A qualitative risk assessment for visual-only post-mortem meat inspection of cattle, sheep, goats and farmed/wild deer

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The UK Food Standards Agency is currently funding research to build the evidence base for the modernisation of meat inspection. This includes an assessment of the risks to public health and animal health/welfare of moving to a visual-only post-mortem meat inspection (PMMI), where routine mandatory palpation and incision procedures are omitted. In this paper we present the results of a risk assessment for a change from current to visual-only PMMI for cattle, sheep/goats and farmed/wild deer.

A large list of hazard/species pairings were assessed and prioritised by a process of hazard identification. Twelve hazard/species pairings were selected for full consideration within the final risk assessment. The results of the public health risk assessment indicated that all hazard/species pairings were negligible with the exception of Cysticercus bovis in cattle, which was judged to be of low-medium increased risk for systems not conforming to criteria as laid down by EC Regulation 1244/2007, compared to systems that do conform to Regulations for visual-only PMMI.

Most hazard/species pairings were concluded to pose a potential increased risk to animal health/welfare, including Mycobacterium bovis (very low – low increase in risk, but with considerable uncertainty), Fasciola hepatica (negligible – very low) and Cysticercus bovis (very low – low). Due to low feedback rates to farmers, the real risk to animal health/welfare for F. hepatica and C. bovis, including animals in non-conforming systems under visual-only PMMI, is probably negligible. That then leaves M. bovis as the only confirmed non-negligible animal health and welfare risk.

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1. Introduction

Official meat inspection is important for assuring the safety of meat and is also required to ensure access to international trade. However, current post-mortem meat inspection (PMMI) that employs typical macroscopic inspection techniques, namely visual examination, palpation and incision, cannot detect the foodborne hazards that are of importance today, e.g. Salmonella, Campylobacter and Escherichia coli 0157 (EFSA, 2009).

The European Commission (EC) has recognised a need to develop a more effective, risk-based approach to meat inspection (EC, 2000). This would improve efficiency in controlling the most important public health hazards associated with meat at abattoirs whilst maintaining surveillance of animal health/welfare issues. The subsequent Food Hygiene Regulations (Regulations (EC) 852/2004, 853/2004 and 854/2004) enabled implementation of different approaches to PMMI for pigs, calves and lambs, provided certain criteria were met and that it was based on a sound risk assessment. These regulations included the requirements to supply Food Chain Information (FCI) (epidemiological data, heard health data, production data), from farmers to the slaughterhouse operator and Official Veterinarian (OV) before arrival of animals at the slaughterhouse. EC Regulation 854/2004 allowed official conduct visual-only PMMI (i.e. without mandatory use of incision and/or palpation techniques in routine slaughter) of fattening pigs reared indoors from controlled housing conditions and integrated production systems. EC regulation 1244/2007 extended the principle of visual-only PMMI to cattle and sheep/goats, provided certain age and management conditions are met (including ‘all-in-all-out’ production and cattle/sheep being less than 8/12 months old respectively).
A previous risk assessment (Hill, Donaldson, et al., 2013), addressing the risk arising from moving to visual-only PMMI of all pigs in the UK, concluded that the risk in relation to public health hazards detectable by current PMMI (including Mycobacterium bovis) would be negligible. It was also concluded that there would be a very low increased risk to animal health/welfare due to tuberculosis (TB) lesions being missed by meat inspectors (colloquial name for Official Auxiliaries in the UK) if they omitted incision of the head lymph nodes, because current PMMI is the only surveillance mechanism for identifying the presence of TB pathology in pigs. As part of the UK Food Standards Agency’s (FSA’s) continuing process to modernise meat inspection a similar risk assessment has been conducted for other livestock species where visual-only meat inspection has been allowed by current legislation, specifically cattle, sheep/goats and, in addition, farmed/wild deer.

The specific risk question asked by the FSA was: “What is the change in risk for i) public health and ii) animal health/welfare if the derogation for visual only post-mortem meat inspection, established in EC Regulation 1244/2007 for cattle and sheep/goats under certain age and management criteria, are extended to all age groups and quality-assured production systems of these species and farmed/wild deer in the UK?” While the study was focused on the UK, many of the results/conclusions will be applicable to other countries, especially within the EU. We highlight where results may be transferable across countries.

2. Materials and methods

2.1. Definitions

For clarity, we first define relevant terminology, concordant with the relevant EU legislation and risk analysis frameworks. To undergo visual-only PMMI there are several requirements as specified in Annex II of Regulation (EC) 1244/2007, including that animals are raised under “controlled and integrated production systems”. An integrated system is defined as a herd that has detailed information available for all the animals from birth to slaughter and their management conditions. There are also several other criteria relating to ‘all-in-all-out’ systems, feed and bedding that make up the definition for a “controlled” system.

Expert opinion from the English Beef and Lamb Executive (EBLEX) suggests that all quality-assured farms in England and Wales, regardless of production type, would currently meet the criteria for a fully integrated system. This is due to meeting feed and management requirements, the traceability between farm and abattoir provided by FCI, and the various animal movement licence systems for cattle and sheep.

