Quantification of the informative value of meat inspection to detect biological hazards for pork consumers in Europe

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Abstract

Meat inspection at slaughterhouse was the main mean of control used historically to protect consumers from biological hazards transmitted by the consumption of pork. The epidemiological evolution of biological hazards led the European Union to promulgate new food safety legislation in the form of the Hygiene Package, based on a risk analysis approach. This package authorizes Member States to develop new meat inspection methods in order to accentuate consumer health protection. However, the levels of detection of biological hazards during traditional meat inspection have not been established, particularly in quantitative terms. Such an assessment is needed to define risk-based meat inspection schemes. The aim of this study was to provide elements to quantify the lack of detection of biological hazards by current meat inspection methods. A literature review of 440 references was undertaken to summarise information on the incidence of foodborne zoonoses and the prevalence of biological hazards on/in pork carcasses. Then for each hazard, the incidence rate of zoonosis induced by pork consumption (I_pork) and the ratio of non-control of hazard at and after meat inspection (NC) were calculated. The comparison between incidence rates and non-control scores show that the three most frequent hazards Salmonella enterica, Campylobacter spp., Yersinia enterocolitica (I_pork = 3.374; 2.170 and 2.826 cases per 100,000 inhabitants per annum, respectively) cannot be detected by macroscopic examination of carcasses (NC = 1.19223; 0.27756; 0.08341, respectively). Consequently, new means of hazards control are needed to complete the classical macroscopic examination.

Introduction

Pork is the most consumed meat in the European Union (DEVINE, 2003). Management of hazards transmitted to humans by consumption of pork is therefore of major health significance. Meat inspection is the oldest means used at slaughterhouse to protect the consumer health. It is based on an ante mortem clinical examination and a macroscopic post mortem examination of the carcass, including incision or palpation of lymph nodes and organs to detect clinical signs or macroscopic lesions potentially correlated with the presence of hazards (THORNTON, 1957). Additional bacteriological or chemical analyses can also be performed if relevant to assess the safety of carcasses. In 2002 the European Commission promulgated the Food Law (regulation (EC) 178/2002) whose main objective is to apply risk analysis to food safety legislation, with risk assessment - a "scientifically based process consisting of four steps: hazard identification, hazard characterisation, exposure assessment and risk characterisation" - as primary step. A preliminary study concerning hazard identification has shown that 35 biological hazards may be transmitted to humans by the consumption of pork: 12 are parasitic, 14 bacterial and 9 viral (FOSSE et al., 2005). Of these, 12 were defined as current established European hazards, i.e.
hazards whose presence on pork and whose transmission to humans by food consumption is established today in the countries of the European Union. Three were parasitic (Sarcocystis suihominis, Toxoplasma gondii and Trichinella spiralis) and nine were bacterial (thermophilic campylobacters, Clostridium botulinum, Clostridium perfringens, Listeria monocytogenes, Mycobacterium spp., Salmonella enterica, Staphylococcus aureus, shiga-toxin producing Escherichia coli or STEC, Yersinia enterocolitica). The impact on human health of biological hazards transmitted by the consumption of contaminated pork, which may be assessed by the consecutive incidence of clinical cases in humans, is closely linked with their occurrence on pork carcasses, and also their detectability during meat inspection. However, levels of contamination of carcasses are often not fully known, whereas risk analysis has to include such information, especially to estimate the detectability of biological hazards at meat inspection. Moreover, few studies have included data from all the countries of the European Union to assess the mean impact of biological hazards transmitted by pork on human health. The purpose of this article was to explore the informative value of the epidemiological indicators available in European countries in order to apply risk assessment to pork meat inspection. Assessment of the mean occurrence of hazards transmitted to humans by the consumption of pork in Europe was therefore first implemented. Mean levels of prevalence of biological hazards on pork carcasses was also estimated. A ratio for non-control (NC) of risks for consumers after meat inspection was calculated.

Material and methods

A review of four hundred and forty-nine papers was carried out to collect information regarding the prevalence of biological hazards potentially transmitted to humans by the consumption of pork on carcasses and the exposure of humans to these hazards due to the consumption of pork. These articles were searched on CAB and Medline databases. This study only addresses the main category of pig produced in Europe, i.e. indoor reared and finished pig. To assess the occurrence of clinical cases in humans induced by biological hazards, only information concerning western European countries (former EU-15) population was studied.

