expert opinion was used for identification of conditions of potential concern. Tiers 3 & 4 combined provide a full risk and benefit assessment of conditions likely to significantly change in risk status (from the two criteria above) given visual-only inspection of outdoor pigs. For
completeness and transparency, we assess both the absolute and relative risks of both indoor and outdoor production for the conditions assessed in Tier 3.

The risk assessment stage is conducted using a modified version of methods described by the OIE for import risk analysis (OIE, 2004). Under traditional OIE guidelines, there are three components: release assessment, exposure assessment and consequence assessment. Under release assessment we first assess the additional rate of carcasses (from indoor or outdoor pigs) that will enter the food chain given visual inspection of pigs with diseases of human or animal importance. Exposure and consequence assessment are treated as one, where we assess for both indoor and outdoor pigs the absolute risk to public or animal health from moving to a visual-only system of meat inspection protocol in UK abattoirs (compared to current traditional meat inspection methods). Finally we conclude with risk estimates, assessing the relative difference in risk between indoor and outdoor pigs based on the burden of relevant conditions in each type of production, and the likely human/animal consequences that occur because of the potentially increased flux of contaminated meat into the food chain, or the decreased rate of reporting of conditions back to farmers.

The benefit assessment is conducted on a similar premise as the risk assessment, taking into account the magnitude of any decrease in “exposure” (e.g. the decrease in the likelihood of meat inspector exposure to *M. bovis* through not incising the mesenteric lymph node), or the consequence of this decreased exposure (health benefits only).
Figure 1: Tiered approach to risk and benefit assessment. Conditions that are unlikely to change in risk given visual inspection methods are identified in Hazard Identification (Tier 1). We conduct a preliminary risk assessment on conditions where risk may potentially change. Given further review, those conditions where risk will probably change are assessed in Tier 3. Benefit assessment is conducted only on those conditions identified for Tier 3 assessment.
2.1 *Hazard identification (Tier 1)*

A comprehensive list of distinct infectious agents and post-mortem conditions was taken from the Veterinary Laboratories Agency’s own protocol for post-mortem inspection of submitted carcasses. Using the expertise within the project team we shortlisted those diseases and conditions that may potentially be affected by a change to visual inspection methods, and posed a clear human and/or animal health threat. Those conditions where detection was unchanged because of visual inspection, or clearly posed no human or animal health risk, were not considered any further. Literature review was used to follow up any conditions which were unclear in terms of implication for detection or health. The diseases and conditions that were shortlisted (see Appendix 1) were then investigated in more detail in the preliminary risk assessment.

2.2 *Preliminary risk assessment (Tier 2)*

Each condition in the shortlist was assessed using the preliminary risk assessment framework (See Appendix 2). The standard risk assessment framework was followed, but only a brief literature review was undertaken for each condition. However, this review was able to identify that most conditions were of either negligible risk to human or animal health, or that the likelihood of detecting that condition at post-mortem would not be altered by changing to a visual inspection method of post-mortem inspection. A change in risk to either human or animal health was judged to potentially occur for two conditions: porcine tuberculosis (pTB) and endocarditis.

2.3 *Risk assessment (Tier 3)*

We assessed the risk of human or animal health infection because of changing to a visual inspection post-mortem (PM) for pTB and endocarditis independently.

2.3.1 *Tuberculosis (M. avium, M. bovis and M. intracellulare)*

*Overview*
EC Regulation 854/2004 requires that all pigs must be inspected for tuberculosis during routine post-mortem meat inspection. If suspect tuberculosis lesions are localized e.g. in the lymph glands of the head or the intestines, then the affected organ is condemned. If lesions are found in more than one part of the carcass site (e.g. head and intestines) then the whole carcass is condemned. If signs of generalized pTB are not found (due to relatively young age of slaughter pigs systemic infection is unlikely), in the case of localized pTB the rest of the carcass is fit for human consumption.

Caseous lymphadenitis in pigs is characterised by small nodules, usually in the lymph nodes and primarily of the head, neck and those that drain the small intestine (mesenteric lymph nodes). These may occur as a result of infection with *Mycobacterium bovis* (bovine tuberculosis), *Mycobacterium avium* (avian tuberculosis) and *Mycobacterium intracellulare*. Caseous lymphadenitis of the head and neck can also be caused by *Rhodococcus equi* (Dvorska et al., 1999; Komijn et al., 2007b). However, these lesions cannot be differentiated from those caused by tuberculosis unless bacteriological examination is performed (Taylor, 2006; Yager, 1992).

Infection of pigs with TB is usually associated with *M. avium*; however there has been a recent increase in the number of *M. bovis* isolates cultured from suspect submissions to the VLA from pig meat inspection¹. The most likely *M. bovis* infection source for pigs in the UK is infected badgers (BPEx, 2010b; Gallagher et al., 2005; Smith et al., 2006). Their urine or mucus containing *M. bovis* can contaminate farrowing beds so that when newborn piglets inhale into the bed or suckle, they become infected. Another route of pig infection from badgers includes home mill and mix units using contaminated grain from their own or other stores. Infection can also occur *via* contact with other infected animals such as cattle, deer or wild boar (Essey, 1981; Thoen, 1992). *M. avium* can be present in and excreted by wild birds and in particular starlings (Smit et al., 1987; Thoen, 1991) which may contaminate food and bedding.

thus being a source of infection for pigs (Hejlicek and Treml, 1997; Pavlik et al., 2000; Thegerstrom et al., 2005). *M. avium* is also found in the environment along with *M. intracellulare*. Sources include compost, peat, bedding materials, saw dust and drinking water (Engel et al., 1978; Matlova et al., 2005; Matlova et al., 2004). However, pigs are considered to be dead-end or spillover hosts, and are not thought to be important in the transfer or perpetuation of tuberculosis to other pigs or livestock species.

*R. equi* is primarily a soil resident (Barton and Hughes, 1984; Yager, 1992) and will potentially multiply in the presence of horse manure (Takai et al., 1986). It is also a transient in the intestinal tract of many animals including pigs, cattle, deer, horses, sheep, goats and wild birds (Woolcock et al., 1979). From the above evidence it would therefore be logical to expect a greater incidence of tuberculosis and *R. equi* in outdoor pigs.

**Release assessment**

Until recently the vast majority of incidents of tuberculosis in pigs in the UK were caused by *M. avium* and *M. intracellulare* (BPEx, 2010b). More recently, several incidents of *M. bovis* have been confirmed in the South West and the Midlands (specimens taken during meat inspection submitted to VLA under Defra project SB4510, referred to the TB culture database from now on), thought to be as a result of the organism being highly present in the environment (although higher reporting incidence cannot be ruled out). In 2009 there were 24 confirmed cases of *M. bovis* and 15 cases of *M. avium* in pigs in GB. In 2010, there have been 29 confirmed cases of *M. bovis* and 36 cases of *M. avium* (although there are still specimens to be confirmed as positive at the time of writing). All incidents were detected through meat inspection.

In order to comply with EC regulation, the FSA have implemented a system for recording conditions reported by meat inspectors from the FSA Operations Group at

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abattoirs to increase collection and reporting of Food Chain Information. This database application, New Generation AM/PM, records the frequency of selected conditions which is then passed back to farmers and their veterinary surgeons in order to help screen for potential threats to human health, animal health and animal welfare.