We define all production systems that meet the criteria as laid down by EC Regulation 1244/2007 as “conforming” systems and those that do not as “non-conforming” systems. For example, only those cattle slaughtered at an age of less than 8 months and produced in an integrated and controlled production system will be classed as “conforming”.

Another important clarification is that while a system may be conforming, not all batches/animals are able to be visually-only inspected. Only non-suspect animals would be eligible for routine/normal slaughter and visual-only PMMI. These animals are: a) NOT considered as posing higher risk according to FCI, b) NOT showing relevant abnormalities at ante-mortem inspection and c) NOT showing relevant abnormalities at visual PMMI. Hence, if visual-only PMMI was implemented for all red meat animals slaughtered in the UK, then some animals will still be diverted to a category where carcases/organs would be palpated/incised in addition to visual-only PMMI.

Sensitivity of detection of infection is defined as the ability of PMMI to detect an infected animal, rather than the sensitivity of detecting visible lesions (in the context of TB, for example). That is, the sole concern is the ability to detect true infection of an animal. We define categories of risk as published previously by EFSA (EFSA, 2006). Finally, for parsimony, all further references to animal health are taken to include both health and welfare issues.

2.2. Risk assessment framework

The risk assessment framework used in this assessment is identical to that carried out for visual-only PMMI for pigs (Hill, Donaldson, et al., 2013). Briefly, there are two main criteria that determine whether the risk will change: i) is the sensitivity of detecting a hazard affected as a consequence of switching from current to visual-only PMMI? and ii) is the hazard of concern more prevalent in non-conforming systems than conforming systems? If the answer to one or both of these questions is no, then non-conforming production systems pose no greater risk than conforming systems.

We define two risk terms: the “impact” of a hazard on either public health and/or animal health/welfare under current PMMI legislation (i.e. for conforming systems), and the “relative risk” of extending current provisions for visual-only PMMI to all age groups and quality-assured production systems (i.e. including non-conforming systems). Therefore, the “impact” rating, where applicable, acts as a baseline, from which we compare the relative risk (i.e. an impact of a certain will be rated between “negligible” and “very high”, but will also be assigned an additional rating between “negligible” and “very high” based on the increase in risk posed by allowing more animals to be processed via visual-only PMMI). Each rating from negligible to very high is awarded via the subjective assessment of the risk assessment team, based on the current scientific evidence available.

We assume 100% compliance with legislation and a 100% action taken by farmers in order to address animal health issues. This is the only realistic way to make direct comparisons on the impact of the change from current to visual-only PMMI on animal health and welfare. The risk assessment framework, shown in Fig. 1, largely follows the OIE guidelines for microbiological risk assessment (OIE, 2004), with an additional Hazard Identification stage.

During the Hazard Identification and Release Assessment stages of the framework a number of decision criteria were used to identify hazards where there may be a significant change in public/
animal health risk between current and visual-only PMMI. Only those hazards which were deemed to pose a potential risk are taken forward for full risk assessment.

A comprehensive list of distinct infectious agents and post-mortem conditions was taken from the Animal Health and Veterinary Laboratories Agency’s (AHVLA’s) own protocol for post-mortem inspection of submitted cattle (78 hazards), sheep/goat (71) and deer (54) carcases. A full list of the hazards/species pairings considered are given in the full report to the UK FSA (Hill, Horigan, et al., 2013). Using a combination of literature review and the expertise within the project team, hazards were shortlisted by considering those where a likely decrease in sensitivity would be observed under visual-only inspection methods, and in addition pose a potential threat to human and/or animal health. The hazards that were shortlisted as vulnerable to a change in risk after hazard identification and release assessment were *Mycobacterium avium* subsp. paratuberculosis (MAP) (cattle), *M. bovis* (all species), *Fasciola hepatica* (all species), *Erysipelothrix rhusiopathiae* (cattle, sheep, deer), *Dictyocaulus viviparus* (cattle, deer), *Dictyocaulus filaria* (sheep/goats), *Cysticercus bovis* (cattle), *Caseous lymphadenitis* (CLA) (sheep, goats) and *Jaagsiekte* (Ovine Pulmonary Adenocarcinoma — OPA) (sheep, goats).

2.3. Exposure and consequence assessments

2.3.1. Assessment by decision criteria

The assessments of each hazard/disease pairing is summarised in Table 1. The final two columns give the relative risk estimate i.e. what is the risk posed by non-conforming systems relative to the risk posed by conforming systems? We make the *a priori* assumption that the risk from conforming systems is “acceptable”, hence by definition the risk posed by non-conforming systems can only be “unacceptable” if the relative risk is greater for these systems than conforming systems.

Only one non-negligible increase in the relative risk to public health risk could be identified by including both conforming and non-conforming systems in visual-only PMMI, which was *C. bovis* in cattle (low increase in risk). Three increases in animal health risk were identified: *M. bovis* in cattle, *F. hepatica* in cattle/deer and *M. bovis* in cattle. We summarise the non-negligible risks below.