For each current established European hazard: i) from 3 to 43 values of rates of prevalence on pork carcasses were compiled and from this information, a mean rate of prevalence on pork carcasses ($P_{\text{car}}$) was calculated for each hazard; ii) from 1 to 58 data regarding the incidence of the foodborne disease in humans induced by biological hazards in western European countries were collected. A mean incidence rate (I) was calculated for each hazard. The pork attributable proportion (PAP), i.e. for each current established European biological hazard responsible for foodborne disease in humans, the proportion of clinical cases induced by the consumption of contaminated pork, was calculated from: i) data concerning the number of clinical cases of foodborne disease according to the food vehicle of transmission (OLSEN et al., 2000; DANSK ZOONOSECENTER, 2001): $PAP = \frac{n_{\text{pork}}}{n_{\text{total}}}$ with $n_{\text{pork}}$ and $n_{\text{total}}$, for one given hazard, the number of human cases due to pork consumption and the total number of human cases due to food consumption, respectively; ii) or, when exhaustive data was lacking, from data concerning the proportion of outbreaks induced by pork according to the mean number of clinical cases per outbreak (SOCKETT et al., 1993; SCHMIDT and GERVELMEYER, 2003; HAEGHEBAERT et al., 2002; HAEGHEBAERT et al., 2003): $PAP = \left(\frac{O_{\text{pork}}}{O_{\text{total}}} \times N \right)$ with $O_{\text{pork}}$ and $O_{\text{total}}$, for one given hazard, the number of outbreaks due to pork consumption and the total number of outbreaks due to food consumption, respectively; $N$: the mean number of human cases per outbreak; iii) or, when those information was lacking, PAP was the estimate given by an expert panel in a study performed in the United States in 2006 (HOFFMANN et al.,
The incidence rate of clinical cases in humans induced by the consumption of pork ($I_{pork}$) may be considered in relation to the mean incidence rate ($I$) and the estimate of the pork attributable proportion (PAP):

$$I_{pork} = I \times PAP$$

Moreover, $I_{pork}$ may also be considered as a function of the level of consumption of pork ($\text{Cons}_{\text{pork}}$), the mean prevalence of the biological hazard in pork carcasses ($P_{\text{car}}$), the score of non-detection of hazards at meat inspection (ND), the potential secondary contamination of meat from inspection step to consumption step (SC) and the susceptibility of consumers to the hazard (Su):

$$I_{pork} = f(\text{Cons}_{\text{pork}}, P_{\text{car}}, ND, SC, Su)$$

Variations in levels of consumption of pork between European countries are small (DEVINE, 2003). So we considered $\text{Cons}_{\text{pork}}$ as a constant. Sensitive subpopulations are usually described: Young children, Olderly, Pregnant and neonates, and Immunocompromised (YOPI) (GERBA et al., 1996). But today quantitative information about the mean susceptibility of a whole population to a specific biological hazard is often lacking. So we considered here the value of Su for the whole population as a constant for each hazard in each European country. Consequently, a score of non-detection of hazards at meat inspection (ND) and a ratio of non-control of hazards (NC) at and after meat inspection were calculated by the following equations:

$$ND = \int \left( \frac{I_{pork}}{P_{\text{car}} \times SC} \right) = \int \left( \frac{I \times PAP}{P_{\text{car}} \times SC} \right)$$

and then: $NC = \int (ND \times SC) = \frac{I_{pork}}{P_{\text{car}}}$

Results

*Yersinia enterocolitica* and *Clostridium perfringens* are the two main hazards identified on pork carcasses, with mean rates of prevalence higher than 30%. *Listeria monocytogenes* ($P_{\text{car}} = 25.8\%$) and *Staphylococcus aureus* (23.8\%) have the next highest prevalence rates, before *Sarcocystis suihominis* (15.7\%) and *Toxoplasma gondii* (12.5%), whereas the mean prevalence rates of other hazards are lower than 10\% (Table 1).

*Salmonella enterica*, *Yersinia enterocolitica* and *Campylobacter* spp. are the three most frequent hazards reported in human clinical cases which may be related to the consumption of pork, with $I_{pork}$ of 3.374, 2.826 and 2.170 cases per 100,000 inhabitants per annum, respectively. The other hazards have $I_{pork}$ lower than 1 case per 100,000 inhabitants per annum (Table 1).
Table 1. Mean rate of incidence of human clinical cases (I), mean Pork Attributable Proportion (PAP), mean rate of incidence of human cases due to the consumption of pork (I_pork), mean rate of prevalence of biological hazards on pork carcasses (P_car) and ratios of non control (NC) after meat inspection according to biological current established European hazards.

