Toxoplasma gondii in U.S. Swine Operations: An Assessment of Management Factors

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Abstract

Sera from hogs were analyzed using the modified direct agglutination test (MAT). Serum samples were collected from sows which were part of the National Animal Health Monitoring System (NAHMS) swine survey. The blood sera on file represented 394 randomly selected hog farms throughout the United States. Additionally, the NAHMS survey included information on type of production facilities and level of cat, dog, or bird access to the facilities. Of the sows tested 19 percent tested positive for toxoplasmosis.

This study showed a positive relationship between sows or herds testing positive for *Toxoplasma gondii* and three factors: 1) method of rodent control, 2) type of production facility, and 3) access of certain animals (cats, dogs, birds) to production facilities. These data indicate that it will be difficult to eliminate *T. gondii* from swine herds which allow cat or dog access to facilities. Use of cats as a method of rodent control should be discouraged. We found a strong association between use of "bait only" for rodent control and the herd testing negative as compared to the use of "cats only" for rodent control. Greater industry awareness is needed for methods of rodent control through the use of baits. Sows in herds where female replacements were raised internally were significantly more likely to test positive for toxoplasmosis. Sows in confinement facilities had a significantly lower prevalence of *Toxoplasma gondii*. Herds testing positive were significantly smaller than those which were negative. In general, there were not any regional differences in prevalence rates. Sows testing positive did not have a reduced level of productivity.

Introduction

Toxoplasma gondii (*T. gondii*) is a microscopic parasite. Infection with *T. gondii* is termed "toxoplasmosis." *T. gondii* is infectious for both animals and humans. In pregnant women, toxoplasmosis may cause stillbirths, abortions, early infant mortality, blindness, and crippling in children. Similarly for animals, infection may cause abortions, stillbirths, and non-viable offspring among domestic, farm, fur-bearing, and game animals. Reducing the risk of acquiring *T. gondii* directly benefits society through the potential for reduced transmission of toxoplasmosis to humans and animals.

The human illness costs of congenital toxoplasmosis are estimated to range from $368 million to $8.8 billion annually in the United States (Roberts and Frenkel, 1990). About half of the adult human population in the United States has anti-*Toxoplasma gondii* antibodies, indicating previous exposure and infection (Dubey et al., 1991). Handling raw pork or eating undercooked pork is thought to be a major cause of maternal infection which is transmitted to the vulnerable fetus (the child may be born normal, may have or develop visual problems, or be born mentally retarded) (Roberts and Frenkel; Frenkel; Roberts). A study by J.P. Dubey found that 23% of market hogs had positive serum samples for anti-*Toxoplasma gondii* antibodies and infective cysts were isolated from edible pork tissues (Dubey, 1990).

Cats are the definitive hosts for *Toxoplasma gondii*, since all the developmental stages occur in the cat and not in other species. However, all species of birds and mammals can be carriers of *Toxoplasma gondii*. Hogs can become infected by eating oocysts from a contaminated environment (for example, in feed contaminated by cats) or by eating poorly cooked meats that are contaminated (for example, rodents dying in hog pens).

Objective

The overall objective was to study the relationship between anti-*Toxoplasma gondii* antibodies in hogs and farm management practices to control cat and rodent access to hogs.

Procedures

This study was undertaken to obtain further information on toxoplasmosis infection in U.S. swine. Serum samples from individual animals (sows) were first assayed for evidence of *T. gondii* infection using the modified agglutination test. Serologic results were then combined with herd data to evaluate possible associations between farm management practices and *T. gondii* infection. Data on individual sows and their litters allowed analysis of sow productivity.

Data for this study were obtained from a random survey of swine herds conducted by the National Animal Health Monitoring System (NAHMS) during 1989-1990 in 18 states. As part of the survey, a general farm management and policy questionnaire was completed by 1,663 swine producers. The survey included questions on production facilities, biosecurity measures, management practices, pig inventory, etc.

Sow serum samples were collected from 412 of the 1,663 producers. These producers represented 17 states. Blood samples from 10 randomly selected sows were collected from each herd. Serum was frozen at -20 C until assayed by the modified agglutination test (MAT) for antibodies against *T. gondii*. Serum samples were available from 3,473 sows for *T. gondii* antibody tests. A herd was considered positive if one animal tested positive for antibodies against *T. gondii*; a herd was considered negative if 10 animals tested negative. If fewer than 10 sows were tested and all tested negative the herd was not included in herd analysis results.