2.3.2. *M. bovis in cattle*

2.3.2.1. Overview. Surveillance for bovine TB is the most comprehensive among all animal diseases in the UK, and remains a high priority for Agricultural Departments within the UK. It includes mandatory testing of herds using the tuberculin skin test every one or four years, depending on previous history of the herd and geographical location (supplemented with pre-movement skin testing, ad hoc testing and additional gamma interferon blood testing of some infected herds, depending on the location and epidemiological situation of the breakdown). The testing regime is complemented by PMMI (with back-tracking and tuberculin skin testing of affected herds), where several mandatory procedures (e.g. the incision of certain lymph nodes) are aimed at detecting localised TB associated lesions.

2.3.2.2. Difference in prevalence between conforming and non-conforming animals. FSA meat inspection data (unpublished) categorise cattle into calves (<8 months) and adults (>8 months), hence we are able to broadly differentiate between the relative prevalence of TB in non-conforming and conforming systems since calves slaughtered at <8 months are usually reared indoors (Mary Vickers, EBLEX, personal communication). The PMMI detection rate of *Mycobacterium* spp. in the UK during the period 2008—2011 was 0.27% in adult cattle (22,514 suspect lesions/8,484,371 cattle slaughtered) and 0.04% in calves (73/190,493), a statistically significant difference (p < 0.05). Considering the epidemiology of TB infection in cattle, this difference between age groups is not unexpected, given that older cattle grazed outside will be far more likely to be exposed to *M. bovis*, especially in high risk areas. Furthermore, it is known that the sensitivity of detection at PMMI increases with age.

2.3.2.3. Sensitivity of detection. In a recent systematic review of the sensitivity of different tests for TB it was estimated that the sensitivity of PMMI (worldwide) was between 30 and 50% (EFSA, 2012b).

<table>
<thead>
<tr>
<th>Hazard/species pairing</th>
<th>Relative prevalence in NC versus C systems</th>
<th>Relative sensitivity of VO versus T PMMI</th>
<th>Foodborne public health impact</th>
<th>Animal health or welfare impact</th>
<th>Relative risk to public health</th>
<th>Relative risk to animal health and/or welfare</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. bovis</em> in cattle</td>
<td><em>+</em></td>
<td>—**</td>
<td>N</td>
<td>L—M</td>
<td>N</td>
<td>VL—L increase</td>
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<tr>
<td><em>M. bovis</em> in sheep/goats</td>
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<td>—</td>
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<tr>
<td><em>M. bovis</em> in deer</td>
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<td><em>E. rhusiopathiae</em> in all species</td>
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<td>CLA in sheep/goats</td>
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<tr>
<td><em>F. hepatica</em> in cattle/deer</td>
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<td>—</td>
<td>N</td>
<td>N/VL increase</td>
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<td>N/VL increase</td>
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<td><em>F. hepatica</em> in sheep/goats</td>
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<td>N</td>
<td>N/VL increase</td>
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<tr>
<td>D. viviparus in cattle and deer</td>
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<tr>
<td>D. filaria in sheep/goats</td>
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<tr>
<td><em>C. bovis</em> in cattle</td>
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<td>—</td>
<td>L</td>
<td>VL—L</td>
<td>L—M</td>
<td>VL—L</td>
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<tr>
<td>Jaagsiekte in sheep/goats</td>
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<td>—</td>
<td>N</td>
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<tr>
<td>MAP in cattle</td>
<td>+</td>
<td>—</td>
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</tbody>
</table>

Key: P — prevalence; NC — Non-conforming system; C — Conforming system; VO — Visual-only; T — Traditional; N — Negligible; VL — Very Low; L — Low; M — Medium.

*+*/*—* indicates increase/decrease in prevalence in non-conforming systems compared to conforming systems. Greater number of plus or minus signs indicates increasing scale, e.g. **+** — higher increase than + (within region of 1–10× greater prevalence than conforming systems, +++ > 10× greater prevalence).

**+*/—* indicates increase/decrease in sensitivity of visual-only versus traditional PMMI. Greater number of plus or minus signs indicates increasing scale, e.g. ++ — higher increase than +.
although the sensitivity estimate is based on a comparison against a
gold standard of culture, and so is not an estimate of the "true"
sensitivity of detection. In a recent study of TB pathology in UK
cattle the authors found that 55.5% (111/200) of skin-test positive
animals (reactors) and 14% (28/200) of in-contact (skin-test nega-
tive) animals had macroscopically detectable lesions at post-mortem
examination (Liebana et al., 2008). These examinations were
much more thorough than could be expected at PMMI, hence we
can conclude that even in the best case scenario at least 1 in 2 TB-
positive cattle are not spotted during routine PMMI inspection.
The true sensitivity of traditional meat inspection for detection of TB-
associated lesions is probably much lower than the 30% quoted
by Downs et al. For cattle with PMMI-detectable lesions, omitting
incision could result in a large (almost 100%) reduction in
sensitivity.

If we assess that the animal-level sensitivity of PMMI is around
20%, four out of every five TB-infected cattle pass through PMMI
undetected. Therefore, of the 1038 positive M. bovis samples taken
at the abattoir in 2010 (AHVLA, 2011), we can estimate that
somewhere between 1000 (if sensitivity is 50%) and 20,000 (5% sensitivity)
infected cattle went undetected into the food chain in
2010.