The data extract we are using for this risk assessment contains records for 47,504 batches of pigs slaughtered between 18/08/2009 and 09/09/2010. For the purposes of this risk assessment, we interrogated the database in order to evaluate the current state of conditions recorded in the pilot study to determine the prevalence of TB-like lesions in indoor and outdoor reared finisher pigs. Within the database there are four selectable options for system type: Indoor, Outdoor, BornOutdoor and Other Systems. For our purposes we investigated Indoor (including BornOutdoor pigs as Indoor) and Outdoor finishers only (i.e. we ignored Null and Other Systems).

The New Generation AM/PM database does not accurately capture denominator data. We are able to reliably estimate the number of batches slaughtered (37,062 indoor and 2,044 outdoor batches), but we are unable to reliably estimate the number of pigs within each of those batches, as the number of pigs per batch is recorded only for about half of the batches. Denominator data are obviously crucial for estimating prevalence, and so we have made some approximate estimates of the number of pigs slaughtered through those indoor and outdoor batches captured within the system. For those batches where we know the batch size, the average batch size is 154.7 for BornOutdoors, 103.4 for Indoors and 105.5 for Outdoors. We extrapolate the average size of the known batch sizes to those batches with an unknown size, and apply the average over all batches. That is:

- BornOutdoors – 6394 * 154.7 ~ 989,024 total pigs slaughtered.
- Indoors – 30668 * 103.4 ~ 3,170,074 total pigs slaughtered.
- Outdoors – 2044 * 105.5 ~ 215,728 total pigs slaughtered OUTDOORS.
- BornOutdoors + Indoors ~ 4,159,097 total pigs slaughtered INDOORS.

While uncertain, we can therefore estimate that roughly 5% of total pigs slaughtered were raised outdoors (and are automatically excluded from current visual inspection regulations).

The incidence of TB-type lesions were recorded on the New Generation AM/PM database, which were used as a proxy for caseous lymphadenitis. TB-type lesions are
recorded throughout the carcass in the database, but our original analysis of the data suggested that indoor production was of higher TB-incidence than outdoor production (0.0094% and 0.0060% respectively). This result arises due to the large number of TB-like lesions recorded under the “Misc – estimated weight” category. However, inspection of the VLA culture database suggests the overwhelming number of positive TB submissions (30/34) are from the head lymph nodes. We have therefore considered only those TB-like lesions found in the head, which is likely to be a more reliable indicator of true TB infection. There were 85 TB-like submissions from the head in 37,062 indoor batches and 10 submissions from 2,044 outdoor batches. Using the same average batch sizes as above, estimated prevalences of 0.002% and 0.0046% were obtained for indoor and outdoor production respectively. Outdoor production was associated with significantly higher levels of TB-like lesions (p<0.03). Analysis of the cases confirmed at the VLA support this result, where 4 of 40 confirmed pig TB incidents (where data relating to production type were available) in 2007-2010 were from outdoor herds (10% of incidents, whereas above we estimate that only 5% of pigs slaughtered are reared outdoors from birth to slaughter). However, while outdoor pig production could be twice as likely to result in TB-infection as indoor production, incidence (or at least detected incidence) in both indoor and outdoor pigs can be considered as very low.

There are several uncertainties associated with this trial dataset, including the absence of batch size for a proportion of the batches recorded and the accuracy of FCI input. Therefore, we also investigated other datasets to estimate the relative proportion of pigs reared under indoor or outdoor conditions since weaning. For a risk assessment of Salmonella in pigs carried out for EFSA (Snary, 2010) detailed analyses of farm types were carried out on the raw datasets from two UK studies, the baseline breeding pig survey carried out for EFSA (EFSA, 2009a), and another survey carried out for a VLA epidemiological study (Defra project OZ0323). The two studies recorded numerous farm management factors for 50-100 farms, including herd size, farm type (breeder-finisher, finisher only etc) and whether production was mainly indoors or outdoors (the breeding survey only covered farms with sows present). While in that risk assessment we estimated that over 60% and over 40% of slaughtered pigs born on breeder-weaner farms and breeder-grower farms were born outside, a large majority of these pigs are moved inside after weaning. However, we have no quantitative data
to estimate the percentage of these outside farms that would have a combination of outside and inside production systems. Assuming that breeder-finishing farms are a more reliable source of information (if these are listed as outside production, we assume it is more likely that all stages of production will be completely outside) then approximately 11% of pigs reared on breeding-finishing farms can be classed as outdoor pigs. We previously estimated that breeder-finisher production accounts for 52% of the pigs produced per year in the UK; therefore we estimate that outdoor production (from breeder-finisher herds) makes up around 5% of total pig production in the UK. We estimate using similar calculations a figure of 2-3% based on figures from the VLA study. Using the same study, finisher only production (contributing around 46% of total pig production) contributed very little in terms of outdoor pigs – approximately 1-2%. Therefore, from these analyses, which also contain a number of assumptions, we estimate that between 5-10% of total UK pig production is reared outdoors after weaning.

There are no directly available data to assess the change in sensitivity of detection of TB by British meat inspectors if they switched to visual-only examination. However, surrogate data are available from the Visual Inspection Pilot study carried out by the FSA in 2008/09, which surveyed 5,056 pigs. Visual meat inspection was performed on half of the pigs (2,528 pigs) and traditional inspection was performed on the other half. The carcasses were then re-inspected by an Official Veterinarian (OV) after meat inspection to determine whether there were any conditions present that had not been detected. Caseous lymphadenitis was not recorded in the FSA study, and hence we used the presence of abscesses in the lymph nodes as a proxy. Nine cases of abscesses in the lymph nodes were not detected by visual inspection compared to 4 cases by traditional inspection; hence we conclude that the non-detection rate for visual inspection is higher than for traditional meat inspection methods.

In addition to the above FSA study, we have investigated data from the VLA culture database. Observation of the reported gross pathology relating to the specimens submitted to VLA TB culture database (positive for either M. bovis or M. avium) suggest that TB is overwhelmingly picked up in the mandibular/submaxillary lymph nodes, with only one specific mention of caseous lesions in the mesenteric lymph node. However, several mentions of caseous lesions on either the bronchial,
retropharyngeal or mediastinal lymph nodes are recorded, which are visually inspected/palpated rather than incised. Personal communications with an Official Veterinarian (Anne Caley, FSA Operations Group) and the Veterinary Investigation Officer who manages the TB culture database (Tim Crawshaw, VLA Starcross) suggest that the sensitivity of TB detection during pig meat inspection will be significantly reduced if the mandibular lymph node is not incised and/or other lymph nodes are not touched or palpated. Hence, given the above information/expert opinion, we assess that there would be a substantial reduction in the identification of TB lesions by moving to a visual-only system of meat inspection.

Regardless of the macroscopic examination method, a certain number of TB lesions will not be grossly visible and so will escape detection (Thoen, 1992). However, none of the studies mentioned above were able to determine the absolute sensitivity of TB detection by either traditional or visual-only methods. Hence, we do not know what the relative importance is of the difference between traditional and visual-only inspection methods, and therefore cannot estimate the relative increase in risk to public/animal health between traditional and visual-only inspection.

