Likelihood of introducing selected exotic diseases to domestic swine in the continental United States of America through uncooked swill

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Summary
To help policy makers determine the need for current regulations (which require cooking of swill prior to feeding to swine), an assessment of the likelihood of exposing domestic swine in the continental United States of America (USA) to selected foreign animal disease agents by feeding uncooked swill was carried out.

The hazard was assumed to originate from contraband food items entering the USA and subsequently being discarded in household waste. Such food waste may be collected by licensed waste feeders and fed to swine.

This study showed that, of the four diseases studied, the probability of exposure was highest for the classical swine fever (hog cholera) virus. The median annual likelihood of one or more contaminated loads of swill being fed to swine in the continental USA was estimated as follows:
- classical swine fever virus: 0.063
- foot and mouth disease virus: 0.043
- swine vesicular disease virus: 0.005
- African swine fever virus: 0.005.

Keywords

Introduction
In the United States of America (USA), any person who feeds swill (food waste) to swine from a source other than his own household requires a state or federal government licence. In addition, the swill must be cooked prior to feeding it to the animals. These regulations are mandated by the Swine Health Protection Act of 1980. Regulatory personnel inspect swill feeding operations regularly to ensure that the pigs are healthy and that the facility complies with regulations.

The Act was designed to prevent transmission of certain animal diseases to and among swine through swill. At the time the legislation was introduced, it was assumed that pigs were likely to be exposed to foreign disease agents through swill. This assumption was based on epidemiological investigations of swine disease outbreaks in various locations around the world. However, no formal risk assessment was conducted at that time. More recently, questions have arisen about whether swill, if not cooked specifically for the purpose of swine health safety, is really a hazard to swine. In 1994, the Animal and Plant Health Inspection Service (APHIS) of the United States Department of Agriculture (USDA), Veterinary Services division conducted a quantitative risk assessment to determine the likelihood of exposing swine in the USA to agents of selected diseases through the feeding of uncooked swill. This information could then be used to help evaluate the value of current cooking requirements.
Materials and methods

The risk assessment focused on the risk to swine in facilities which were licensed under the 1980 Swine Health Protection Act. Although all facilities are currently required to cook swill prior to feeding, this assessment estimated the likelihood of swine exposure if swill were fed without being specifically processed on-farm to kill possible disease agents.

Four swine diseases not present in the USA were examined, as follows:
- foot and mouth disease (FMD)
- swine vesicular disease (SVD)
- classical swine fever (CSF) (hog cholera)
- African swine fever (ASF).

This selection was based on historical evidence of disease spread through swill and on world-wide prevalence. As the agents of these diseases are not present in the USA, swill originating from domestic products does not present a hazard. Products of concern are those which can harbour the agents and which enter the USA from countries where the agent is present. A certain proportion of these products are assumed to be contaminated. For transmission to occur, portions of these products must then be discarded and subsequently presented to swine. The assessment evaluated the probability of each of these steps occurring and the overall likelihood of contaminated swill being presented to swine.

Products of animal origin may enter the USA in several ways. Legal importation of products may occur under controlled circumstances. Illegal importation of food items of animal origin (contraband) also occurs. Products which are contaminated with agents of these diseases may enter the USA through legal imports, but the probability is estimated to be low (4) due to the regulation of such products. Contraband may enter the USA through a variety of methods. This assessment focused specifically on contraband introduced by travellers through established ports of entry and on items sent through the mail. The quantity of contraband entering through channels other than ports of entry and mail could not be estimated reliably due to a lack of data. Qualitative assessment indicated that these channels account for a relatively small quantity of contraband, therefore these were excluded from the quantitative assessment.

It was assumed that contraband would be discarded exclusively in waste from households. Most frequently, contraband is brought into the USA for personal use by individuals or families. Waste from other facilities (e.g. restaurants) is more likely to contain food items which were acquired legally from a common source, and is unlikely to include individual pieces of contraband food.

Figure 1 illustrates potential pathways for exposure of swine in the USA to agents of these foreign animal diseases through swill. For the risk assessment, the probability at each branch of the scenario tree was estimated and used to calculate the overall likelihood of exposure through contaminated contraband.