2.3.2.4. Impact on public health. Meat-borne transmission of M. bovis is theoretically possible, but it has not been documented in
the UK or EU to date. Pasteurisation of milk in the UK reduced
human M. bovis infection dramatically (Grange & Yates, 1994; de la
Rua-Domenech, 2006), and despite increases in the incidence of
bovine TB in South-West England and Wales, human cases of M. bovis
have remained stable at a rate of around 50 confirmed cases per year (ACMSF, 2003; Grange & Yates, 1994; HPA, 2010; de la
Rua-Domenech, 2006). This suggests the vast majority of human M. bovis cases are from raw milk consumption or the reactivation of
latent infections. The authors of a quantitative risk assessment for
human M. bovis infection via meat consumption in the UK esti-
mated that a maximum of 24 new cases per year could be attrib-
uted to beef consumption (ACMSF, 2010a, 2010b, 2011). This estimate of 24 cases is likely to be a large over-estimate, because it
was assumed that all cases in under-35 year olds can be attributed
to meat consumption. Given that most cases of M. bovis are far more likely to be attributed to raw milk consumption (the sale of raw milk is still legal in England and Wales), then this figure is likely to
be much lower in reality. While it is possible that there would be an
increase in the proportion of TB-infected cattle remaining unde-
tected during PMMI if visual-only inspection was extended to non-
conforming systems, the relative increase in risk to public health
from M. bovis is negligible, as is the overall impact on public health
from consumption of beef.

2.3.2.5. Impact on animal health/welfare. In 2010, 22.2% of all new
confirmed herd breakdowns1 (Officially TB Free Status Withdrawn,
or OTF-W) were identified during PMMI (AHVLA, 2011). Where TB
is identified by meat inspection in a previously Officially-
Tuberculosis Free (OTF) herd, typically a sole animal is identified
(Olea-Popelka et al., 2008). Therefore, omitting incision of lymph
nodes and palpation is likely to reduce sensitivity of detection of
TB-associated lesions at PMMI to near zero. Consequently we can
expect a reduction in the number of herds identified as TB-positive
through PMMI if non-conforming systems are included in visual-
only PMMI (although it is unknown how many positive herds
remain unidentified through current PMMI).

Around 30–50% of herds re-tested within a year of routine
testing are confirmed, peaking at 66% for herds tested 3–4 years
previously (AHVLA, 2011). In 2010, 382 herds (41.6% of all OTF-W
new incidents identified within the abattoir) had skin-test posi-
tive reactors, comprising a total of 2694 cattle (an average of 7.8
reactors per reactor-positive herd). Hence we can reasonably
assume that around 3000 reactors are removed each year due to
PMMI: this could be important in reducing the numbers of days-at-
risk in which TB-infected cattle remain able to pose a transmission
risk to other cattle or wildlife.

The implications of the proposed changes in PMMI for TB control
programmes in the UK are hard to ascertain. In high-risk areas, cattle
herds will be tested on farm every year, and so the impact of the
removal of PMMI as a tool to prevent the transmission of infection
within-herd and/or between herds is probably limited. While
within-herd (cattle-to-cattle) transmission rates are hard to deter-
mine, modelling and observational data suggest that spread of
infection between cattle on the same herd would be in the region of
single figures over the course of 1–4 years (Barlow, Kean, Hickling,
Livingstone, & Robson, 1997; Conlan et al., 2012; Fischer, van
Roermund, Hemerik, van Asseldonk, & de Jong, 2005; Phillips,
Foster, Morris, & Teversen, 2003). Hence, while PMMI is relatively
more important in herds from lower-risk areas with a longer testing
interval, within-herd spread would probably still be limited. Given
the epidemiology of TB in cattle, then the relative increase in risk to
animal health is probably very low — low, although this cannot be
stated with great confidence as there are significant uncertainties
present in this assessment. Further research is required to make
a more certain assessment and rule out a higher relative risk.

2.3.3. F. hepatica in cattle/deer

2.3.3.1. Overview. F. hepatica, commonly known as liver fluke, is
a common trematode parasite of ruminants which has a major
impact on livestock in terms of morbidity and mortality (Salimi-
Bejestani et al., 2005). Eggs from the adult worm inhabiting the
host’s bile duct enter the duodenum with the bile and leave the
host via the faeces. The snail Lymnaea truncatula forms the inter-
mediate host, ingesting the eggs and subsequently depositing
cercariae on blades of grass where they can remain viable for 1 year.

The disease is usually diagnosed in the live animal either on the
basis of microscopic observation of eggs in faeces (Boray, 1985),
serological tests for parasitic antigens or specific antibodies in
serum. Over the past 40 years fascioliasis in cattle has increased in
significance with the number of cases being diagnosed increasing.
Enhanced surveillance for human fascioliasis was carried out after a
reported increase in livestock Fasciola cases in the UK. For the year
2008–2009, 11 human cases were confirmed by reference labora-
tories in England and Wales. All cases were either in people who
had recently travelled to fascioliasis-endemic areas of the globe or
had consumed Fasciola infested vegetation from abroad (Chand,
Herman, Partridge, Hewitt, & Chiodini, 2009).

