A cost-effectiveness analysis for *Salmonella* interventions in the British pig meat production chain.


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Abstract

In 2002 a British *Salmonella* monitoring programme for pigs was introduced, with the intention of reducing the prevalence of *Salmonella* in pigs at slaughter and hence the number of *Salmonella* cases in humans attributable to British pig meat. While the primary focus has so far arguably been on reducing the prevalence of *Salmonella* in slaughter pigs, the programme is intended to reduce *Salmonella* across the whole production chain. In support of this programme, and as part of a large risk-based study, a risk assessment and cost-effectiveness analysis were developed to investigate the effect of the following interventions: vaccination, feeding of organic acids, rodent control, anal bunging and washing and drying of the carcass at dehairing.

In the best case scenario investigated using the risk assessment, the number of cases attributable to pig meat consumption fell by 81%, 70%, 60% and 36% when bunging, rodent control, organic acid and vaccination interventions were assumed to be universally applied across the GB pig industry (from a baseline of 600 pig meat-attributable cases). Adoption of interventions on farms or in abattoirs will incur costs for these businesses whilst, since the aim is to protect public health, benefits would be enjoyed by society as a whole. Therefore, in promoting any control measures, these should protect public health at the lowest cost to business. Data on the costs of each intervention were collected and used to populate a risk-economic model. This predicted that bunging was the most cost-effective (~£3,600 per human case prevented), with organic acids and vaccination being the most cost-effective farm interventions (~£13,000 per human case prevented). While these results are based on a number of important simplifying assumptions, this type of evidence would assist in formulating a future GB National Control Plan at a time when the British pig industry faces a stringent economic situation.

Introduction

Surveys of British pigs at slaughter between 1999 and 2007 have consistently shown that approximately one quarter were infected with *Salmonella* (Davies *et al.* 2004; Anon 2008). Most infected pigs do not show any clinical signs. However, they do represent a potential threat to human health. There were 13,213 reported human cases of salmonellosis in UK in 2007 and approximately 13% of these were due to *Salmonella Typhimurium*, which is found in all domestic livestock and is the most common serovar to be isolated from British pigs (Defra 2008). Reducing the prevalence of *Salmonella* infection in pigs at slaughter, or the prevalence of contaminated carcasses in the abattoir, would potentially offer public health benefits, although evidence of the proportion of human cases that are attributable to GB pig meat products is equivocal (Amin *et al.*, 2009). The European Commission (EC) will set targets for reducing prevalence of *Salmonella* in live pigs, based on the results of a 2007 survey (Anon 2008).

The British Pig Executive (BPEx) launched the Zoonoses Action Plan (ZAP) in 2002 with the aim of reducing the prevalence of *Salmonella* infection in pigs slaughtered in quality assured abattoirs by 25%. However, the scheme failed to achieve its goal, since there was no change in the prevalence of infection (Anon 2008b). Control of *Salmonella* on farms is feasible but challenging. Farmers are reluctant to adopt control measures which do not yield direct benefits, despite an acceptance that protection of public health is important (Fraser *et al.* 2009; Van Dam *et al.* 2009). However, farms may not be the optimal point in the pork supply chain to intervene in order to reduce the prevalence of *Salmonella* infection and control.
may be realised through interventions at more than one level in the supply chain (Unneverh and Jensen 2001).

This paper reports on an analysis of the relative cost-effectiveness of selected interventions on-farm compared with at abattoir in reducing Salmonella infection in pork in Great Britain (GB). A set of interventions on-farm and at abattoir levels were identified. A quantitative microbial risk assessment (QMRA) model (Simons et al. 2009) was used to predict the impact of each intervention upon the annual number of human Salmonella illnesses attributable to pork chops, bacon and sausages. The cost of implementing each intervention was estimated, both for individual farms and abattoirs, and for the industry as a whole. The estimated effectiveness and cost of implementation were combined for each intervention in order to produce an estimate of its cost-effectiveness.

