Toxoplasma gondii: Controlling the Public Health Risk from Pork

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Toxoplasma overview

Protozoan which causes birth defects and abortion in humans, death in the immuno-compromised due to recrudescent infections and occasionally clinical disease in healthy adults.

- Transplacental transmission to the fetus can result in miscarriage, stillbirth, or congenital infection
- Toxoplasmosis is a major opportunistic infection in the immuno-compromised (second most common infection of the CNS) and generally results from reactivation of latent infections
- Clinical toxoplasmosis is rare in healthy adults, but does occur in the form of lymphadenopathy, chorioretinitis, encephalopathy or meningoencephalitis
Human Toxoplasmosis

In the United States:

- Up to 1.5 million new cases occur each year, correlating with a prevalence in the population of > 20%
- *Toxoplasma* is the third leading cause of death due to foodborne illness in the United States
- The cost of human toxoplasmosis ranges as high as $5.3 billion annually

Worldwide:

- Up to 1/3 of population worldwide and up to 80% in France.
Estimated Deaths by Known Foodborne Pathogens

Listeria and Toxoplasma gondii account for almost 50% of total.

- Toxoplasma 20.7%
- Listeria 27.6%
- Other 51.7%

Source: Centers for Disease Control and Prevention, National Center for Infectious Diseases, "Food-Related Illness and Death in the United States," Emerging Infectious Diseases, Vol. 5, No. 5 (1999), Table 3.
Source of Infection to Humans

• The Centers for Disease Control estimate that 50% of human infections are foodborne
  • Data from age distribution of infection, groups who do not eat certain meats and genotyping support this assumption
• Of the meat animal species, only pork is known to harbor *Toxoplasma*

However,

• No currently available test can differentiate infections caused by oocysts, produced by cats, or tissue cysts, which would be ingested in meat
Nevertheless, consumer advocacy groups have highlighted foodborne toxoplasmosis as a source of miscarriage in humans.

Protect Your Unborn Baby: Important Food Safety Information to Help Avoid Miscarriage

According to the Centers for Disease Control and Prevention (CDC), each year *T. gondii* infections due to eating contaminated meats and unwashed fruits and vegetables sicken about 112,500 and kill about 375 Americans. In addition, congenital toxoplasmosis, where the parasite is transmitted from the pregnant woman to her fetus, is estimated to cause mental retardation and blindness in as many as 400 to 6,000 children and may kill another 80 fetuses and newborns each year. Because *T. gondii* can cause such severe problems, toxoplasmosis accounts for $3.3 billion to $7.8 billion per year in economic costs. The government ranks it as one of the most expensive forms of food poisoning.
Toxoplasma Infection in Livestock and Poultry
Toxoplasma gondii

- ~0.8% of market weight and 5-10% of breeder pigs in confinement are known to harbor *T. gondii*; prevalence rates in pigs in non-confinement systems may exceed 50%

- Prevalence rate in market weight pigs dropped from 3% to 0.8% in 10 years (1990 to 2000 NAHMS); confinement raised pigs show even lower prevalence rates
Recent Prevalence Data for *Toxoplasma* in U.S. Hogs

<table>
<thead>
<tr>
<th>State</th>
<th>No. tested</th>
<th>No pos.</th>
<th>% pos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Connecticut</td>
<td>383</td>
<td>219</td>
<td>57.2</td>
</tr>
<tr>
<td>Massachusetts</td>
<td>817</td>
<td>398</td>
<td>48.7</td>
</tr>
<tr>
<td>New Hampshire</td>
<td>95</td>
<td>34</td>
<td>35.8</td>
</tr>
<tr>
<td>Rhode Island</td>
<td>157</td>
<td>90</td>
<td>57.3</td>
</tr>
<tr>
<td>Vermont</td>
<td>445</td>
<td>159</td>
<td>35.7</td>
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</tbody>
</table>