2.3.3.2. Difference in prevalence between conforming and non-
conforming animals. FSA PMMI records show a marked increase
in prevalence of detected fascioliasis in older cattle with an annual
average of 20,838 cases per 100,000 cattle over the past 4 years
compared to 142 cases per 100,000 calves. The rate of detection of
Fasciola in deer was 30 per 100,000 wild deer and 6233 recordings
per 100,000 farmed deer. The prevalence of Fasciola infection at
PMMI for wild deer is probably greatly underestimated due to the
practice of presenting the carcass only (i.e. minus pluck-heart, liver
and lungs) for inspection at the slaughterhouse unless the hunter
suspects any abnormality.

1 A herd breakdown is defined as a herd that has had one or more suspect TB reactors identified at either tuberculin test or meat inspection. If TB is confirmed, then the herd is classified as a confirmed herd breakdown.
2.3.3. Sensitivity of detection. Current mandatory meat inspection procedures for liver in bovines are as follows. Bovines under 6 weeks of age require visual inspection of the liver and the hepatic and pancreatic lymph nodes, palpation and, if necessary, incision of the liver and its lymph nodes. Bovines over 6 weeks of age require visual inspection and palpation of the liver, hepatic and pancreatic lymph nodes, and the incision of the gastric surface of the liver (and at the base of the caudate lobe for bovines) to examine the bile ducts. For deer mandatory meat inspection requires visual inspection only with incision where deemed necessary if abnormalities are detected. This procedure would not change under visually only meat inspection so the sensitivity of detection of Fasciola for deer would remain the same.

Although clinical signs in the animal at farm level allow the farmer to instigate a fluke management programme, many cases of F. hepatica are subclinical and are only detected by the presence of lesions during PMMI. Approximately 20% of slaughterhouse throughput of cattle over the age of 8 months is found to have Fasciola infested livers. Using coproscopy as the gold standard, visual liver inspection was estimated to have an average sensitivity of 63.2% (55.6–70.6%; 95% credible interval) (Rapsch et al., 2006). We can therefore make a broad statement that up to 30–40% of liver flukes would be missed under visual-only PMMI (although of course some of this 30–40% would be missed under other combinations of visual/palpation/incision procedures). However, from current meat inspection data, herd-level sensitivity for cattle would probably remain broadly constant (as within-herd prevalence is relatively high).

2.3.3.4. Impact on public health. As human liver fluke infections do not occur from ingestion of infested bovine liver there is no increased public health risk from omission of these incisions. Despite the described parallel rise in human and veterinary fascioliasis, there is no evidence that recent human cases resulted from zoonotic transmission within the UK (Chand et al., 2009). Hence, the current impact on public health for conforming systems is negligible, as is any increase in relative risk by allowing non-conforming systems to be inspected via visual-only PMMI.

2.3.3.5. Impact on animal health. The under-detection estimated for visual-only PMMI could be detrimental to animal health and welfare if the lack of feedback to the farmer prevents instigation of a fluke management programme. However, given the current prevalence of Fasciola in cattle, it is unlikely that the drop in animal-level sensitivity would significantly impact herd-level sensitivity (as it is unlikely that all infected cattle within a herd would be missed).

Despite detection of clinical signs at the farm level the frequency of detection of F. hepatica at PMMI is still high for cattle over 8 months of age (~20%) and farmed deer (6.5%), indicating many cases are subclinical. Visual-only PMMI would likely reduce sensitivity of detection in all species, but probably not enough to significantly reduce herd-level sensitivity. Given the lack of information regarding the reduction of sensitivity for cattle and farmed deer the increased risk might be very low rather than negligible.

Viable cysticerci in muscles can be easily missed at PMMI since the translucent cysts blend with the surrounding host tissue. Only upon death and degeneration of the parasite is there a sufficient host inflammatory response to create a more detectable lesion. T. saginata is less of a public health concern than Taenia solium (the helminth cycling between humans and pigs) but has proved more difficult to eradicate due to a greater difficulty in detecting animals that are lightly infected, and a global propensity to consume raw or semi-cooked beef (Pawlowski & Murrell, 2001). If an animal has generalised infection the carcase and offal are declared unfit for human consumption. If the infection is localised, detected cysts are removed and the carcase has to be stored at a temperature not exceeding –10 °C for >14 days or –7 °C for >3 weeks before release for human consumption. This cold treatment kills any remaining viable cysticerci.

2.3.4.2. Difference in prevalence between conforming and non-conforming animals. The rates of detection of C. bovis from UK PMMI data from 2008 to 2011 are 0.008% (15/190,493) and 0.032 (2674/84,487,371) for slaughtered calves and adult cattle respectively.

While detection of cysts is more difficult in calves than in adult cattle, the seroprevalence of bovine Cysticercosis does appear to be positively correlated with increasing age (Dorny et al., 2000). This is explained by the fact that infection is accidental and that the risk of historical exposure increases with the age of the animal. Hence, we can reasonably ascertain that the difference in incidence rates between calves and adult cattle is real (although may be not as great as indicated by meat inspection data).