Herd data and serologic information were used to study the relationships between *T. gondii* infection in sows and specific farm management practices. Two methods were used for analysis: logistical regression and calculation of the odds ratio. Much of the data available for analysis was categorical, i.e., presence or absence of *T. gondii* antibodies, type of swine facilities, type of rodent control, etc. The logistic procedure fits this type of data. Given the presence of a significant relationship, the odds ratio is a measure of the strength of the association between infection and a specific variable.

Results

As shown in Table 1, 19 percent of the sows tested were positive. This varied by state but few conclusions can be drawn between states because of the low number of herds tested in most states. The average sow herd size for the 412 farms was 191 sows.

Information in Table 2 shows the aggregate results for herds which tested positive or negative. A positive herd was a herd which had at least one sow which tested positive. For this analysis 209 herds (51%) tested negative and 203 (49%) tested positive. This analysis included all herds irrespective of the number of sows tested. For further herd level analysis, herds with fewer than 10 sows tested and all tested negative were dropped from the analysis. With fewer than 10 sows tested per herd and all testing negative, the further conclusion that the probability of all sows in the herd testing negative was considered to be too low to be included as a negative herd. Herds with at least one sow testing positive were retained as a positive herd for analysis. Of the 209 herds where all sows tested negative, 88 had fewer than 10 sows tested. This left 121 herds (37%) which tested negative and 203 (62%) which tested positive; or 324 herds.

Information selected for in-depth management strategy analysis were: operation size; swine production facility type; access of dogs, cats, or birds to the production facilities; and rodent control method. Sow replacement method, state and region effects, and sow parity were also evaluated. Two methods were used for variable selection: a) multiple regression was used to assist in identifying variables associated with *Toxoplasma gondii* prevalence and titer levels and, b) literature review and researcher knowledge of the disease epidemiology.

Table 1. Prevalence of *Toxoplasma gondii* antibodies in hogs (sows), by state.

State	Number of Herds	Number of Sows Tested			Prevalence Rate
		Negative	Positive	Total	
Alabama	11	64	33	97	34%
California	27	125	19	144	13%
Colorado	9	79	0	79	0%
Illinois	38	307	42	349	12%
Indiana	45	328	89	417	22%
Iowa	25	191	37	228	16%
Maryland	11	79	19	98	19%
Michigan	33	249	62	311	20%
Minnesota	17	131	18	149	12%
Nebraska	31	235	31	266	12%
N. Carolina	41	296	63	359	18%
Ohio	44	278	102	380	26%
Oregon	21	90	13	103	14%
Pennsylvania	19	103	34	137	24%
Tennessee	9	51	26	77	34%
Virginia	8	47	8	55	15%
Wisconsin	23	138	76	214	36%
TOTAL	412	2795	678	3473	19%

Table 2. Distribution of Herds by Number of Sows Tested, Number of Herds Positive, Negative, and Total Number of Herds Retained for Herd Level Analysis

	Number of Herds			Number Herds Retained				
Number of Sows Tested per Herd	All Sows Tested Negative	At Least One Sow Tested Positive	Total Farms Tested	All Sows Tested Negative	All Sows Tested Negative	At Least One Sow Tested Positive	Total Herds	Average Herd Size
10	121	114	235	241	121	114	235	241
9	27	25	52	218	0	25	25	172
8	6	18	24	195	0	18	18	114
7	8	9	17	115	0	9	9	57
6	14	12	26	56	0	12	12	59
5	6	10	16	47	0	10	10	51
4	3	7	10	108	0	7	7	52
3	8	4	12	20	0	4	4	16
2	10	2	12	57	0	2	2	35
1	6	2	8	46	0	2	2	155
<10	88	89	177		0	89	89	
Total	209	203	412	192	121	203	324	202

Herds were classified by method used for breeding stock replacement. The three possibilities were: raise all replacements, purchase all replacements, and the mixed method (some raised, some purchased). Use of the chi squared distribution test of the farms which raised all sows showed that they were significantly different from those which purchased all replacements. Among herds that raised all replacement females, 65% were positive as compared to 46% of herds that purchased all replacements (Table 3). The percent of positive herds raising all replacements was significantly higher than herds purchasing replacements (chi-square test). Differences in "within herd" prevalence between these two groups are shown, as well. Twenty-six percent of sows from herds raising replacements were positive as compared to 15% of sows from herds where all replacements were purchased.