Gamble et al. 1998
## Recent Prevalence Data for *Toxoplasma* in U.S. Hogs

<table>
<thead>
<tr>
<th>State</th>
<th>Source</th>
<th>No. tested</th>
<th>No pos.</th>
<th>% pos.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Illinois</td>
<td>Sow slaughter</td>
<td>3498</td>
<td>723</td>
<td>20.7</td>
</tr>
<tr>
<td>Indiana</td>
<td>PRV samples</td>
<td>3646</td>
<td>1574</td>
<td>43.2</td>
</tr>
<tr>
<td>New Jersey</td>
<td>PRV samples</td>
<td>1504</td>
<td>498</td>
<td>33.1</td>
</tr>
<tr>
<td>Pennsylvania-1</td>
<td>Market hogs</td>
<td>2755</td>
<td>122</td>
<td>4.4</td>
</tr>
<tr>
<td>Pennsylvania-2</td>
<td>Market hogs</td>
<td>3900</td>
<td>54</td>
<td>1.4</td>
</tr>
<tr>
<td>Ohio</td>
<td>Market hogs</td>
<td>567</td>
<td>3</td>
<td>0.5</td>
</tr>
<tr>
<td>Iowa-1 (hoops)</td>
<td>Market hogs</td>
<td>1319</td>
<td>88</td>
<td>6.7</td>
</tr>
<tr>
<td>Iowa-2</td>
<td>Market hogs</td>
<td>8326</td>
<td>12</td>
<td>0.14</td>
</tr>
</tbody>
</table>
Toxoplasma gondii

- It has been estimated that foodborne infections may account for up to 50% of human toxoplasmosis in the U.S.
- Little information exists on the actual occurrence of *T. gondii* in meat other than pork (or pigs) in the U.S.
National Retail Meats Survey for *Toxoplasma gondii*

A three year study to determine the risk to the U.S. consumer of purchasing meat (beef, pork, chicken) containing viable *T. gondii* tissue cysts from the retail meat case.
National Retail Meats Survey for *Toxoplasma gondii*

Survey of 28 metropolitan statistical areas (MSAs), each representing ~8 million people and covering 80% of the U.S. population.
Population and sample size estimates by region

<table>
<thead>
<tr>
<th>Region</th>
<th>Population in millions</th>
<th>% of total</th>
<th># MSAs sampled</th>
<th>Required sample # (per commodity)</th>
<th>Actual sample #</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>46.3</td>
<td>21.2</td>
<td>6</td>
<td>475</td>
<td>450</td>
</tr>
<tr>
<td>Midwest</td>
<td>46.6</td>
<td>21.3</td>
<td>6</td>
<td>417</td>
<td>450</td>
</tr>
<tr>
<td>South</td>
<td>72.6</td>
<td>33.2</td>
<td>9</td>
<td>650</td>
<td>675</td>
</tr>
<tr>
<td>West</td>
<td>53.1</td>
<td>24.3</td>
<td>7</td>
<td>475</td>
<td>525</td>
</tr>
<tr>
<td>Total</td>
<td>218.6</td>
<td>100</td>
<td>28</td>
<td>1958</td>
<td>2100</td>
</tr>
</tbody>
</table>
National Retail Meats Survey for *Toxoplasma gondii*

- Stores sampled were selected from a comprehensive list of retail grocery outlets in each MSA:
  - small grocery stores/superettes
  - supermarkets
  - club stores
- A total of 6282 meat samples tested from 28 MSAs, 2094 each of beef, pork, and chicken
National Retail Meats Survey for *Toxoplasma gondii*

- 25 stores surveyed in each MSA; 9 samples collected from each store, no ground product sampled:
  - 3 pork samples-loin, loin chops, center cut loin chop, or tenderloin
  - 3 beef samples-eye round roast, rib roast, rib eye, strip loin, boneless loin, or tenderloin
  - 3 chicken-boneless breasts

- Samples (1kg each (2.2 pounds) minimum, boneless) were selected at the retail outlet using a random number sampling plan. Shipped cold overnight back to Beltsville Lab.
National Retail Meats Survey for *Toxoplasma gondii*

- 6 samples (100 grams from each sample) of each commodity were fed to 1 cat (1 cat samples 2 stores for 1 commodity), remaining meats saved until results of bioassay were determined
- Oocyst shedding was monitored for 14 days after the last feeding; fecal floats bio-assayed in mice
- Additional assays conducted:
  - ELISA using tissue fluids
  - Nested PCR using TgB1 primers
  - Genotyping of positive *Toxoplasma* isolates
  - Using SAG 2 and 5 hyper-variable microsatellite loci.
3 pork* samples, 1 kg each are collected from every store. Samples selected by random number sampling procedure.