2.3.4.3. Sensitivity of detection. Mandatory meat inspection includes incisions into the internal (pterygoid) and external (masseter) mastication muscles (not applicable to animals under six weeks of age), a lengthwise incision of the heart in cattle of all ages and visual examination of the cut surfaces. However, only a proportion of the cysts are located in these so-called predilection sites, i.e. the heart (15.7%) and masseter muscles (6.5%) (Dorny & Praet, 2007). In addition, the success of the method is highly dependent on the skills of the meat inspector and stage of degeneration of the cysticerci.

Since the early 1990s EU regulated modifications were introduced in meat inspection methods in order to reduce costs and time of veterinary control. These included a reduction in the number of incisions of the organs, including the heart, at PMMI. There is some evidence that the reduction in the number of cuts in the heart has led to a reduction in sensitivity of meat inspection for Cysticercus detection (Dorny et al., 2000). The sensitivity of meat inspection of carcases with light infestations (1–10 cysts) of C. bovis is believed to be low (27%), rising to 43% for animals with 11–20 cysts and 78% when 20 or more cysts are present (EFSA, 2005). The available research thus suggests that the prevalence of bovine cysticercosis in the EU as determined through meat inspection is greatly underestimated (Dorny & Praet, 2007); the actual prevalence could be 3–10 times higher. Heavy infestations in cattle are uncommon, with light infections being most common as a result of accidental ingestion of eggs that have been disseminated in the environment. Hence, if similar sensitivities are applied to current UK meat inspection procedures, then the prevalence of C. bovis infection could be anywhere between 24 and 80 per 100,000 calves slaughtered (0.008%·3·100,000 – 0.008%·10·100,000), and 100–300 per 100,000 adult cattle slaughtered.

2.3.4.4. Impact on public health. In a risk assessment model for human infection with T. saginata in New Zealand under current PMMI conditions the mean number of human infections per year as...
a result of consumption of *C. bovis* infected beef in the export and domestic market was estimated at 0.5 and 1.1 respectively (van der Lогt, Hathaway, & Vose, 1997). If PMMI procedures were not carried out for the detection of *C. bovis* the mean numbers of human infections was estimated to increase to 0.61 and 1.3 respectively, roughly a 20% increase.

Ninety-eight human cases of *T. saginata* were reported in the UK in 2011. During the same year, 975 cases of bovine Cysticercus were recorded at PMMI but a possible 2925—9750 cases were undetected (assuming an under detection rate of 3—10-fold). Assuming the 98 cases arose as a consequence of these undetected cases this equates to 1 case of human infection from every 30—100 undetected cases. Over the last 12 years 1207 *Taenia* cases were recorded by the HPA (unpublished data, HPA), of which roughly 98% were *T. saginata*. However, no other information on these cases with regards source of infection was available.

In terms of the number of cases, if the New Zealand risk assessment is broadly applicable to the UK situation, we can expect an increase in the number of human cases per year of around 20% (from approximately 100 cases per year to around 120) if a move from traditional to visual-only meat inspection is allowed for all cattle. Therefore, the increase in risk from allowing non-conforming systems to undergo visual-only PMMI is considered low-medium, but from an overall current impact to public health that is very low—low.

### 2.3.4.5. Impact on animal health/welfare

Naturally occurring *C. bovis* infections in cattle are unlikely to produce any clinical signs. Heavy infestations will occasionally show muscle stiffness and fever though such infestations are rare in the UK. The main reasons for the persistence of *T. saginata* in Europe include the low sensitivity of current meat inspection protocols and cattle husbandry systems which allow grazing on pastures and drinking from water streams (Dorny & Praet, 2007). If *C. bovis* is detected at PMMI in the UK meat inspectors feed this back to the producer. This information is considered by the FSA to be for the producer to act upon. The FSA does not check or follow up if any action was taken by the producer. Hence, it is not known how effective feedback from PMMI to the farmer is in reducing *C. bovis* infection on-farm. In addition, the lack of any regulated treatment for the disease in the live animal makes it difficult for the farmer to compile an eradication program. However, as Cysticercosis is usually subclinical and current PMMI remains the only form of general surveillance for *C. bovis*, any reduction in detection by employing a visual-only PMMI could be considered a potential increase in risk.

The impact on animal health/welfare incurred by changing to a visual-only PMMI method for calves under the age of 8 months is probably very low, determined by the low prevalence of the disease and the difficulty in visualising cysts in this animal group at PMMI (meaning the relative change in sensitivity will be minimal). The increased risk to animal health/welfare incurred by changing to a visual-only PMMI method for animals over the age of 8 months is considered to be very low—low. Although the frequency of detection at PMMI is low, removing the heart incisions is likely to reduce sensitivity of meat inspection even further.

### 2.3.5. Brief discussion of negligible risk hazard/species pairings

An important reason for the assessment of many of the other hazard/species pairings as ‘negligible’ is that visual-only PMMI would not see a large change in procedures from current PMMI. For example, the incision of lymph nodes is not required in sheep or goats, and hence the primary method for identifying *M. bovis* is already non-mandatory for these species. It is therefore unsurprising that *M. bovis* in sheep/goats and deer is rarely detected at the slaughterhouse, with only 30 positive submissions from sheep and 6 from goats in 2011. Over the four year period 2008—2011 there were 14 and 15 positive submissions from farmed and wild deer respectively. While PMMI remains the only surveillance for TB in non-bovine species, a drop in the rate of current detection due to visual-only PMMI of these species would be a negligible risk to national public or animal health.