Materials and Methods

For more information on the QMRA methods, (see accompanying paper Hill et al. 2009). To calculate a cost-effectiveness ratio for each intervention we combine the estimated economic cost of each of the interventions with the predicted effectiveness. In order to jointly consider both the farm and abattoir interventions we must use comparable cost and effectiveness measures for all interventions. Therefore, the cost measure we use is the industry cost in terms of pigs and the effectiveness measure is the average percentage change, according to the model, in the number of human cases of Salmonella due to pork chops, bacon and sausages per year.

The cost-effectiveness ratio for intervention \(i\), \(E(i)\), is calculated by dividing the percentage change in human illnesses, \(P(i)\), by the cost associated with that intervention, \(C(i)\). We also multiply by a factor of 10,000 to make the results clearer.

\[
E(i) = \frac{P(i)}{C(i)} \times 10,000
\]

This gives a measure that is comparable between interventions, such that an intervention with a high value should be considered more cost-effective than an intervention with a lower value.

Results

The results are shown in Table 2, which shows the average number of human Salmonella illness per year attributable to pork chops, bacon and sausages, predicted by the MRA, the percentage change from the baseline model (which estimated a mean number of illnesses of 600.6), the estimated cost of the intervention and the cost-effectiveness estimate. We also show the results of the cost-effectiveness analysis in the form of a bar chart (Figure 3). From this figure it can be seen that the brushing intervention is the most cost-effective while washing is the least cost-effective.
Table 2: Cost-effectiveness ratios of interventions

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Number of human illnesses per year</th>
<th>Percentage change, $P(i)$</th>
<th>Industry cost in terms of pigs, $C(i)$</th>
<th>Cost-effectiveness ratio, $E(i)$</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Farm Interventions</strong></td>
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<tr>
<td>Organic acids</td>
<td>241.37</td>
<td>59.82%</td>
<td>£4,450,000</td>
<td>0.13</td>
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<tr>
<td>Rodent control</td>
<td>182.26</td>
<td>69.65%</td>
<td>£22,351,412</td>
<td>0.03</td>
</tr>
<tr>
<td>Vaccination</td>
<td>381.24</td>
<td>36.52%</td>
<td>£2,951,531</td>
<td>0.12</td>
</tr>
<tr>
<td><strong>Abattoir interventions</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bunging</td>
<td>113.76</td>
<td>81.06%</td>
<td>£1,755,000</td>
<td>0.53</td>
</tr>
<tr>
<td>Washing and drying</td>
<td>527.16</td>
<td>12.23%</td>
<td>£5,202,000</td>
<td>0.02</td>
</tr>
<tr>
<td>Washing</td>
<td>564.55</td>
<td>6.00%</td>
<td>£5,202,000</td>
<td>0.01</td>
</tr>
</tbody>
</table>

Figure 3: Comparison of cost-effectiveness of interventions

Discussion

The results presented predict that bunging would be the most cost-effective intervention for the reduction of human *Salmonella* illnesses due to pork meat. Perhaps surprisingly the intervention favoured by farmers (which based on the results of a previous study VLA (2006) was rodent control), was not relatively cost-effective. It is well known how farmers are resistant to change and adoption of different practices, suggesting that pig farmers may resist the adoption of the more cost effective farm practices, e.g. organic acids. This may present a problem to regulators and, if our results are confirmed, may pave the way to downstream interventions in the supply chain rather than upstream. Unless the farm level intervention effectively reduces the prevalence of pathogens in the whole pig population, such that re-contamination becomes highly unlikely, it is likely that the effect of money invested at the beginning of the food chain is diluted if re-contamination of carcasses is probable later on in the chain. This suggests a need for optimising cost-effectiveness for the whole chain rather than focusing in isolated parts.
Therefore it would appear that a supply chain HACCP would be a more effective and efficient than having one for each agent in the supply chain. These results may assist farmers and other food-chain members in deciding with policy-makers where to act and who should pay.

Conclusion

This paper has analysed the cost-effectiveness of farm and abattoir level interventions on Salmonella prevalence reduction. We predict that the most cost-effective intervention is bunging, while washing was the least cost effective.

References

Fraser, R., Williams, N., Powell, L., Cook, A. (2009) Reducing Campylobacter and Salmonella Infection: Two Studies of the Economic Cost and Attitude to Adoption of On-farm Biosecurity Measures (Accepted for publication by Zoonoses & Public Health June 2009)