100g from each sample are pooled and fed to one cat.

Daily microscopic examination of feces for oocysts:
- If sample positive, visible oocysts.
- If sample negative, no visible oocysts and mouse bioassay negative.

Tissue cysts or tachyzoites demonstrated and bioassayed in mice.

Sample positive:
- Tissue cysts or tachyzoites demonstrated.
- Bioassayed in mice.

Sample negative:
- No visible oocysts and mouse bioassay negative.

50 g pork pepsin digested and bioassayed in mice.

* Same sampling procedure used for chicken and beef.
Results

- All beef samples negative by bioassay and by serology

- All chicken samples negative by bioassay; 1.4% positive by serology (29/2094)

- 0.38% pork samples (8/2094) positive by bioassay; 0.57% positive by serology (12/2094)
### Bioassay positive pork samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>TF ELISA</th>
<th>PCR TgB1</th>
<th>SAG 2</th>
<th>MG</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boston, MA 1</td>
<td>+</td>
<td>-</td>
<td>II</td>
<td>A</td>
</tr>
<tr>
<td>Boston, MA 2</td>
<td>+</td>
<td>-</td>
<td>II</td>
<td>A</td>
</tr>
<tr>
<td>Bergen, NJ 1</td>
<td>-</td>
<td>-</td>
<td>III</td>
<td>D</td>
</tr>
<tr>
<td>Bergen, NJ 2</td>
<td>-</td>
<td>-</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Columbus, OH</td>
<td>+</td>
<td>-</td>
<td>III</td>
<td>B</td>
</tr>
<tr>
<td>San Jose, CA</td>
<td>-</td>
<td>-</td>
<td>I</td>
<td>C</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>+</td>
<td>-</td>
<td>II</td>
<td>F</td>
</tr>
<tr>
<td>Greenville, SC</td>
<td>-</td>
<td>-</td>
<td>II</td>
<td>A</td>
</tr>
</tbody>
</table>
Risk to consumers of purchasing *T. gondii* contaminated pork from U.S. retail stores

<table>
<thead>
<tr>
<th>Region</th>
<th>Minimum likely prevalence, 95%CL</th>
<th>Probability over time 1 year</th>
<th>Probability over time 10 years</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S.</td>
<td>0.38% (8/2094) 0.00165, 0.0075</td>
<td>6.26</td>
<td>47.65</td>
</tr>
<tr>
<td>Northeast</td>
<td>0.89% (4/450) 0.0024, 0.0226</td>
<td>14.09</td>
<td>78.12</td>
</tr>
<tr>
<td>Midwest, South, West</td>
<td>0.24% (4/1644) 0.0007, 0.0062</td>
<td>4.06</td>
<td>33.91</td>
</tr>
</tbody>
</table>

U.S. annual pork consumption 23.5 kg
Summary

• There is a low but measurable level of *T. gondii* in commercially available pork. No measurable risk was found in commercially available beef or chicken.

• Post harvest technologies contribute to the low level of *T. gondii* in pork; ~40-50% of fresh pork is pumped or enhanced.

• Retail meat case temperatures vary widely, and are an under utilized method of control.

• The risk of acquiring contaminated meat as determined in this study is too low to explain the source of most *T. gondii* infections in the U.S.
Conclusion

Exposure to infectious oocysts from cat feces is likely the source of most *T. gondii* infections in the U.S.
Conclusion

A low level of T. gondii in fresh pork suggests that all fresh pork must be assumed to be infected, and should be frozen at 8°F or less before consumption, or thoroughly cooked to an internal temperature of 160°F (no pink); organic/free range pork and chicken must be treated similarly.
Putting flavor back into pork
More and more farmers are stepping up to the plate by raising free-range pigs that deliver better taste
By Alison Arnett, Boston Globe Staff

Wal-Mart Eyes Organic Foods, And Brand Names Get in Line
By MELANIE WARNER (New York Times); Business/Financial Desk
Increasing Popularity of Organic/Free Range Meats

- Organic food sales within the U.S. have enjoyed 17-20% growth for the past few years.