<table>
<thead>
<tr>
<th>Hazard</th>
<th>I</th>
<th>(n)</th>
<th>PAP</th>
<th>I_pork</th>
<th>P_car</th>
<th>(n)</th>
<th>min P_car : max P_car</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Parasitic hazard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sarcocystis suihominis</td>
<td>0.0025</td>
<td>1</td>
<td></td>
<td></td>
<td>0.00025</td>
<td>15.7</td>
<td>0.8 : 32.0</td>
<td>0.000016</td>
</tr>
<tr>
<td>Toxoplasma gondii</td>
<td>4.250</td>
<td>2</td>
<td></td>
<td></td>
<td>0.425</td>
<td>12.5</td>
<td>0.9 : 33.0</td>
<td>0.03395</td>
</tr>
<tr>
<td>Trichinella spiralis</td>
<td>0.025</td>
<td>29</td>
<td></td>
<td></td>
<td>0.014</td>
<td>0.4</td>
<td>3x10^-6 : 1.2</td>
<td>0.03911</td>
</tr>
<tr>
<td>Bacterial hazard</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Campylobacter spp.</td>
<td>62.980</td>
<td>35</td>
<td>3.6</td>
<td>2.170</td>
<td>7.8</td>
<td>12</td>
<td>0</td>
<td>31.5</td>
</tr>
<tr>
<td>Clostridium botulinum</td>
<td>0.117</td>
<td>35</td>
<td>23.8</td>
<td>0.028</td>
<td>32.6*</td>
<td></td>
<td></td>
<td>0.00086</td>
</tr>
<tr>
<td>Clostridium perfringens</td>
<td>0.730</td>
<td>21</td>
<td>20.3</td>
<td>0.148</td>
<td>32.6</td>
<td>3</td>
<td>10.4 : 66.0</td>
<td>0.00454</td>
</tr>
<tr>
<td>Listeria monocytogenes</td>
<td>0.305</td>
<td>34</td>
<td>13.8</td>
<td>0.042</td>
<td>25.8</td>
<td>6</td>
<td>10.7 : 48.0</td>
<td>0.00163</td>
</tr>
<tr>
<td>Mycobacterium spp.</td>
<td>0.003</td>
<td>2</td>
<td>33.3</td>
<td>0.001</td>
<td>5.8</td>
<td>2</td>
<td>0.7 : 10.9</td>
<td>0.00017</td>
</tr>
<tr>
<td>Salmonella enterica</td>
<td>51.537</td>
<td>58</td>
<td>6.6</td>
<td>3.374</td>
<td>2.8</td>
<td>43</td>
<td>0</td>
<td>45.6</td>
</tr>
<tr>
<td>Staphylococcus aureus</td>
<td>0.547</td>
<td>29</td>
<td>12.2</td>
<td>0.067</td>
<td>23.8</td>
<td>5</td>
<td>10.3 : 57.7</td>
<td>0.00282</td>
</tr>
<tr>
<td>STEC</td>
<td>1.292</td>
<td>83</td>
<td>2.2</td>
<td>0.029</td>
<td>7.2</td>
<td>9</td>
<td>0</td>
<td>50.0</td>
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<tr>
<td>Yersinia enterocolitica</td>
<td>3.654</td>
<td>15</td>
<td>77.3</td>
<td>2.826</td>
<td>33.9</td>
<td>5</td>
<td>0 : 80.0</td>
<td>0.08341</td>
</tr>
</tbody>
</table>

(n): number of data used to calculate the mean value, \(\text{min}\) minimal value, \(\text{max}\) maximal value, * estimated value, considering that C. botulinum and C. perfringens have the same biological characteristics, notably in their digestive origin. Thus, the prevalence of C. botulinum may be considered similar to the prevalence of C. perfringens.

Salmonella enterica is characterized by the highest non-control ratio (1.19223), before Campylobacter spp. (0.27756) and Yersinia enterocolitica (0.08341).

Discussion

Information regarding the prevalence rates for hazards on pork carcasses and the occurrence of the clinical disease they induce in humans is needed to assess risks due to pork consumption. However, although many hazards have a huge impact on public health, such information is not yet available, mainly because of the cost and difficulties of detection of these hazards in food. Moreover, even when enough information is available to calculate mean rates of prevalence or incidence, and when it is obtained with sensitive and efficient methods, the range of available values is often huge. This variation may be due to differences in: i) sensitivity of analytical methods, ii) recording of clinical cases, or also iii) actual incidence of clinical cases in humans in the area or country. Consequently, the incidence of some hazards may be underestimated, particularly when the hazard mainly result in isolated cases.

Evaluation of the non-control of hazards at and after meat inspection was considered both according to the presence of the hazard on pig carcasses, and to the incidence of clinical cases induced by pork consumption. This evaluation overlooks the effects of pork processing and such an approach may therefore be considered as a first step in evaluation. The secondary contamination of pork after meat inspection and before consumption is indeed not quantitatively assessable.
Conclusion

This study demonstrated that hazards with high rates of incidence due to pork consumption (I_pork) are those which have the highest non-control ratios. Such a result should lead to changes in meat inspection methods to take account of hazards which cannot be detected by macroscopic examination of carcasses. Consequently, to reduce the human exposure to these hazards, either a reduction of their prevalence in pigs entering the slaughterhouse or a carcass sampling design to identify their presence by analytical tools are needed. However, given that systematic sampling to look for all main hazards is not reasonably feasible, the assessment of on-farm existing pre-harvesting information and/or a dedicated on-farm pre-harvesting sampling protocol for laboratory analyses seem to be useful.

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References