Exposure and consequence assessment

Public health

Of current concern is the increase in M. bovis infections in pigs in the UK. M. bovis is a zoonotic agent that can cause a condition very similar to human tuberculosis. Infection occurs typically though ingestion of milk, but infection through aerosol inhalation or direct contact with mucous membranes and skin abrasions may also occur (Ashford et al., 2001; Grange and Yates, 1994). M. bovis was once a common cause of tuberculosis infections in humans; however, the introduction of pasteurized

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3 For example, if there are 20 cases of pTB identified every year through traditional meat inspection, what percentage of the total number of cases in the pig population do these 20 represent? Are there 25 total cases, or 1000? Should only 1 of the identified 20 cases be identified using visual-only meat inspection, then if there are 25 total cases then the sensitivity of detection drops from 80% to 4%, a significant decrease in sensitivity and a potentially significant change in risk. However, if the number of total cases is 1000, then the sensitivity of detection drops from 2% to 0.1%, a much less significant change, and the relevance of the difference in risk between indoor and outdoor pigs is reduced.
milk and tuberculin screening of cattle herds has largely eliminated this as a public health problem (Collins and Grange, 1987; de la Rua-Domenech, 2006; HPA, 2010).

*M. avium* is a potential zoonotic pathogen as it can produce disease in immunocompromised hosts with AIDs and pulmonary disease in immunocompetent adults (Biet et al., 2005; Wagner and Young, 2004; Wisselink et al., 2010). It can also cause cervical lymphadenitis in young, otherwise healthy children between 0 and 4 years of age (Bruijnesteijn van Coppenraet et al., 2008; Haverkamp et al., 2004). *M. intracellulare* mainly causes respiratory infections in humans and results in the formation of granulomatous lesions in the lungs and the bronchial system (Griffith et al., 2007).

According to the Health Protection Agency’s 2008 annual report on human tuberculosis surveillance in the UK (HPA, 2009b), there were 8,417 human cases of tuberculosis reported in 2007. Out of those, 5,075 (60%) were culture confirmed with the species identified in 5,014 (98.8%) cases. Of these species-confirmed cases, 4,954 (98.8%) were *M. tuberculosis*, 24 (0.5%) were *M. bovis* and 36 (0.7%) were *M. africanum*. No cases of *M. avium* or *M. intracellulare* were observed. Hence, at present, less than 1% of all confirmed cases of tuberculosis in humans are due to infection with non-*M. tuberculosis* strains. Indeed, it appears only *M. bovis* poses a potential, but low, risk to human health from pigs.

In 2009, there were 9,153 human cases of tuberculosis provisionally reported in the UK (HPA, 2011), therefore we estimate that less than 50 cases are due to infection with *M. bovis*. The majority of *M. bovis* cases are in people over 65 years old (and who had drunk unpasteurised milk in the past) or those of any age who picked up the infection abroad (HPA, 2010). The incidence of *M. bovis* in cattle is increasing, particularly in the south west of England, where in any one year over 1% of cattle herds are infected (HPA, 2010). However, despite this significant burden within the cattle population the Health Protection Agency classifies the current risk to human health from foodborne *M. bovis* as negligible (HPA, 2010), to which the figures reported above attest. Pigs are classed as a spill-over host (BPEx, 2010b; de la Rua-Domenech, 2006) with only 24 confirmed cases of *M. bovis* in GB in 2009. While we do not know how many pTB-infected pigs enter the food chain, pigs can only
contribute a very small proportion of any cases compared to raw milk consumption. Therefore, it is assessed that zoonotic transmission of *M. bovis* from pigs to humans in the UK is highly likely to be negligible.

*R. equi* is known as a bacterial species with zoonotic potential (Komijn et al., 2007a) and mainly causes lung disease in humans infected with HIV (Hondalus, 1997; Linder, 1997; Prescott, 1991). The Health Protection Agency describes *R. equi* as an uncommon pathogen with 2 confirmed cases in the period 2003 to 2007 in England, Wales and Northern Ireland (HPA, 2009a). Thus it is assessed in this document that the risk to human health in the UK from *R. equi* infection via consumption of pig meat is highly likely to be negligible.

**Animal health and welfare**

*M. bovis, M. avium, M. intracellulare* and *R. equi* infections have no apparent effect on the health or performance of pigs and diagnosis by physical examination of the live pig is usually impossible as there are no significant clinical signs (Komijn et al., 2007a; Thoen et al., 1992; Yager, 1992). Lesions associated with tuberculosis and *R. equi* are usually detected during meat inspection at slaughter by incision (EC, 2000) and brought to the farmer’s attention by high carcass condemnation rates causing economic loss (Pate et al., 2004; Tirkkonen et al., 2007). It has been reported that *M. avium* is excreted continuously in faeces from infected pigs which indicates that pig-to-pig transmission may occur by faecal-oral infection (Ellsworth et al., 1980; Hibiya et al., 2010). However, it is more commonly accepted that pigs are dead-end hosts for TB, not posing a risk to any other pig.

Several Animal Health visits have ensued to the farms where pTB have been identified via meat inspection, and the available reports suggest that the vector of transmission is common with cattle: badgers or other wildlife. Hence, biosecurity seems to be key. However, given the continued rise of *M. bovis* in cattle, it is open to question just how effective biosecurity can be in preventing some cases of infection, especially for animals kept outdoors. TB infection in pigs is sporadic and rare, and can only currently be detected at meat inspection. Given the low-level, random nature of infection pig farmers are unlikely to instigate many biosecurity measures unless
they are suffering large economic losses because of condemnations at the abattoir. In the current situation, the extra number of TB-infected pigs missed if visual inspection was implemented would probably not lead to increased numbers of TB infections in live pigs. Hence, the diminution in animal health/welfare, because of the removal of the very small protective effect of meat inspection for TB in pigs, is very likely to be negligible. Given the rise in cattle TB (*M. bovis*) the risk could also increase in pigs due to an increase in prevalence of a shared vector (e.g. badgers). Should a significant increase in cattle and pig pTB isolation rates continue, then as a very precautionary measure there could be regional variations where the incision of the mandibular lymph node is included in meat inspection for pigs raised in cattle TB-restriction areas.

*Risk estimation*

The incidence of TB-type lesions is estimated to be very low with a prevalence of 0.0020% for indoor pigs and 0.0046% for outdoor pigs (approximately a 2-fold relative increase). In 2009, 8,824,174 finisher pigs were slaughtered in the UK (Defra, 2011). Approximately 95% (8,382,965) are reared indoors (since weaning) and 5% (441,209) are reared outdoors (FSA New Generation AM/PM database). Of those suspect specimens taken from pig meat inspection and submitted to the VLA for culture, we were able to identify the farm type (indoor or outdoor) for 20 (16 indoor and 4 outdoor) of the confirmed cases of pTB in 2010. Assuming, as a worst-case, that the sensitivity of pTB detection decreases to 0% under visual-only inspection then under current EU regulations 16 approximately 80% of the 29 *M. bovis* and 36 *M. avium* reported cases would have been missed. Including outdoor production in the EU regulations would have meant that somewhere in the region of 100% of currently identifiable cases would have been missed (under the worst-case scenario). We are unable to calculate the approximate number of missed cases under traditional meat inspection, and hence the relative decrease in absolute sensitivity of detection moving to a visual-only inspection system would incur.

*Public health*
We estimate that around 50 human cases of TB per year are due to infection with non-\textit{M. tuberculosis} strains. The vast majority of these 50 cases will be \textit{M. bovis} infection linked to raw milk consumption. The Health Protection Agency classifies the current foodborne risk to human health from \textit{M. bovis} as negligible and indeed the number of these cases that occur as a result of zoonotic transmission via consumption of pig meat is highly likely to be negligible. \textit{M. avium} is extremely rare and is considered a negligible risk to public health. Similarly, the increase in risk to human health from \textit{R. equi} as a result of the change from traditional to visual meat inspection is assessed to be negligible. It is highly unlikely that an additional 30 or so (as reported in 2010) pTB-infected heads/carcasses entering the food chain should change this risk estimate because of a change in meat inspection methods, regardless of whether the carcasses are from indoor or outdoor herds.