Table 3. Number of Herds, Herd Size, and Percent Positive and Negative by Type of Sow Replacement Strategies.

Type of Sow Replacement	Number of Herds			Percent of Herds		Average Number Sows per Herd			Number of Sows Tested			Percent of Sows	
	Total	Pos.	Neg.	Pos.	Neg.	Total	Pos.	Neg.	Total	Pos.	Neg.	Pos.	Neg.
All Raised[a]	226	147	79	65%	35%	182	151	240	2,034	521	1,513	26%	74%
All Purchased[b]	48	22	26	46%	54%	316	174	437	446	65	381	15%	85%
Mixed[c]	34	23	11	68%	32%	180	93	363	321	55	266	17%	83%
Total	308	192	116	62%	38%	203	147	295	2,801	641	2,160	23%	77%

[a]All replacement females selected from the herd.

[b]All replacement females are purchased and brought into the herd.

[c]Some replacement females are selected from the herds and some are purchased.

Herd size was also significantly different between positive and negative herds (t-test).

Positive herds were significantly smaller than negative herds. Positive herds were smaller for all three replacement strategies: 151 sows vs. 240 sows for raised replacements; 174 vs. 437 sows for purchased replacements; and 93 vs. 363 sows for mixed replacement strategies. The positive herds averaged 147 sows, while the negative herds were double that size or 295 sows.

For facility analysis, herds were placed in one of three categories by facility type: total confinement, open buildings, or no buildings (Table 4). Herds with mixed facilities were classified according to the lowest level of confinement. For example, herds with some confinement and some open building facilities were considered "open building herds."

Facility type had an impact on the *Toxoplasma* status of herds. Herds in "no building" and "open building" categories had a significantly higher percent of herds test positive than did the total confinement operations. Approximately half of the total confinement herds were positive as compared to 70% of the "open building" or "no building" herds. A higher percent of the sows from open building (27%) and no building (26%) herds were positive as compared to the total confinement systems (18%). As with the sow replacement comparison, herd size was again a strong factor. Negative herds with total confinement averaged 402 sows, compared to 219 for the "open building" and 110 for the "no building" herds. The positive herds for both total confinement and open building systems were significantly smaller than were the negative herds for the respective systems.

Table 4. Number of Herds, Herd Size, and Percent Positive and Negative by Type of Housing.

Type of Swine Housing	Number of Herds			Percent of Herds		Average Number Sows per Herd			Number of Sows Tested			Percent of Sows	
	Total	Pos.	Neg.	Pos.	Neg.	Total	Pos.	Neg.	Total	Pos.	Neg.	Pos.	Neg.
Total Confinement[a]	126	66	60	52%	48%	278	164	402	1,194	215	979	18%	82%
Open Building[b]	122	85	37	70%	30%	151	121	219	1,079	288	791	27%	73%
No Building[c]	60	41	19	68%	32%	152	171	110	528	138	390	26%	74%
Total	308	192	116	62%	38%	203	147	296	2,801	641	2,160	23%	78%

[a]All swine facilities are total confinement - enclosed.
[b]Some swine facilities are open building - not totally enclosed.
[c]Some swine facilities are pasture or hut facility.

Cat, dog, or bird access to swine production facilities was based on producer response to the respective NAHMS survey questionnaire. The question on access was asked for all phases of production. For the analysis, cats, dogs, or birds were considered to have access if they had access to at least one production phase. No access reflected that cats, dogs, or birds did not have access to facilities in any of the production phases.