A nested binomial model was used to estimate the probability of one or more instances of contaminated swill being presented to swine annually (4). Given the uncertainty of the exact value of some input variables, these input variables were modelled as probability distributions and stochastic simulation was used to combine the variables into an output distribution of likelihood estimates. The simulations were performed using @RISK® commercial software. Simulations were run for each of the four disease agents. Each iteration...
represented one year, and used Monte Carlo modelling to select values from the input distributions. The result reported was the estimated annual likelihood that contaminated contraband would be present in swill fed to swine. Two thousand iterations were run for each disease agent, and the results were summarised using percentile values and cumulative density functions. The summary of results from multiple iterations illustrates the probability of the estimated likelihood of exposure to these agents falling within certain bounds, as well as the uncertainty of that estimated likelihood.

To determine the probability that swine will be exposed to contaminated contraband in one year through swill from households, values must be obtained or estimated for the following:

a) Quantity of contraband entering the continental USA annually which may eventually be present in swill fed to swine.

b) Proportion of contaminated contraband, based on:
   - prevalence of disease in the country of origin
   - type of contraband
   - survival time of the agent
   - processing of product.

c) Processing which may occur in the household prior to discard, affecting survival of agent.

d) Quantity of food for human consumption in households in the continental USA per year which is suitable for swine feeding.

e) Ratio of the quantity of contaminated contraband in the USA to the total quantity of food for human consumption in households.

f) Ratio (R) of contaminated contraband to all food in waste. Assume that contraband may be discarded at the same rate as other foods, or less frequently, so that swill may have the same ratio of contaminated contraband to total tonnage as in food, or the ratio may be lower.

g) Quantity of swill fed by swill feeders.

h) Number of loads of swill fed to swine annually.

i) Probability that one or more loads of swill fed to swine annually will contain contaminated contraband.

**Input value estimates**

Table 1 illustrates the input values used to estimate the annual likelihood that CSF virus will be present in swill fed to swine in the USA. It is presented as an example of the calculations performed for each of the four disease agents.

It should be noted that there are some differences between the example seen in Table 1 and the model used to estimate the likelihood of exposure. Most importantly, the model used distributions as input values in some cases, rather than single point estimates. The spreadsheet presented allows only a single point estimate (usually the mean value) to be used in a single iteration. Using distributions and running many iterations allowed a more accurate portrayal of input values where the precise value was unknown, and produced a distribution of outcome likelihood estimates, rather than a single point estimate as shown in this example.

**Quantity of contraband entering the continental United States of America annually**

The estimate of how much foreign food of animal origin enters the continental USA illegally every year, by type and country of origin, was derived in three parts, namely:

- estimation of the quantity of contraband intercepted at ports
- identification of the origins and types of products intercepted
- estimation of the quantity of contraband food missed at ports, which therefore entered the USA.

The total quantity of contraband animal products intercepted at international airports, seaports, land border ports and mail facilities during 1993 was obtained from USDA/APHIS/Plant Protection and Quarantine (PPQ). To determine the origin and type of contraband intercepted, a questionnaire (4) was administered to PPQ officers who work at major international airports. The questionnaire requested information on the quantities, type and origin of contraband materials intercepted annually. The results of the questionnaire were used to estimate the amount of contraband from each country belonging to each commodity type (pork, beef, etc.).

Several studies have been conducted to estimate the effectiveness of efforts to prevent entry of contraband food in personal baggage at airports. The USDA Program Planning and Development, Evaluation Services Division began data collection for an evaluation of Mediterranean fruit fly (Medfly) exclusion initiatives in 1993 (USDA, unpublished data), and in 1989 the USDA Agricultural Research Service completed a study which evaluated the effectiveness of different screening methods for contraband recovery (T.F. Schatzki, unpublished findings). These studies indicate that between 50% and 90% of contraband food of animal origin in passenger baggage escapes interception by PPQ personnel. This information, and the data described above, were used to estimate the amount, origin and type of contraband items of animal origin which were not detected at ports of entry. The amount of contraband entering the continental USA was estimated to be between 450,000 and 4 million kg annually.