\textbf{Conclusions:}

- Risk to public health from pTB infection in indoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to public health from pTB infection in outdoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to public health from pTB infection in indoor pigs under Visual-only meat inspection system: Lower relative risk to public health than from outdoor pig production. \textit{Negligible absolute risk to public health from indoor pig production.}
- Risk to public health from pTB infection in outdoor pigs under Visual-only meat inspection system: Higher relative risk to public health than from indoor pig production. \textit{Negligible absolute risk to public health from outdoor pig production.}

\textit{Animal (pigs) health and welfare}
The causative agents for caseous lymphadenitis have no apparent effect on the health or production performance of pigs. Diagnosis by physical examination of the live pig is usually impossible as there are no significant clinical signs. Lesions are usually detected during meat inspection at slaughter by incision and brought to the farmer’s attention by high carcass condemnation rates. Therefore by not performing traditional methods (palpation, incision) of meat inspection, it is probable that fewer cases of tuberculosis will be observed and reported. However, there are so few cases of TB reported (even with current meat inspection methods) it is unlikely any discernable change in the health or welfare of pigs can be achieved by this method of reporting alone. Conversely, given meat inspection is the only identification method for TB in pigs at the moment; it does provide a valuable monitoring role, which could be important given the recent reported increases in the incidence of *M. bovis*. For this reason, we assign a negligible risk to animal health/welfare for the current situation, but a negligible -very low increase in risk if pigs are inspected visually.

Conclusions:

- Risk to animal health/welfare from pTB infection in indoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to animal health/welfare from pTB infection in outdoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to animal health/welfare from pTB infection in indoor pigs under Visual-only meat inspection system: Lower relative risk to animal health/welfare than from outdoor pig production. Negligible absolute risk to animal health/welfare from indoor pig production.
- Risk to animal health/welfare from pTB infection in outdoor pigs under Visual-only meat inspection system: Higher relative risk to animal health/welfare than from indoor pig production. Negligible absolute risk to animal health/welfare from outdoor pig production.

2.3.2 Endocarditis
Overview

Endocarditis is the inflammation of the endocardium - internal lining of the heart. Bacterial endocarditis is one of the significant bacterial infections in pigs and other domestic animals. The main pathogens causing endocarditis in swine are *Erysipelothrix rhusiopathiae*, *Streptococci* spp., *Actinomyces pyogenes*, and *Escherichia coli*. Bacteraemia following infection in some remote organs, muscle or bones may result also in a lesion in the endocardium. The valves are the most frequently affected. Emboli from the heart are a frequent cause of pulmonary abscessation or pulmonary thrombosis (Jubb et al., 1993). Of these conditions, the two primary pathogens associated with public and animal health impacts as noted by Robinson and Maxie (Robinson, 1993), as well as by Alban et al (Alban, 2008), are *Streptococcus suis* (*S. suis*) and *E. rhusiopathiae*.

*S. suis* is an important pathogen associated with disease in both pigs and humans. *S. suis* infection in pigs has been reported worldwide alongside increasing reports of infection in humans (Wertheim et al., 2009a). Healthy pigs can carry multiple serotypes of *S. suis* in their nasal cavities, tonsils and upper respiratory, genital and alimentary tracts. There are 34 serotypes, of which types 1, 2 and 14 are most commonly isolated. Although over 50% of the 34 serotypes are isolated and associated with disease in England and Wales, serotype 2 is the most pathogenic for both pigs and humans (Lun et al., 2007). It is usually transmitted nasally or orally and colonises the tonsil of both clinically ill and healthy pigs; piglets usually become infected after contact with infected sows. Clinical signs associated with *S. suis* infection in pigs include meningitis, pneumonia and arthritis in addition to necropsy findings of endocarditis and lesions consistent with septicaemia. Pigs housed in suboptimum conditions (e.g. poor housing with inadequate ventilation) are found to be more predisposed to infection, a problem aggravated by stress and subsequent immune suppression (Staats et al., 1997).

*E. rhusiopathiae* has been found as a commensal or pathogen in a wide variety of animals; however the major reservoir is believed to be domestic pigs. The bacterium causes swine erysipelas in pigs which is characterised in its subacute form by diamond-shaped lesions on the skin and in acute cases can cause septicaemia and
fever. Other pathological findings include arthritis and endocarditis (Reboli and Farrar, 1989). Although information on the prevalence of disease in the UK is unavailable, it is considered to be a widespread disease and endemic worldwide. Up to 50% of healthy pigs can carry the organism in their tonsils (Takahashi et al., 1987).

The carcass of an animal affected with endocarditis which had shown fever and loss of condition on ante-mortem examination and embolic lesions in organs on post-mortem examination is condemned. The carcasses of pigs with ulcerative or verrucose endocarditis with no signs of systemic changes may be conditionally approved, pending heat treatment, but the affected organ is condemned. The carcasses of pigs with endocarditis showing infiltration of fibrous tissue are approved, but the heart is condemned (FAO, 2010).

Release assessment

Using the extract from the FSA New Generation AM/PM database as described in the TB risk assessment above, endocarditis was recorded in 675 pigs from 172 batches of indoor pigs and 24 pigs from 13 batches of outdoor-produced pigs. Using the same denominator estimates as for TB, we established an estimated individual pig prevalence of 0.0162% and 0.0111% for indoor and outdoor production respectively. Indoor production was associated with significantly higher levels of endocarditis (p<0.01). This may be due to the increased stress commonly found in intensively managed herds, where high population density as well as poor ventilation, mixing and concurrent disease may contribute (Clifton-Hadley, 1984; Sanford, 1989).

Endocarditis is frequently associated with vegetation on the valves of the heart that would generally be detected via incision. Therefore, replacement of traditional meat inspection including an incision into the heart with visual inspection would decrease the frequency with which endocarditis is detected. Unfortunately, the recent FSA VIP study did not show any endocarditis cases and therefore cannot be used to estimate any reductions in sensitivity of detection (although it does indicate the low prevalence of the condition).
Wouda et al investigated 599 Dutch pigs for how often endocarditis would pass into the food chain if incision of the heart was omitted (Wouda, 1987). They concluded that 25% of pigs determined to have endocarditis would have passed into the food chain if incision of the head was omitted. Therefore, while uncertain and only from one study, we can cautiously estimate that 75% of the affected carcasses were identified without traditional incision of the heart, probably due to external lesions or other pathological findings.

From the New Generation AM/PM study, 735 rejections occurred due to detection of endocarditis. Assuming the conclusions reached by Wouda are valid, of those 735 cases of endocarditis detected, a further 184 (25%) would have entered the food chain if visual inspection methods were used. This is in addition to any affected hearts currently entering the food chain due to being undetected at meat inspection (Fries et al calculated that 2,200 hearts with lesions caused by *E. rhusiopathiae* are consumed per annum using traditional meat inspection protocols in Germany (Fries, 1999)).