Odds ratios were used to determine the strength of the association between facility types and herd toxoplasmosis status, and between method of rodent control and herd status. Logistic regression was used to test for the sign and level of significance. Information on significant farm management strategies and production systems, as they relate to the level of *T. gondii* in swine herds, are presented in Tables 5 and 6. For both the odds ratio and the logistic regression the items compared are described in the table. For example, in the first comparison of Table 5, open

housing is compared to total confinement. Additionally, Table 5 includes herds which raised all female replacements. For purchased female replacements information was not available on types of facilities they were raised in.

Information from comparisons evaluating the effect of different types of facilities on infection status provide further evidence that total confinement operations had a lower probability of being positive for *T. gondii*. For example, in the first comparison (open housing vs total confinement) the odds ratio (OR) was 0.57. The interpretation is that the probability that a total confinement herd was positive was 57% of the probability of a herd with open housing being positive for *T. gondii*. Or, stated another way, herds with open housing were 1.75 (1/0.57) times more likely to test positive for *T. gondii* than herds in total confinement facilities. Similarly, total confinement operations were less likely to test positive for *T. gondii* than operations with no buildings (OR = 0.452). A comparison of no building vs. open building herds found no significant difference in terms of the probability of being positive for *T. gondii*.

The lower two-thirds of Table 5 presents an assessment of the impact of specific management measures on herd infection status. The access of dogs or birds to production facilities had a positive relationship to a herd testing positive for *T. gondii*. Operations with dog access were 1.81 times (OR = 0.552) more likely to test positive while those with bird access were 3.84 times (OR = 0.263) more likely to test positive.

The lack of significance between cat access and *T. gondii* was surprising since cats are recognized as the "definitive host" of *T. gondii*. On the other hand, an analysis of type of rodent control relative to herd status suggested a link to cats. Specifically, herds using bait as the only method of rodent control were 2.6 times more likely to test negative for *T. gondii* than herds using other methods or combinations of methods. Herds using only bait compared to those using only cats for rodent control were 6.1 times more likely to be negative. Alternatively, herds using only cats were 3 times (1/0.33) more likely to be positive when compared to all other methods or combinations of rodent control.

Analysis of herd management strategies for operations with total confinement facilities shows similar results (Table 6). Here again, operations with cat, dog or bird access were more likely to test positive for *T. gondii*. Information presented in Table 6 provides a similar comparison to that of Table 5, except Table 6 consists only of herds with total confinement housing. This includes herds that purchase replacement females, as well as herds that raise all replacement females or have a mixture of raised as well as purchased females. Again, the access of dogs or birds to production facilities is associated with *T. gondii* infection. Overall, the access of cats was just marginally positively related in this particular comparison. The use of bait only as a means of rodent control significantly reduced the likelihood of the herd having a positive *T. gondii* test, while the use of cats only significantly increases the chances of having a positive test.

Individual sow information was available for those participants who provided individual sow diary card information. This information was available for the farrowing period. Data from sow diary cards and individual sow *Toxoplasma gondii* blood test were merged. There were 322 herds which had both and there were 2018 sows which had blood test information and a sow diary card providing productivity information on the same sow. After extensive analysis, accounting for such factors as cross-fostering of pigs, and analysis of productivity

Table 5. Analysis of Herd Level Farm Management Strategies and *T. gondii* Tests for Herds with Raised Female Replacements

Comparison Item	Number of Farms			Odds Ratio	95%		Chi-Square test	Logistic Regress.
	Total	Pos.	Neg.		Lower bound	Upper bound		
Open Housing vs. Total Confinement								
Total farm	180	113	67	0.57	0.309	1.049	0.07	(+)***
Total confinement farm	89	50	39					
Open housing farm	91	63	28					
No Building vs. Total Confinement								
Total farm	135	84	51	0.452	0.209	0.982	0.044	(+)***
Total confinement farm	89	50	39					
No building farm	46	34	12					
No Building vs. Open Housing								
Total farm	137	97	40	0.797	0.358	1.758	0.569	
Open housing farm	91	63	28					
No building farm	46	34	12					
Dogs Access vs. Not Access								
Total farm	198	134	64	0.552	0.293	1.039	0.064	(+)***
Dogs not access farm	60	35	25					
Dogs access farm	138	99	39					
Cats Access vs. Not Access								
Total farm	213	142	71	0.755	0.332	1.807	0.554	
Cats not access farm	26	16	10					
Cats access farm	187	126	61					
Birds Access vs. Not Access								
Total farm	226	147	79	0.263	0.093	0.741	0.007	(+)*
Birds not access farm	17	6	11					
Birds access farm	209	141	68					
Bait and Cats vs. All Others[(a)]								
Total farm	226	147	79	0.936	0.506	1.73	0.836	
All others[(a)]	209	133	62					
Bait and cats	17	14	17					
Bait Only vs All Others[(b)]								
Total farm	226	147	79	2.605	1.227	5.528	0.012	(-)**
All others[(b)]	195	133	62					
Bait only	31	14	17					
Bait Only vs. Cats Only								
Total farm	61	39	22	6.071	1.842	20.009	0.002	(-)*
Cats only	30	25	5					
Bait only	31	14	17					
Cats Only vs. All Others[(c)]								
Total farm	226	147	79	0.33	0.121	0.899	0.024	(+)**
All others[(c)]	196	122	74					
Cats only	30	25	5					