The proposed change in meat inspection procedures to a visual-only technique could only affect detection of MAP in cattle as this is the only animal group currently subject to mandatory palpation of the mesenteric lymph nodes. The others already undergo visual-only appraisal of the relevant tissues. The links between MAP and public health are still debatable, but it would appear that the meat-borne risk is negligible. With regard to animal health, even in a worst-case scenario, where all the recently identified cases would be missed by the change in inspection procedure, the numbers remain very low. Thus, a change to visual-only meat inspection is very likely to be of negligible risk to animal health. As PMMI is the only detection method for MAP, it may be necessary to conduct other surveillance activities if visual-only PMMI was introduced, or at least retain traditional PMMI procedures in areas of high MAP risk.

*Dictyocaulus* spp. and Jaagsiekte are not zoonotic. *E. rhusiopathiae* and CLA are considered to be occupational human hazards; the omission of incisions and palpation of lymph nodes/organs presumably only lower the already extremely small risk to meat inspectors. Diagnosis of joint ill (causative agent *E. rhusiopathiae*), Jaagsiekte, *Dictyocaulus* spp. and CLA is most likely in the live animal at the farm, and so there is a limited value of feedback to farmers.

### 3. Discussion

The modernisation of meat inspection in Europe is continuing with several EFSA Scientific Opinions either underway (red meat species) or published (swine, poultry, farmed game) to propose changes to PMMI (EFSA, 2011, 2012a). This risk assessment fits into the context of modernisation by focussing on the aspect of visual-only PMMI. While visual-only PMMI is already allowed under certain conditions for pigs and red meat species, it has not been implemented in the UK.

The results of this risk assessment for cattle, sheep/goats and wild/farmed deer, given the available data, and current assumed rates of infection, suggest that the only increased risk to public health through meat is from *C. bovis* in cattle. The relative increase in meat-borne risk of *C. bovis* if all cattle were allowed to undergo visual-only PMMI was considered to be low-medium, up from a very low human burden under the current rules of traditional PMMI (100 cases per year, but most of these are likely to be caused by consuming beef abroad).

The most recent EFSA report on Cysticercus (EFSA, 2010) concluded that monitoring should continue to be based on traditional meat inspection according to current European legislation, because more sensitive methods are not yet commercially available or fully validated for a routine diagnosis. Regulation (EC) No 854/2004 currently allows the use of serological tests on cattle, and it was recommended within the EFSA opinion that such tests be further developed for use as a routine surveillance tool as soon as possible. In preliminary studies, the Ag-ELISA method indicated 3.09% of cattle were cysticercus-positive whilst only 0.26% positives were detected by conventional meat inspection (Dorny et al., 2000). However, this was 12 years ago and as yet there is still no validated test for the detection of *C. bovis* suitable as a replacement for meat inspection.

Another EFSA opinion also expressed concern over TB in cattle should visual-only meat inspection be allowed for all cattle (EFSA, 2004). However, the results of a recent UK risk assessment
suggest that TB can be classed as a negligible meat-borne risk (ACMSF, 2010b). Meat inspection may indirectly contribute to protecting raw milk consumers from TB by identifying positive-yet-OTF herds supplying raw milk in between tuberculin tests, but the likelihood of such an occurrence is small given the small number of raw milk suppliers currently trading.

With regards to animal health/welfare, we concluded that there would be an increase in risk for M. bovis in cattle (very low—low increase, but with wide uncertainty), F. hepatica in cattle and deer and C. bovis in cattle (both very low—low increase). These conclusions were made as the removal of the relevant mandatory incisions would mean that the relative sensitivity of detection of these hazards would be reduced, potentially sufficiently so to reduce herd-level sensitivity. Herd-level sensitivity is an important aspect of meat inspection, as the real value of meat inspection for animal health (surveillance) is feedback to farmers.

In order to conduct the risk assessment we assumed that there would be 100% feedback of conditions to farmers, and 100% positive action from farmers given feedback on any of these conditions. The judgements made about the increases in relative risk to animal health are borderline with the assumptions of 100% feedback and compliance, but probably verge on negligible given realistic assumptions about the level of feedback to farmers that currently occurs for F. hepatica and C. bovis. In addition, serological surveillance of C. bovis and F. hepatica is preferred at the herd level. The situation is markedly different for M. bovis in cattle, where there is a control programme in force, leading to almost 100% of PMMI-detected herds being placed under immediate movement restrictions. It is known that 10–20% of breakdown herds within the UK are identified during PMMI, which does raise a pertinent question of whether removing the mandatory incisions of the head and neck lymph nodes poses a realistic threat to animal health/welfare because of the detriment to the overall sensitivity of animal surveillance.