Hence we can assume that the sensitivity of meat inspection in detecting endocarditis would fall significantly if visual inspection occurred. Assuming an annual throughput of around 8.8 million head of pigs slaughtered in the UK, where 95% are from indoor production and 5% from outdoor production, we can estimate that around a 330 additional hearts with endocarditis would enter the food chain from indoor production whilst outdoor production would contribute an additional 13 hearts to the food chain.

*Exposure and consequence assessment*

**Public health**

*S. suis* infection in humans is usually associated with meningitis, but other pathological findings reported include endocarditis, cellulitis, rhabdomyolysis, arthritis, pneumonia and endophthalmitis. There have been at least two deaths in splenectomised men where there has been a fulminating septicaemia – one was a
contractor in Yorkshire taken on as a casual labourer in a pig farm who died 24 hours after starting work on the farm and the other was a butcher in France. In many cases, the initial diagnostic Gram staining of cerebrospinal fluid may implicate pneumococcal meningitis as opposed to \textit{S. suis} meningitis (Gottschalk, 2004). Currently there are 2-3 human cases of \textit{S. suis} infection reported each year in the UK\textsuperscript{4}, although it a likely that there is a significant number of misdiagnoses and underreporting due to difficulty in correctly identifying \textit{S. suis} as the causative agent (Danish work showed that in eight particular cases it was identified erroneously five times as \textit{Streptococcus viridans} (Donsakul et al., 2003)). Illness in humans is associated with direct contact with pigs as an occupational hazard rather than as a foodborne risk. However, processing or consuming undercooked pork products may also be a risk factor (Wertheim et al., 2009b).

Given the rarity of \textit{S. suis} infection in the UK, it is worthwhile noting epidemiological and mortality evidence from elsewhere. An outbreak of \textit{S. suis} in Sichuan Province, China, in 2005 was associated with 38 deaths out of 204 documented human cases; the 1998-99 \textit{S. suis} outbreak in Jiangsu Province reported 14 deaths out of 25 human cases. Almost all the human patients had direct contact with infected pigs (97% of the 205 patients investigated), and Du et al reported that eight people who were confirmed as having eaten well-cooked pork from sick pigs did not develop clinical signs (Du YP, 2000).

Arends and Zanen (1988) report that the risk of developing \textit{S. suis} meningitis among Dutch abattoir workers and pig breeders was estimated to be 1500 times higher than among persons not working in the pork industry. During 2004 a total of 112 isolates were found in pigs in England and Wales, of which 46% (51) were \textit{S. suis} type 2, the serotype most commonly associated with human infection\textsuperscript{4}.

Therefore we can conclude \textit{S. suis} infection is rare in humans in the UK and occurs predominantly via occupational exposure to pigs or their carcasses, and that immunocompromised individuals may be more at risk. The potential increase in

\textsuperscript{4} As reported on the Health Protection Agency website: http://www.hpa.org.uk/Topics/InfectiousDiseases/InfectionsAZ/StreptococcusSuis/GeneralInformation
foodborne risk due to additional affected hearts reaching the food chain is unlikely to produce a significant increase in the number of *S. suis* infection in humans, primarily due to the fact that food consumption is not the main route of infection, especially given the inability of the bacteria to survive proper cooking processes (Leps and Fries, 2009).

*E. rhusiopathiae* is a zoonotic agent causing localised skin infections known as Erysipeloid; systemic infection in humans is uncommon but has been found to cause endocarditis in rare cases. Erysipeloid is considered an occupational hazard mostly affecting individuals working with uncooked carcasses including abattoir workers, fishermen and butchers (Conklin and Steele, 1979). Proper heat-treatment will inactivate some or all of the bacteria reducing its potential as a foodborne pathogen. Reliable figures on Erysipeloid are difficult to find. There have been cases of systemic *E. rhusiopathiae* but they are very rare and also generally involve direct contact with infected pigs (Reboli and Farrar, 1989).

**Animal health & welfare**

The New Generation AM/PM scheme, in which information recorded by the scheme is passed directly back to the farmer and the veterinary surgeon associated with the farm, does include Endocarditis as a condition. If the calculations given in the exposure assessment are of the right magnitude then per year somewhere around 300-400 hearts with endocarditis will be missed by visual-only inspection, over and above that already missed by traditional meat inspection methods. If there are 8.8 million pigs slaughtered per year, this means that visual inspection will lead to a decrease in detection of roughly 1 heart for every 20,000-30,000 carcasses processed.

Anecdotal evidence received from an Official Veterinarian (OV) (Anne Caley, FSA Operations Group) suggested that farmers are unlikely to make any changes to their practices as a consequence of hearts being condemned due to endocarditis. Endocarditis is not currently one of the pig health conditions monitored by the British Pig Health Scheme (BPHS) which pass information of incidence of conditions back to farms upon slaughter at abattoir, so presumably it is relatively down the scale in terms of economic importance to farmers. In summary, it is unlikely that endocarditis
conditions currently identified at inspection and fed back to farmers have a major impact in improving animal health in practice. It is therefore unlikely that a farmer will modify their management system due to a small decrease in the rate of reporting endocarditis back to farmers due to moving to visual-only meat inspection.

Risk estimation

Human Health

Very few cases of *S. suis* and *E. rhusiopathiae* human infections are reported each year in the UK, and the majority, if not all, are linked to occupational exposure to pigs or raw pork. Even so, the risk of infection via any route (pig-borne or other) can only be considered as very low (at a maximum). As most infections are linked to occupational exposure to pigs, foodborne infection via consumption of pork is negligible.

We roughly estimate that about 25% of carcasses with endocarditis that are detected under current inspection methods would be missed under visual meat inspection, which would lead to perhaps a maximum from both indoor and outdoor production of around 300-400 extra hearts entering the food chain per year (a rate of perhaps 1 in 20,000-30,000 hearts). While the numbers this estimate is based on are uncertain, it is unlikely this magnitude of change in numbers will have anything other than a negligible effect on human health. Finally, outdoor pigs are less likely to be afflicted with this condition; hence the risk to public health from outdoor pigs is lower than the risk associated with indoor pigs.

Conclusions:

- **Risk to public health from endocarditis infection in indoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.**
• Risk to public health from endocarditis infection in outdoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.

• Risk to public health from endocarditis infection in indoor pigs under Visual-only meat inspection system: Higher relative risk to public health than from outdoor pig production. *Negligible absolute risk to public health from indoor pig production.*

• Risk to public health from endocarditis infection in outdoor pigs under Visual-only meat inspection system: Lower relative risk to public health than from indoor pig production. *Negligible absolute risk to public health from outdoor pig production.*

Animal Health and Welfare

Vegetative endocarditis is a chronic manifestation of *S. suis* or *E. rhusiopathiae* infections. Endocarditis in pigs is intermittent and fairly rare (although *S. suis* can still be considered an important zoonosis), and detectable only at meat inspection. If the incidence of endocarditis on a farm was high then it is likely that the farmer would report pigs showing signs of heart failure, an increase in sudden deaths, or an increased incidence of the clinical signs associated with these bacterial infections. Acute or subacute *E. rhusiopathiae* is likely to be picked up ante-mortem due to its characteristic rhomboid skin lesions.