(a) All others includes bait only or cats only for rodent control.
(b) All others includes bait and cats or cats only for rodent control.
(c) All others includes bait only or bait and cats for rodent control.
* Significant at 1% level.
** Significant at 5% level.
***Significant at 10% level.

Table 6. Analysis of Herd Level Farm Management Strategies and *T. gondii* Tests for Herds with Total Confinement Housing

Comparison Item	Number of Farms			Odds Ratio	95%		Chi-Square Test	Logistic Regress.
	Total	Pos.	Neg.		Lower Bound	Upper Bound		
Dogs Access vs. Not Access								
Total farm	109	60	49	0.412	0.186	0.910	0.027	(+)**
Dogs not access farm	41	17	24					
Dogs access farm	68	43	25					
Cats Access vs. Not Access								
Total farm	114	66	48	0.434	0.173	1.084	0.07	(+)***
Cats not access farm	24	10	14					
Cats access farm	90	56	34					
Birds Access vs. No Access								
Total farm	128	68	60	0.23	0.089	0.593	0.001	(+)*
Birds not access farm	27	7	20					
Birds access farm	90	56	34					
Bait and Cats vs. All Others[(a)]								
Total farm	128	68	60	0.376	0.176	0.802	0.01	(+)*
All others[(a)]	43	16	27					
Bait and cats	85	52	33					
Bait Only vs. All Others[(b)]								
Total farm	128	68	60	4.683	1.964	11.167	0.000	(-)*
All others[(b)]	94	59	35					
Bait only	34	9	25					
Bait Only vs. Cats Only								
Total farm	42	15	27	8.333	1.416	49.042	0.016[(d)]	(-)**
Cats only	8	6	2					
Bait only	34	9	25					
Cats Only vs. All Others[(c)]								
Total farm	128	68	60	0.3	0.06	1.5	0.0004[(d)]	(+)
All others[(c)]	119	61	58					
Cats only	9	7	2					

(a) All others includes bait only or cats only for rodent control.
(b) All others includes bait and cats or cats only for rodent control.
(c) All others includes bait only or bait and cats for rodent control.
(d) Fisher test rather than χ^2 was used for these tests because of small number of observations.
* Significant at 1% level.
** Significant at 5% level.
*** Significant at 10% level.

levels, etc., it was concluded that the presence or absence of a positive *Toxoplasma gondii* test for a sow did not impact the sow's productivity. This analysis was based on the use of simple and multiple linear regression.

An analysis was also completed to see if the percent of herds or sows which tested positive for *Toxoplasma gondii* varied by region of the country. This comparison was conducted in two ways: the first the Northern United States as compared to the Southern United States. The second was a Midwest, Southeast, and Western comparison. In general, regional differences were not evident. Significance tests did not show differences. These results were different than those shown in some previous studies where it was indicated that a larger percentage of the sows located in the Southern or Southeastern Region of the United States tested positive for *Toxoplasma gondii* than sows located in the Northern Region of the United States. It is not felt that these results are inconsistent from the previous results. What may be reflected are the changes in the types of production systems that are used in swine production, particularly in the Southeastern area of the United States, where there has been a rapid movement toward larger swine production operations and to confinement facilities.

The following provides a summary of the study results.