- The Organic Food Production Act of 1990 and the National Organic Program explicitly require that organic meat and meat products must come from animals that have been given access to the outdoors.
The Trouble with Organic/Free Range Meats

The lack of **biosecurity** in organic/free-range pig production systems (non-confinement rearing) results in *Toxoplasma* infection rates in pigs which can exceed 50%
Transmission of *Toxoplasma gondii*
Risk Factors Associated With Transmission of *Toxoplasma* to Pigs


Cats sampled from farms with *Toxoplasma* infected pigs had seropositive rates of 41.9 – 70.7%

Weigel et al. (1995)

*Toxoplasma* infection in swine correlated with evidence of infection in juvenile cats and house mice

Assadi-Rad et al. (1995)

Outdoor housing, small farm size and exposure to cats were risk factors associated with *Toxoplasma* infection
Risk Factors Associated With Transmission of *Toxoplasma* to Pigs

Dubey et al. (1995)

In addition to cats and mice, *Toxoplasma* was found in raccoons, skunks, opossums, rats and other wildlife around infected pig farms.

<table>
<thead>
<tr>
<th>Animal</th>
<th>Percentage Infected</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raccoons</td>
<td>67%</td>
</tr>
<tr>
<td>Skunks</td>
<td>38.9%</td>
</tr>
<tr>
<td>Opossums</td>
<td>22.7%</td>
</tr>
<tr>
<td>Rats</td>
<td>6.3%</td>
</tr>
<tr>
<td>Mice</td>
<td>2.2%</td>
</tr>
</tbody>
</table>
Confinement Farm Study
Introduction

• Pigs raised outdoors can have very high infection rates with *Toxoplasma gondii*
  • 47.5% of pigs tested in outdoor operations in the northeastern United States were infected (Gamble et al., 1999)

• Risks for exposure of pigs to *Toxoplasma* include the presence of oocysts in the environment, feed or water and contact with infected rodents or wildlife

• Confinement management eliminates many of the risks for exposure of pigs to *Toxoplasma*
Confinement Farm Study
Objectives

• To determine the prevalence of *Toxoplasma gondii* infection in pigs raised in confinement management systems

• To determine if targeted interventions can further reduce the risk of exposure of confinement-reared pigs to *Toxoplasma*
Methods

- Testing for *Toxoplasma gondii* infection, using a commercial ELISA, was conducted on a statistical sample of pigs from 58 confinement-type pork production sites.
- An audit of Good Production Practices was conducted on these same farms to identify risks associated with transmission of zoonotic parasites.
- A subset of tested and audited farms were selected for interventions to reduce the risk of exposure of pigs to *Toxoplasma*.
- Testing was conducted through 3 additional production cycles to determine the effect of these targeted interventions.
Results

- A total of 6/58 farms had one or more pigs with antibodies to *Toxoplasma gondii* on initial testing
- Overall prevalence in confinement-raised pigs was 0.14% (12/8434), while prevalence within infected herds was 1.2%
- Production practice audits were conducted on 28 of the 58 pork production sites
  - Cats were present on 5/6 (83.3 %) *Toxoplasma* positive sites and 7/21 (33.3 %) of *Toxoplasma* negative sites; oocysts were recovered from fecal samples and 1/1 cat was seropositive
  - Mice were present on virtually all production sites, although numbers varied; the presence of rodents did not appear to correlate with *Toxoplasma* prevalence
  - Barn-only boots or boot washes were not common practices on any farms visited and were not used on *Toxoplasma* positive farms
Success in Implementation of Good Production Practices

Percent compliance with a 34 point audit of Good Production Practices

<table>
<thead>
<tr>
<th></th>
<th>Pre-intervention audit score</th>
<th>Post-intervention audit score</th>
<th>Percent change</th>
</tr>
</thead>
<tbody>
<tr>
<td>All study farms</td>
<td>56.6</td>
<td>64.8</td>
<td>+14.5%</td>
</tr>
<tr>
<td>Toxoplasma positive study farms</td>
<td>62.6</td>
<td>75.2</td>
<td>+20.1%</td>
</tr>
</tbody>
</table>
Implementation of Boot Hygiene