**Proportion of contraband which is contaminated upon entry into the United States of America**

The proportion of contaminated contraband was calculated in several steps. The likelihood that a product was contaminated...
Table I
Examples of input values used in the assessment for classical swine fever (hog cholera) virus

<table>
<thead>
<tr>
<th>Annual amount</th>
<th>Distribution</th>
<th>Min.</th>
<th>Max.</th>
<th>Most likely value or point estimate</th>
<th>Single iteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Contaminated contraband in the USA</td>
<td>Uniform</td>
<td>450,000</td>
<td>4,000,000</td>
<td>2.2E+06 kg</td>
<td></td>
</tr>
<tr>
<td>Likelihood contaminated</td>
<td>Multiple triangular, with weights</td>
<td></td>
<td>0.0237</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Still infected after handling in house</td>
<td>Point</td>
<td>0.15</td>
<td>0.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amount of contaminated contraband/year</td>
<td>Output</td>
<td>1,598</td>
<td>14,150</td>
<td>7.893 kg</td>
<td></td>
</tr>
<tr>
<td>Contaminated waste</td>
<td>Point</td>
<td>1.24E+11</td>
<td>1.24E+11 kg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio contaminated contraband: domestic in food</td>
<td>Point</td>
<td>1.14E−07</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ratio contaminated contraband: domestic in waste</td>
<td>Uniform</td>
<td>0</td>
<td>1.14E−07</td>
<td>3.16E−08</td>
<td></td>
</tr>
<tr>
<td>Annual probability that contaminated swill is fed to swine</td>
<td>Uniform</td>
<td>3.46E+06</td>
<td>3.52E+06</td>
<td>3.45E+06 kg</td>
<td></td>
</tr>
<tr>
<td>Weight of load</td>
<td>Triangular</td>
<td>0.06</td>
<td>3</td>
<td>1.36 kg</td>
<td></td>
</tr>
<tr>
<td>Number of loads fed per year</td>
<td>Output</td>
<td>1.13E+06</td>
<td>4.38E+07</td>
<td>2.54E+06</td>
<td>0.0776</td>
</tr>
<tr>
<td>Probability that one or more contaminated loads are included in swill fed to swine annually: output based on median of all distributions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

with an agent was assumed initially to be equal to the prevalence of the disease in the species in the country of origin. Further adjustments were then made to reflect product type and handling (4).

Data from the Office International des Epizooties (OIE) (1) were used, along with input from USDA/APHIS/International Services representatives, to estimate the disease status for the four diseases in each country identified as a source of contraband food items. Countries were grouped by prevalence of disease. Estimations of prevalence were made as follows:

- low prevalence countries: 0-0.001 (with the most likely value set at 0.0005)
- medium prevalence countries: 0.001-0.05 (with the most likely value set at 0.03)
- high prevalence countries: 0.05-0.2 (with the most likely value set at 0.1).

The proportion of contraband intercepted from each country was estimated using information from the Contraband Interception Survey (4). These data were used to estimate the proportion of contraband products entering the USA from countries at each prevalence level.

A literature review was completed to determine which products were capable of carrying each disease agent, and how long the agent could be expected to survive in the product (4). If a product could not carry the agent, the proportion contaminated for that product was set to zero. If the agent could be expected to survive in the product for fourteen days, it was assumed that the agent could survive long enough to complete transit to swine in the USA, and the likelihood of contamination was assumed to be equal to the prevalence in the country of origin.

Processing techniques (such as sausage-making) were evaluated for the effect on survival of agents. CSF, SVD and ASF agents can survive many types of processing methods and therefore it was assumed that such processing was sufficient to inactivate the virus in only 0% to 25% of contaminated samples. On account of the sensitivity of the FMD virus to acidity, inactivation of the virus in 50% of FMD-contaminated items was assumed as a result of processing in the country of origin.

Processing which may occur in the household
The likelihood of the disease agent in question surviving handling in a household was also evaluated: products may be cooked or otherwise handled in such a manner that the disease agent would be inactivated. An assumption was made that in 85% of the contaminated products, the agent would be inactivated by household processing prior to being discarded. Therefore, 15% of the originally contaminated contraband would still carry the agent.