A review of bovine TB incidents detected in the slaughterhouse was undertaken by the AHVLA in 2010 (AHVLA, 2010). As expected, submissions of suspect TB lesions were higher in abattoirs located in high-risk areas (South-West England and Wales). The confirmation rate of M. bovis by culture/histology was also higher in high-risk areas. However, there was a marked increase in the percentage of breakdown herds identified by PMMI within 4 yearly testing parishes — 45% versus 16–21% in yearly tested parishes. These results confirm the assumption that slaughterhouse PMMI is more valuable for low-risk areas where herds are routinely tested at less regular intervals, although there may well be a decreased sensitivity and specificity of slaughterhouse detection in these areas.

The main result for PMMI animal health surveillance of TB in cattle is that around 3000 reactor cattle are slaughtered per year as a result of OTF-status being withdrawn through TB detection at the abattoir, which will have some value in preventing the transmission of disease. However, while on average more reactors are detected the longer the time since the last routine herd test, the majority of new OTF-W incidents identified in the slaughterhouse come from yearly-tested herds (593/654–90.6%) (AHVLA, 2011). Given the relatively slow spread of TB it could be argued that yearly-tested herds are tested regularly enough to minimise any potential risk of TB spread through non-detection of slaughterhouse cases given visual-only PMMI; pre-movement testing would reduce this risk still further. That would then leave in the region of 60–70 herds (at current rates of infection) that would not be identified under visual-only PMMI in higher test interval parishes. It is not possible to confirm without further research whether the removal of up to 700 reactors per year in these low-risk areas, and subsequent movement restrictions on the affected herds, is crucial in preventing the further spread of TB into low-risk areas.

While outside the scope of this qualitative assessment, further quantitative analysis of new OTF-W incidents detected at the slaughterhouse could more accurately describe the increase in the number of days-at-risk as a result of visual-only PMMI (i.e. the total time in which cattle remain undetected in their herds before the next tuberculin test). This could give an indication of how important surveillance of cattle at slaughter is to the efforts in controlling/preventing the spread of TB in cattle.

There are many factors that need to be considered when developing any bovine TB policy, including the economics of the farm and the political considerations involved. No factors apart from public health and animal health/welfare are considered in this assessment, and explicitly so. As with current parish testing intervals, a reasonable approach to visual-only PMMI may be to consider the risk on a regional rather than national basis, and/or on the basis of certain conforming and non-conforming systems. That is, cattle from 4-yearly testing parishes (regardless of abattoir location), or from higher-risk systems, are inspected using mandatory incision and palpation methods. This would hopefully fit within a visual-only PMMI system relatively easily, as provision must still be made to more thoroughly inspect cattle from specified high-risk herds, or from herds that fail to supply relevant FCI to the abattoir in time for slaughter.

One limitation of this study is the data used, which are not necessarily representative of disease burdens across the UK, and are of course subject to change. This injects a note of caution into the interpretation of this risk assessment. However, there may well be a strong case for a change to the current EC regulation if clear benefits to public health and/or animal health/welfare can be achieved by moving to a visual-only PMMI inspection method for all systems of production. At the very least there could be justification for relaxing the definition of a conforming system, for example by allowing outdoor production that meets certain other criteria. The only potentially compelling reason to maintain mandatory incision/palpation procedures is to maintain the maximum possible sensitivity of bovine TB surveillance, in order to achieve eradication of the disease (where of course doing anything to reduce the status quo could be argued to be potentially dangerous, especially in light of the increased incidence in cattle TB over the previous decade). It was outside the scope of this project to determine the cost-benefit of such a policy.

While this study concentrated on the UK, the broad conclusions are likely to remain relevant for other EU Member States (MSS) and for developed countries around the world. The UK has one of the highest rates of bovine TB incidence in humans and cattle in the European Union (EFSA, 2013a), but pasteurisation of milk effectively prevents any threat to public health, and most cases are likely from before pasteurisation controls (ACMSF, 2010b). The conclusion that animal health would be put at a very low—low increased risk would remain for most countries if visual-only PMMI was adopted, but then the overall impact would be much reduced (if not negligible) in most developed countries compared to the UK. The only other increased risk that was of true concern is C. bovis in cattle, where we assessed that there would be a low increase in public health risk. Similar issues with low sensitivity of meat inspection exist across the European Union (Dorny & Praet, 2007).

This estimated increase in the number of C. bovis cases must be viewed in the context of the overall public health burden of foodborne illness, where many thousands of foodborne illnesses are caused by organisms that are not detectable at gross PMMI (Salmonella spp., Campylobacter spp. and Escherichia coli O157) (EFSA, 2009). While not explicitly considered in this risk assessment, there does seem to be a case for further investigating the public health cost-benefit of conducting traditional PMMI versus transferring any saved costs/resources from implementing visual-only
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PMMI into other food safety activities, such as assurance criteria for pathogens such as Salmonella spp. or Campylobacter spp. (EFSA, 2013b). One suggestion made through a review of the benefits of visual-only PMMI (Hill, Horigan, et al., 2013) is that the extra time a meat inspector may gain through visual-only PMMI could allow more accurate, real-time recording of any observed conditions. This would greatly improve the quality of data produced by PMMI activities, which would help, for example, to improve epidemiological/risk analyses such as this one.

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