The condemnation of the heart alone is unlikely to warrant further action at farm level as the economic impact of sporadic heart rejections is unlikely to be of critical concern for the pig farming industry. Bacteriological confirmation of *S. suis* endocarditis will not be conducted regardless of inspection method and therefore will not result in specific control measures being implemented. However, perhaps more important than the economic significance of endocarditis, is the rarity with which it is detected. At most only a few farms per year would not be able to address the issue of endocarditis because of moving to a visual-only system of meat inspection. Hence, the diminution in animal health/welfare, because of the partial removal of the very
small on-farm effect of the information feed-back from meat inspection regarding endocarditis in pigs, is very likely to be negligible. Finally, the relative risk of not feeding back information to farmers rearing outdoor pigs will be less than it is for indoor pigs, as endocarditis is more common in indoor pigs. The risk to indoor pig health/welfare has already been implicitly deemed acceptable by the implementation of visual-only inspection for indoor pigs in EC Regulation 854/2004; therefore the relatively lower risk to outdoor pig health/welfare must also be deemed acceptable.

Conclusions:

- Risk to animal health/welfare from endocarditis infection in indoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to animal health/welfare from endocarditis infection in outdoor pigs under traditional meat inspection system (head/mesenteric lymph nodes examination by visual+palpation/incision methods): Negligible.
- Risk to animal health/welfare from endocarditis infection in indoor pigs under Visual-only meat inspection system: Higher relative risk to public health than from outdoor pig production. *Negligible absolute risk to public health from indoor pig production.*
- Risk to animal health/welfare from endocarditis infection in outdoor pigs under Visual-only meat inspection system: Lower relative risk to public health than from indoor pig production. *Negligible absolute risk to public health from outdoor pig production.*

### 2.4 Benefit assessment (Tier 4)

We conclude from the risk assessment in Tier 3 above that the only (potentially) non-negligible risk from changing to a visual-only inspection method in the UK is to pig health/welfare on farms because of a potential decrease in the rate of reporting pTB back to farmers (which applies both to indoor and outdoor pigs). Typically, in the case where no or little risk can be found then the benefit component of risk/benefit analysis is not carried out, as there is no need to weigh the benefits against the risks
(EFSA, 2007; FAO/WHO, 2009). However, we briefly review the literature for two potentially beneficial impacts for public health if meat inspection moves from traditional to a visual-only system: the potential for less cross-contamination of the carcass with foodborne hazards such as *Salmonella* *Spp.* or *Yersinia* *Spp.*, and the potential for less occupational exposure of meat inspectors to *S. suis* if the heart incision is omitted.

Incision and palpation of the pluck/organs may cross-contaminate the carcass *Salmonella* spp. and *Yersinia enterocolitica* via the hands/knives of the meat inspectors. However, the evidence that less cross-contamination occurs during visual-only meat inspection compared to traditional meat inspection is sparse and conflicting. The most compelling study on this subject (Hamilton et al., 2002) detected no significant differences in the isolation of *Salmonella* spp. and *Yersinia enterocolitica* when carcasses were inspected post-mortem traditionally (incision of mandibular lymph node, palpation of organs etc) and with a visual-only method (800 carcasses inspected with each method). Given the lack of evidence for a statistically significant reduction in the prevalence of microbiological contamination it is not possible to estimate any beneficial effect from potentially reduced cross-contamination.

Removing the need for incision to the heart and lymph nodes will potentially decrease the occupational exposure risk to abattoir workers and butchers. Whilst there is little substantive evidence for any existing contact risk from pTB, there are certainly confirmed cases of *S. suis* as a result of occupational exposure. Two-three cases of *S. Suis* infection in humans are recorded each year, which are primarily attributable to those individuals with close contact to swine production. Therefore, whilst removing incisions would not affect human exposure at the farm level, it could potentially have a measurable reduction at abattoir level. As above, the data are lacking to make any judgement on the relative rates of occupational infection with *S. suis* during traditional or visual-only meat inspection. However, this route of infection probably presents the most tangible evidence for reduction of meaningful exposure (human or animal) for any of the pathways considered in this assessment. It is unlikely that significant health improvements (in terms of numbers of cases) will be made if visual-only inspection of pigs is implemented, but *S. suis* infection is a potentially life-
threatening condition, so even the prevention of one death every 10-20 years could be perceived as a benefit.

In addition to the biological benefits discussed above, economic benefits may include increased line speed at abattoir and less inspectors at each abattoir needed to fulfil the required inspection demands, but assessment of these purely economic factors were not within the scope of this project.

3 Summary

We have conducted a qualitative risk assessment and a brief benefit assessment of moving to a visual-only post-mortem meat inspection system in British pig abattoirs, with particular reference to the inclusion of pigs raised outdoors since weaning. Under a visual-only meat inspection system, outdoor pigs would pose a higher risk to public and animal health/welfare only when: a) the visual method of inspection decreased the sensitivity of detection of specific health-relevant conditions; and b) the conditions were more prevalent in outdoor than indoor pigs. Through an iterative process of expert elicitation and literature review, we narrowed a large list of meat inspection-detected conditions down to two conditions, caseous lymphadenitis and endocarditis, which would potentially meet the two criteria above. A full qualitative risk assessment was conducted for both.

The risk to public health from the zoonotic agents causing caseous lymphadenitis and endocarditis (primarily *M. avium*, *M. bovis* and *S. suis*) was assessed to be negligible under current meat inspection methods involving both visual and incision techniques. This was because zoonotic transmission of these agents is rare in the UK, and in the case of *S. Suis* linked with occupational exposure rather than foodborne infection from pork. Despite large uncertainties, it is estimated that around 20 extra cases of pTB and 300-400 extra cases of endocarditis in pigs would not be detected if a visual-only meat inspection system was introduced across British abattoirs (at current volumes of pig production). While it cannot be claimed that these additional cases would not cause any extra foodborne risk, it is assessed the public health risk
associated with visual-only inspection would remain in the negligible category, as is currently the case with traditional inspection.

The above conclusions regarding negligible public health risk mean the assessment of the relative impact of risk for outdoor and indoor pigs was somewhat redundant. However, it is likely that outdoor pigs do contribute relatively more cases of porcine TB per slaughtered pig head than indoor pigs, but as stated above it is unlikely this materialises into any significant human risk. Conversely, indoor pigs contribute more cases of endocarditis per slaughtered pig head than outdoor pigs, but again it is unlikely this difference in incidence rate materialises into any significant human risk.

The risk to animal health and welfare potentially associated with visual-only inspection system applied to outdoor pigs is hard to assess because of a lack of relevant data. However, what is certain is that there are very few incidents of TB and endocarditis detected at meat inspection of slaughtered pigs in the UK. This is because of a very low overall TB incidence in pigs at the current time, and although TB infection diagnosis in pigs depends on post-mortem meat inspection detection (which relies on incision technique), only a small additional number of TB-incidents would be missed. If visual-only inspection system were applied to outdoor pigs we estimated that there would be potentially be a very low risk for pig health/welfare in the UK, although we suspect that the risk is in fact negligible (more data are required to confirm this). In respect to endocarditis, although information on this condition in pigs is fed back from meat inspection to farms often no change in on-farm disease control measures is implemented. This is due to the rarity of the condition in pigs overall, and hence the application of visual-only meat inspection to outdoor pigs would represent a negligible risk to pig health/welfare in the UK.