Quantity of food in households
Data on the quantities and type of food consumed in the continental USA were obtained (2). In 1990, considering only those commodities which might potentially be fed to swine, about 1.6E+11 kg of food were consumed in the continental USA. Food consumed at home constitutes 55% of food expenditures. Assuming that food consumed at home costs half as much as food consumed away from home, 77.5% of food or 1.24E+11 kg were consumed in households.
Ratio of contaminated contraband to total food in households

The proportion of food consumed in the household which could be contaminated contraband was estimated using the distributions described above.

Ratio of contaminated contraband to total food in waste discarded from households

Contraband food items were assumed to be discarded at a rate equal to or less than domestic food products, due to their desirability. If contraband were discarded at a rate equal to that of domestic food, the proportion of waste which could be contraband would be equal to the proportion of food that could be contraband (estimated above). This was assumed to be the maximum proportion of USA swill which could be contraband. The minimum proportion of USA swill which could be contraband was estimated to be 0, assuming that contraband food items are preferentially eaten and none are discarded.

Quantity of swill fed

A questionnaire was administered to licensed producers who feed swill to swine. The questionnaire requested information on the amount of swill fed to swine, the general source and relative composition. The components (e.g., amount of pork or beef) of products such as 'plate waste' were estimated using information about the amount of such products eaten by consumers in the USA annually (2). Approximately 2,500 people who fed swill to swine were targeted for the survey; approximately 2,400 questionnaires were returned with data which could be used (4).

The amount of household swill fed to swine in the continental USA in 1993 was estimated to be approximately 3.4 million kg to 3.5 million kg per year (4).

Number of loads of swill fed

Swill is not a homogenous solution but rather a collection of disparate food items in various states of decomposition. To model the feeding of swill to swine required some assumptions to be made regarding a representative unit of waste, termed a 'load'.

For this study, swill feeding was modelled as a sampling problem, using a binomial distribution in which the exponent (or sample size) was the number of loads of swill fed to swine. Given the wide variety of waste items which could potentially be fed to swine, it was difficult to define clearly the exact composition of a load of swill. Since the primary focus of the study was the contaminated contraband which could enter the waste food stream, a load was defined in terms of the average weight of contraband food items intercepted per person at airports. Defining a load in this way allowed the swill feeding process to be modelled in terms of swine sampling among discrete waste units (loads). The probability of the swine sampling (i.e. being fed) a contaminated waste product could then be estimated based partly on the proportion, by weight, of contraband items among all swill fed.

Contraband food items intercepted at airports weighed between 0.08 kg and 3 kg; the average weight was about 1 kg (3). These values were used to create a triangular distribution describing the size of a load. The use of this distribution helped to account for the uncertainty inherent in defining a representative load of swill fed to swine.

Applying this distribution of load size to all swill fed to swine, an estimate of between 1 million and 44 million loads of swill are fed annually to swine in the USA.

Likelihood of contaminated loads being included in swill

The likelihood that one or more contaminated loads were included in the swill fed to swine annually can be estimated using the formula:

\[ 1 - (1 - R)^{\#loads} \]

where R is the ratio of contaminated contraband to domestic food in swill.

Results

The models were used to estimate the probability of swill-fed swine being exposed to at least one load of swill containing contraband contaminated with an agent of one of the four diseases within a period of one year. The 50 and 95 percentile likelihood of exposure estimated by the models are reported for each disease agent (Table II). The 50 percentile column shows the probability value at which 50% of the iterations estimated the likelihood to be less than that value, and 50% returned results where the likelihood was higher. The 95 percentile value is the probability value at which 95% of the iterations returned results where the likelihood was less than that value.

<table>
<thead>
<tr>
<th>Disease</th>
<th>50 percentile likelihood predicted</th>
<th>95 percentile likelihood predicted</th>
</tr>
</thead>
<tbody>
<tr>
<td>Classical swine fever (hog cholera)</td>
<td>0.063</td>
<td>0.34</td>
</tr>
<tr>
<td>Foot and mouth disease</td>
<td>0.043</td>
<td>0.20</td>
</tr>
<tr>
<td>African swine fever</td>
<td>0.005</td>
<td>0.03</td>
</tr>
<tr>
<td>Swine vesicular disease</td>
<td>0.005</td>
<td>0.03</td>
</tr>
</tbody>
</table>
Analysis indicated that the CSF virus was the agent most likely to contaminate swine through uncooked swill. The median likelihood of exposure to CSF virus by feeding household-origin swill in the continental USA was estimated to be approximately 0.063 annually.