- 5/6 farms maintained the requested level of boot hygiene during the subsequent production cycles
  - barn only boots used immediately upon entry
  - boots worn in only one barn
  - requirements applied to all workers and visitors
Average *Toxoplasma* Infection Rates for Farms Before and After Interventions
Toxoplasma Prevalence by Individual Farm

<table>
<thead>
<tr>
<th>Audit</th>
<th>Farm A</th>
<th>Farm B</th>
<th>Farm D</th>
<th>Farm H</th>
<th>Farm K</th>
<th>Farm W</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>0.8</td>
<td>0.2</td>
<td>0.6</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>#2</td>
<td>0.7</td>
<td>0.8</td>
<td>0.5</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>#3</td>
<td>0.6</td>
<td>0.7</td>
<td>0.4</td>
<td>0.2</td>
<td>0.2</td>
<td>0.2</td>
</tr>
<tr>
<td>#4</td>
<td>0.5</td>
<td>0.6</td>
<td>0.3</td>
<td>0.1</td>
<td>0.1</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Intervention ↓
Conclusions

- Biosecurity to eliminate entry by cats, rodents, birds or other wildlife, feed security and good sanitation is not sufficient to avoid exposure of pigs to *Toxoplasma*; a low level of infection can still occur.

- Any introduction of organic material is sufficient to initiate *Toxoplasma* infection in pigs.

- Boot hygiene, and related practices that control the movement of animals and people in pork production facilities can further reduce exposure of pigs to *Toxoplasma* if other Good Production Practices are followed.
Toxoplasma will always be a risk as long as cats are maintained in the swine environment; cats shed millions of oocysts and these stages can survive in the environment for months or even years a single oocyst can cause a full blown infection in a pig.
Control Strategies for *Toxoplasma*

- There is no way to test for *T. gondii* at slaughter
  - Bioassay is the only definitive detection method but not suitable for testing pigs
  - MAT or ELISA is impractical and not 100% accurate
- The best way to control infection is by implementation of good production practices in a manner consistent with the *Trichinella* certification program.
- Programs for *Toxoplasma* control could be driven by regulatory authorities or by packers who wish to improve the microbiological quality of their product
Good Production Practices to Reduce Transmission of *Toxoplasma* in Confinement Reared Pigs

- Implement Good Manufacturing Practices for feed and feed ingredients
- Assure the integrity of confinement housing
- Implement and maintain an effective rodent control program
- Maintain good sanitation disposal practices
- Avoid the introduction of organic material from outside swine housing areas through boot/clothing hygiene
Preventing *Toxoplasma* infection on pork production sites
Producers should be educated about the routes of transmission of *Toxoplasma* and the management practices which will reduce risk of infection.
Post-wean pigs should be purchased from sites which meet good production practices for *Toxoplasma*.
Feed should only come from sources that follow good manufacturing practices; feed should be stored so it is inaccessible to rodents.
Elimination of cats and precautions to avoid introduction of soil, potentially contaminated with oocysts, are major steps in preventing exposure of pigs to *Toxoplasma*. 
As with *Trichinella*, good rodent control is key to avoiding potential exposure of pigs to *Toxoplasma*; the true role of mice in transmission is largely unknown.
All efforts should be made to discourage the presence of cats on pork production sites.
In confinement systems, boot hygiene is the most critical element of *Toxoplasma* control; barn-only, or disposable boots should be worn at all times.
Boot dips can be used in addition to barn-only boots as a precaution against introduction of oocysts.
Summary

• Current evidence suggests that pigs are a source of *Toxoplasma* infection in humans
• Pigs become infected primarily from environmental exposure to oocysts shed by cats
• *Toxoplasma* infection in pigs can be prevented if good management/bio-security practices are followed
• Infection risk will be difficult for pigs raised outdoors
• A proactive approach to *Toxoplasma* control will prevent consumer concern regarding this parasite in pork
Additional Research Needs

• Role of water and feed
• Tools to better define the source of human infection
• Additional studies on the potential role of free-range chicken