As all but one scenario (pTB animal health/welfare risk – very low or negligible) was assessed as negligible, only a brief benefit assessment was conducted (as the requirement for derogations to EC regulations to show no additional risk had been met). The main potential benefits include reducing the cross-contamination of carcasses with foodborne pathogens (e.g. *Salmonella* spp., *Yersinia* spp.), and the exclusion of heart incisions could potentially reduce occupational exposure of meat inspectors to *S. suis*. However, from our review, there was no clear evidence that the
microbiological cross-contamination of carcasses or retail products was reduced by transferring to a visual-only inspection system. Given \textit{S. suis} infection is associated with occupational exposure to pigs or pig carcasses, we can assume, \textit{a priori}, that the elimination of heart incisions would reduce meat inspector exposure. However, the reduction in occupational risk would probably be negligible given that so few \textit{S. suis} cases (of all epidemiological routes) are reported anyway.

In summary the following conclusions have been made:

- **Under visual-only inspection methods there is a negligible absolute risk from \textit{pTB} or endocarditis to public health from either indoor or outdoor pig production.**
- **Under visual-only inspection methods there is a negligible absolute risk from endocarditis to animal health/welfare from either indoor or outdoor pig production.**
- **Under visual-only inspection methods there is a negligible-very low absolute risk from \textit{pTB} to animal health/welfare from indoor pig production.**
- **Under visual-only inspection methods there is a negligible-very low absolute risk from \textit{pTB} to animal health/welfare from outdoor pig production.**
- **There are not enough data to be able to assess the health benefits (either a reduction in foodborne risk because of reduced microbiological contamination of the carcass, or a reduction in \textit{S. suis} exposure of meat inspectors) from moving to a visual-only system of meat inspection.**

## 4 Glossary of terms

**Visual only inspection** – Occurs post mortem at abattoir, as legislated in EC Regulation 854/2004 Chapter 4 Section B.

- Visual inspection of head, throat, mouth, faeces and tongue.
- Visual inspection of lungs, trachea and oesophagus.
- Visual inspection of the pericardium and heart.
- Visual inspection of the diaphragm.
- Visual inspection of the liver and the hepatic and pancreatic lymph nodes.
- Visual inspection of the gastro-intestinal tract, the mesentery, and the gastric and mesenteric lymph nodes.
- Visual inspection of the kidneys.
• Visual inspection of the pleura and peritoneum.
• Visual inspection of the genital organs.

**Traditional meat inspection** - Occurs post mortem at abattoir, as legislated in EC Regulation 854/2004 Chapter 4 Section B. Includes visual inspection as defined above and in addition:
  • Incision and examination of the submaxillary lymph nodes
  • Palpation of lungs and the bronchial and mediastinal lymph nodes. Opening of the trachea and main branches of bronchi, incision of lungs in posterior third, perpendicular to their main axes. Incisions only necessary where lungs are intended for human consumption.
  • Incision of the hearth lengthwise so as to open the ventricles and cut through the interventricular septum.
  • Palpation of the liver and its lymph nodes.
  • Palpation and where necessary, incision of the gastric and mesenteric lymph nodes.
  • Incision, where necessary, of the kidneys and renal lymph nodes.

PM – Post-mortem
bTB – Bovine Tuberculosis
pTB – Porcine Tuberculosis
**TB-like lesions** – Lesions found at post-mortem that whilst indicative of Tuberculosis, do not necessarily confirm Tuberculosis.
5 References


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Appendix 1: Hazard Identification

The VLA’s own list of post-mortem conditions to check for, provided in VISI 156, and was used as a first guide to identify potentially relevant conditions for the risk assessment. Based on previous assessments of conditions (EC Opinion, 2000; Alban et al, 2008), and the expert opinion of the project team consultants (Prof. Sava Bunic and Mr Ian Griffiths) we excluded the majority of conditions. The main reason was that many of the conditions are spotted visually or at ante-mortem, and hence would not be affected by a change in regulations. A first round of elimination was undertaken at the first project meeting. The remaining conditions were then investigated further for those that would be included in the preliminary risk assessment (Tier 2 assessment). Table A1 shows the results of those initial investigations, where conditions highlighted green were included in the preliminary risk assessment (it was determined that virtually all conditions would have animal health/welfare implications to some degree).

Table A1: List of conditions further investigated in the hazard identification; conditions highlighted green were taken forward into preliminary risk assessment. Data was acquired through a brief literature review, and before the New Generation AM/PM Pig database became available.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Prevalence</th>
<th>Detection method</th>
<th>Public health risk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Indoor</td>
<td>Outdoor</td>
<td>Incision</td>
</tr>
<tr>
<td>Endocarditis (heart) - usually bacterial in cause (Streptococcus spp and Erysipelothrix rhusiopathiae) the exceptions being an occasional parasitic or mycotic lesion.</td>
<td>0.01%</td>
<td>NI*</td>
<td>✔</td>
</tr>
<tr>
<td></td>
<td>% caused by Streptococcus spp: 51%</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>E. rhusiopathiae.: 32%</td>
<td></td>
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<tr>
<td></td>
<td>Lactobacillus: 5%</td>
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<td></td>
</tr>
<tr>
<td></td>
<td>Arcanobacterium pyogenes: 1%</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>(Alban, 2008)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Necrosis in lymph</td>
<td>0.01-0.02%</td>
<td>NI</td>
<td>✔</td>
</tr>
</tbody>
</table>

(Alban, 2008)
nodes - these may occur as a result of infection with Mycobacterium bovis (bovine tuberculosis), Mycobacterium avium (avian tuberculosis) or Rhodococcus equi.

<table>
<thead>
<tr>
<th>Condition</th>
<th>Cause %</th>
<th>Nickles</th>
<th>Nickles</th>
<th>Sava Buncic</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lungworm lesions</td>
<td>Mycobacterium spp: 0% R. equi: 63% Nocardia farcinica: 2%</td>
<td>×</td>
<td>✓</td>
<td>×</td>
<td>(EC, 2000)</td>
</tr>
<tr>
<td>Pericarditis (acute and chronic)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Tape worms (Cysticercosis) - occurs in most used muscles (e.g. heart)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Water damage (lung)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Filled stomach</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>×</td>
<td>✓</td>
</tr>
<tr>
<td>Nephropathy (abnormal kidney) - good indicator of presence of other diseases in the pig</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Pneumonia (acute)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>×</td>
</tr>
<tr>
<td>Fracture</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>×</td>
<td>(√)</td>
</tr>
<tr>
<td>Arthritis (acute)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Arthritis (chronic)</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>×</td>
<td>(√)</td>
</tr>
<tr>
<td>Arthritis</td>
<td></td>
<td>“**”</td>
<td>“**”</td>
<td>(√)</td>
<td>×</td>
</tr>
<tr>
<td>Condition</td>
<td>Location</td>
<td>EC (2000)</td>
<td>BPEX (2010a)</td>
<td>Status</td>
<td>Notes</td>
</tr>
<tr>
<td>--------------------------------------------------------</td>
<td>----------</td>
<td>-----------</td>
<td>--------------</td>
<td>--------</td>
<td>----------------------------------------------------------------------</td>
</tr>
<tr>
<td>Lymphadenitis</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Abscesses (single, multilocular and muscles)</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Tumours</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Muscles (PSE and DFD)</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Lymphadenitis multilocular</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Pleurisy</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Peritonitis</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Papular dermatitis (skin lesions)</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Trichinella - nematode worm which causes Trichinellosis</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
<tr>
<td>Toxoplasmosis - caused by the protozoa</td>
<td>Muscles</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>(depends)</td>
</tr>
</tbody>
</table>
other organs where they remain viable for long periods of time.

|       |       |       |       |       |

Key for table

- **Critical conditions** - those conditions that are likely to be missed by visual inspection but detected using traditional inspection methods (i.e. palpating and incision).
- **Conditions** which are assessed to be non critical and therefore not considered in the risk assessment.