Cumulative density functions (CDF) illustrate the distribution of the annual likelihood of exposure estimated for the four disease agents (Figs 2, 3 and 4).

Due to international travel patterns and the world-wide prevalence of the four diseases examined, the likelihood of exposure to CSF or FMD agents was higher than the likelihood of exposure to the agents of ASF or SVD. The sensitivity of the FMD agent to acidity effectively decreases the threat from that agent in some products, such as fresh meats, which somewhat reduces the likelihood of exposure to the FMD agent. The swine viruses are generally hardy viruses, and therefore of these four agents, the CSF virus is the most likely to be introduced to domestic swine in the USA through the feeding of uncooked swill. Likelihood estimates for the ASF and SVD agents were the lowest, and results for both agents were virtually identical.

Swill from sources which have no contact with imported products would not be contaminated and therefore producers feeding only those products would not introduce one of the four diseases to their swine.

Given the relatively high likelihood of exposure estimates for CSF and FMD, the question arises as to why there have been no reported cases in the USA of CSF or FMD since 1976 and 1929, respectively. Many factors enter the process preceding animal infection and reported clinical disease. These factors include: likelihood of contamination of legal imports, on-farm cooking, effects of storage (temperature, pH, etc.), infective dose, host susceptibility, on-farm disease transmission, and clinical disease detection and reporting. This analysis considered only the likelihood of swine being exposed to the four agents through contaminated swill of household origin.
Conclusions

This assessment documented the likelihood of exposing domestic swine in continental USA to a foreign animal disease agent through the feeding of uncooked swill from households. The hazard was assumed to originate from contraband products; the possible hazard originating from legal imports is not discussed in this paper.

A large amount of food of animal origin enters the USA illegally as contraband every year, from countries in which animal diseases exist which are foreign to the USA. There is a potential for such contraband to be contaminated with disease agents, and to be included in food waste from private households which is subsequently fed to swine. Based on the likelihood of exposure estimated by the model, swill from some sources may indeed present a risk of exposing swine to agents of foreign diseases, and it is practical to regulate the feeding of swill from such sources.

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Probabilidad de transmisión de algunas enfermedades exóticas al cerdo doméstico a través de desechos líquidos no procesados en el área continental de Estados Unidos de América

B. Corso

Resumen
Con el fin de ayudar a las autoridades responsables a evaluar la pertinencia del reglamento actual (que exige cocer los desechos líquidos antes de alimentar con ellos a los cerdos), se llevó a cabo una estimación de la probabilidad de que los cerdos domésticos del territorio continental de Estados Unidos de América se vean expuestos a una selección de patógenos exóticos a resultas del consumo de desechos líquidos no procesados.

Se partió de la premisa de que el origen del peligro residía en productos alimentarios introducidos de contrabando en Estados Unidos y eliminados luego junto al resto de basuras domésticas. Fabricantes autorizados pueden después recoger estos residuos y transformarlos en alimento para cerdos.

El estudio puso de manifiesto que, de las cuatro enfermedades examinadas, la probabilidad de exposición más alta correspondía al virus de la peste porcina clásica. En el área continental de Estados Unidos, la probabilidad anual mediana de que los cerdos ingieran uno o más suministros contaminados de desechos se estimó en las siguientes cifras:

- virus de la peste porcina clásica: 0,063;
- virus de la fiebre aftosa: 0,043;
- virus de la enfermedad vesicular porcina: 0,005;
- virus de la peste porcina africana: 0,005.

Palabras clave
Alimentación a base de basura doméstica - Desechos líquidos - Enfermedad vesicular porcina - Estados Unidos de América - Evaluación de riesgos - Fiebre aftosa - Peste porcina africana - Peste porcina clásica.

References