(1) Of the sows tested, 19 percent tested positive for *Toxoplasma gondii*; 81 percent were negative.
(2) Of the herds tested which compared all positive herds to negative herds with 10 sows tested, 63 percent tested positive (at least one sow positive) for *Toxoplasma gondii*.
(3) Of all herds tested, including those which were negative but with fewer than 10 sows tested, 49 percent tested positive for *Toxoplasma gondii*.
(4) Herds testing positive had a significantly smaller number of sows than herds testing negative.
(5) Sows in herds where female replacements were raised internally were significantly more likely to be positive than herds where female replacements were purchased.
(6) Sows in total confinement facilities had a significantly lower prevalence of *Toxoplasma gondii*.
(7) Cat, bird or dog access to swine facilities significantly increased the chance for positive tests.
(8) Use of bait for rodent control, or the exclusion of cats, significantly reduced the prevalence of *Toxoplasma gondii*.
(9) For most regional comparisons, no relationship was found between the prevalence of *Toxoplasma gondii* and region where the farm is located. However, when comparing sows in total confinement and raised conditions, the Midwest and West regions had a significantly higher level of sows which tested positive than did the Southeast region.
(10) No relationship was found between sow parity and *Toxoplasma gondii* test results.
(11) The presence or absence of *Toxoplasma gondii* antibodies, a sow testing positive for *Toxoplasma gondii*, did not appear to impact sow productivity level.

Total confinement facilities had a significantly lower level of *Toxoplasma gondii* infection than did the other types of production facilities: open housing, or no building types of facilities such as open lot or pasture. This is likely associated with the reduced level of cat, dog and/or bird access with some of these facilities, as they were also shown to be important factors.

Herds testing negative were significantly larger than those testing positive. It is not clear that size is the determining factor, but rather the types of management strategies and production facilities associated with the larger operations. Operations with total confinement facilities were on average larger. Similarly, operations that purchased replacement females were larger than those who raised replacements. Additionally, cat, dog, and bird access was greater for smaller operations.

The lack of a regional relationship with *Toxoplasma gondii* prevalence rates, while different from previous reports may reflect ongoing changes in the swine production industry. The trend toward movement of swine into confinement facilities is reducing the exposure to the disease problem.

This study has shown a positive relationship between sows or herds testing positive for *Toxoplasma gondii* and method of rodent control, type of production facility and cat, dog or bird access to production facilities. It will be difficult to eliminate *Toxoplasma gondii* from swine herds which allow for cat, dog or bird access. While cat or dog access to most facilities can be controlled somewhat by not having cats or dogs around the operation, it is difficult to control access of stray cats or dogs from facilities which provide open access. Similarly, control of bird access is even more difficult for facilities with open access, as birds freely move from facility to facility.

Level of control is also related to density of swine production and facilities. In some locations swine production operations may be within a quarter mile from each other, a distance easily traveled by cats, dogs, birds, etc. In these locations it will be quite difficult to control *Toxoplasma gondii* without restricted access facilities. In other locations swine production facilities may be 10 or more miles from the nearest swine production facility. Cats, dogs or birds are much less likely to travel these distances and control or prevention with open facilities can be more easily attained.

The exclusion of cats as a method of rodent control should be considered. While there were only a few operations where cats only or bait only was used for rodent control, there was a strong association between use of bait only and the herd testing negative as compared to the use of cats only for rodent control. Greater industry awareness is needed on methods for the use of bait to control rodents. Information is needed on methods which appear to work, as this appears to be a method for effective reduction of toxoplasmosis in sow herds, as well. Additionally, more research is needed in this area, as there were only a small number of operations using bait control exclusively.

Operations which purchased female replacements were more likely to test negative for *Toxoplasma gondii*. This suggests that a survey of production practices, etc., used by those who produce replacement females for sale may be useful in identifying practices which reduce prevalence of *Toxoplasma gondii*. Moreover, requesting that purchased replacement females be tested for *Toxoplasma gondii* prior to sale may reduce the spread of the disease through the sale of positive animals.

This report represents a summary of the study. A copy of the complete study can be obtained from James Kliebenstein, Economics Department, 178 Heady Hall, Iowa State University, Ames, IA 50011 (Phone: 515-294-7111).

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