(✓) Detection method applied on a case by case basis when considered necessary
✓ (depends) Detection method used for further investigation

**Note:** Animals with a low level of a parasitic infection and/or with lesions only in the lymph nodes, which are not significantly enlarged, would not be identified by visual inspection or possibly by palpation (EC Opinion, 2000).

*No information
** Personal communication.
Appendix 2: Preliminary risk assessment

Following on from the hazard identification, a preliminary risk assessment was carried out. The method for this preliminary risk assessment was to fill out the following table for each condition taken forward to Tier 2 assessment. A decision was then made (described in the risk assessment column) for each condition as to whether to take forward to the full risk assessment (Tier 3).

<table>
<thead>
<tr>
<th>Condition</th>
<th>Preliminary risk assessment</th>
<th>EXPOSURE AND CONSEQUENCE ASSESSMENT</th>
<th>RISK ASSESSMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RELEASE ASSESSMENT</td>
<td></td>
<td>Human. 0.01% of pigs with endocarditis. Risk to humans (via cuts/abrasions) appears very low – WHO. Perhaps increased foodborne risk, however from a VERY low baseline. Pigs: feedback to farms may not occur.</td>
</tr>
<tr>
<td></td>
<td>Increase in observed incidence</td>
<td>Decrease in sensitivity of detection</td>
<td>Possible endocarditis/meningitis in humans. Medium-High consequence. 7 reported cases of S. suis in humans in 2008, association with occupational exposure. Low exposure.</td>
</tr>
<tr>
<td>Endocarditis (heart)</td>
<td>~25% reduction in sensitivity (Wouda, 1987)</td>
<td>Change in release</td>
<td>DECISION: Full RA needed, because of potential serious health issues, lower</td>
</tr>
</tbody>
</table>

|                         |                             |                                      |                 |
| Indoor                 | 675                          |                                      |                 |
| Outdoor                | 24                           |                                      |                 |
| Total Pericarditis     | 699                          |                                      |                 |
| Total pigs             | 4159098                      |                                      |                 |
| Prevalence             | 0.016%                       |                                      |                 |
|                        | 0.003%                       |                                      |                 |
Necrosis in lymph nodes (caseous lymphadenitis) - may occur as a result of infection with Mycobacterium bovis (M. bovis/bovine tuberculosis), Mycobacterium avium (M. avium/avian tuberculosis) or Rhodococcus equi (R. equi).

<table>
<thead>
<tr>
<th>TB-like Lesions in head as proxy</th>
<th>Indoor</th>
<th>Outdoor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total TB like lesions</td>
<td>85</td>
<td>10</td>
</tr>
<tr>
<td>Total pigs</td>
<td>4159098</td>
<td>215728</td>
</tr>
<tr>
<td>Prevalence</td>
<td>0.002%</td>
<td>0.005%</td>
</tr>
</tbody>
</table>

Only detected by incision. (EC, 2000)
Non detection rate at abattoir:
Visual: 0.36%
Traditional: 0.16%
(VIP pilot study)

Rate of TB detection is small (23 cases in 2009) but more common in outdoor pigs. Unlikely to be detected using visual inspection.

Human risk of contracting bovine TB from eating meat is very small. M. bovis is killed by cooking meat properly (Defra, 2008).

M. avium - Prevailing opinion in the literature is that M. avium is not meat-borne, so human infection is unlikely to occur through the consumption of meat. (Alban, 2008)
R. equi has been described as a contact zoonosis and is not known for being food-borne.

Pigs: No clinical signs - TB rarely diagnosed in living pigs. Disease sensitivity using visual inspection. Further investigation of outdoor-indoor pig prevalence needed to confirm indoor greater than outdoor.

Human: Increase in risk of bovine TB infected meat going to consumer. Low risk to human health assuming meat is cooked properly. M. avium and R. equi are not known for being food-borne so very low risk.

Pigs: Probable reduction in the reporting of TB in pigs.

DECISION: TB is considered one of the most important conditions to detect, and visual inspection unlikely to detect. M. bovis and M. avium more prevalent in
Lungworm lesions - caused by lungworms *Metastrongylus* spp.

<table>
<thead>
<tr>
<th>Common in outdoor pigs - mainly due to pigs eating earth worms who act as intermediate hosts for the lungworm.</th>
<th>Usually brought to the farmer's attention by high condemnation rates at slaughter.</th>
<th>outdoor pigs than indoor pigs. Conduct full RA.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only detected by palpating. (EC, 2000) Detection of lungworm infection is considered low priority, unlikely that given the time constraints of processing that extrusion of lung lobes would be carried out in order to identify lungworm invasion. Sava Buncic, PC.</td>
<td>Lungworms are not transferrable to humans. No risk with respect to human health if not detected. (EC, 2000)</td>
<td>Human: No risk to human health if not detected.</td>
</tr>
</tbody>
</table>

Pericarditis (acute and chronic) - a non specific secondary condition associated

| Indoor | Outdoor | |
|---|---|---|---|
| Total Pericarditis | 124145 | 4645 | |
| Total pigs | 415908 | 215728 | |
either with bacterial diseases (commonly Glasser’s diseases and pasteurellosis) or as a complication of enzootic pneumonia (EP).

<table>
<thead>
<tr>
<th>Prevalence</th>
<th>2.98%</th>
<th>2.15%</th>
</tr>
</thead>
</table>

May not be detected without incision. Sava Buncic, Ian Griffiths, PC. Acute Pericarditis (edible tissue) may pass undetected in 0.16/1000 cases with visual inspection as compared to traditional. (Mousing et al., 1997)

pigs. Likely to be detected visually, so only small reduction in sensitivity of detection through visual inspection.

human health if not detected. (EC Opinion, 2000).

Pigs: Reduced feedback to farms.

DECISION: Given more common in indoor pigs, and sensitivity of detection is unlikely to change very much, then probably negligible change in risk, and indeed risk is probably lower in outdoor than indoor pigs. Do not carry forward.

Cysticercosis - an infection caused by the pork tapeworm, *Taenia solium* (*Cysticercus cellulosae*)

Pigs act as intermediate hosts for the tapeworm and become infected by eating vegetation or drinking water contaminated with eggs or gravid tapeworm segments suggesting that incidence is higher in outdoor pigs rather than indoor pigs.

Cysticercosis is usually present in muscle tissue and is easily detected visually when the carcass is split during processing at abattoirs.

Appears to be more common in outdoor pigs given exposure route. Usually detected by visual inspection when the carcass is split during processing.

Possible risk to human health if meat is not cooked properly. The presence of an adult tapeworm in the human intestine may cause non-specific symptoms such as abdominal pain, diarrhea or constipation. The most serious

Human: Negligible increase in risk to human health due to very low reduction in sensitivity of detection.

DECISION: Do not carry forward.
| Sava Buncic, PC. | processing at abattoirs. Therefore very small reduction in sensitivity of detection. Consequences occur when the larvae develop in the brain, causing a condition known as neurocysticercosis (Bobes et al.; Corwin, 1992; Sotelo and Del Brutto, 2000). In 2007 there were 86 reported human cases of taeniasis in the UK. Taeniasis is associated with the tapeworms *T. solium* and *T. saginata* which are found in pigs and cattle, respectively. Cysticercosis in pigs usually has no clinical signs (Corwin, 1992; Ramahefarisoa et al., 2010). |