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Toxoplasma gondii Levels in Swine Operations: Differences Due to Technology Choice and Impact on Costs Production

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Introduction

Toxoplasma gondii is infectious for essentially all warm-blooded animals, including mammals, marsupials, and birds. Species in the family Felidae (cats) are the definitive hosts of *T. gondii*. Sexual reproduction of *T. gondii* in the intestinal epithelium of cats results in the production of oocyts. Oocysts shed in cat feces can persist for months or years in the environment in an infectious form (Frenkel et al., 1975).

In humans, prevalence is commonly 25 to 50 percent and, depending on the population studied, may approach 80 percent (Ahmed, 1992; Arias et al., 1996; Etheredge and Frenkel, 1995; Gutierrez et al., 1996; Haldar et al., 1993; MacKnight and Robinson, 1992; Onadeko et al., 1992). Roberts and Frenkel have shown that toxoplasmosis has been estimated to cost United States consumers from $.4 billion to $8.8 billion per year. Infection in healthy children and adults is usually subclinical and generally passes unnoticed. The greatest concern for humans is congenital infection. Transplacental infection of the fetus occurs in 10-15 percent of pregnant women infected with *Toxoplasma* for the first time during pregnancy (Acha and Szyfres, 1987). Infection under these circumstances may cause stillbirths, abortions, early infant mortality, blindness, and crippling in children. Transmission of *T. gondii* to humans is poorly characterized, but risk factors associated with infection include contact with cats (Ahmed, 1992; Etheredge and Frenkel, 1995; MacKnight and Robinson, 1992; Onadeko et al., 1992), contact with soil or gardening activities (MacKnight and Robinson, 1992), and consumption of raw or undercooked meat containing infectious bradyzoites (Arias et al., 1996; MacKnight and Robinson, 1992).

Like humans, swine become infected by ingesting oocysts from the environment or by consuming raw or under-cooked meats that contain bradyzoites, such as *Toxoplasma*-infected rodent carcasses. Toxoplasmosis is common in domestic swine throughout the world. Recent reports provide prevalence estimates that range from 3.1 to 20.8 percent (Kliebenstein et al., 1997; Patton et al., 1996; Lin et al., 1990; Quehenberger et al., 1990; Smith, 1991; Uggla and Hjort, 1984; Weigel et al., 1995; Zimmerman et al., 1990). The frequency of infection in swine is distinctly age dependent, with prevalence in market animals approximately half (3.1 to 9.0

percent) that of sows (9.4 to 20.8 percent) (Quehenberger et al., 1990; Smith, 1991; Uggla and Hjort, 1984; Weigel et al., 1995; Zimmerman et al., 1990).

Toxoplasmosis in swine is a food safety issue, as opposed to an animal health issue. For balance, it should be noted that the role of meat as a risk factor for human toxoplasmosis is unclear and, indeed, a number of studies have found no association between meat consumption and toxoplasmosis (Ahmed, 1992; Etheredge and Frenkel, 1995; Rawal, 1959; Warren and Dingle, 1966; Wende and Dienst, 1961). Regardless, from the consumers' perspective, toxoplasma-free pork is a more desirable food product. Likewise, from the pork producers' perspective a commodity perceived as safer and more wholesome gains a competitive advantage in the marketplace. Both of these goals are compatible with the benefits gained by society through reduced *T. gondii* infections in humans and animals. Therefore, the purpose of this study was to identify herd characteristics and farm management practices associated with reduced toxoplasmosis in swine with the purpose of formulating recommendations for the prevention of the infection in swine.

Materials and Methods

Data for this study were obtained from a random survey of swine herds conducted by the National Animal Health Monitoring System (NAHMS) during 1995. As part of the study, general farm management information and blood sera were collected from 285 swine producers in 16 states. These data included specific information on production facilities, biosecurity measures, management practices, pig inventory, etc. Sera were collected from sows and market hogs.

Among the 285 herds participating in blood sera collection, serum samples were collected from sows in 226 herds and from market hogs in 282 herds. Serum samples from up to 30 randomly selected animals were collected from each herd; 15 from sows and 15 from market livestock. Following collection, samples were archived at the United States Department of Agriculture (USDA), National Veterinary Services Laboratories (NVSL) and stored at -40 C until assayed for serum antibodies against *T. gondii* by the University of Tennessee Parasitology Laboratory. A total of 3,236 individual sow serum samples and 4712 individual market hog serum samples were assayed for the study.

Sera were tested for antibodies by the modified direct agglutination test (MAT) which uses formalin-fixed tachyzoites as antigen (Patton and Funk, 1992; Dubey and Desmonts, 1987). Samples with antibody titers of $\geq$1:32 were considered positive. Studies have shown that the MAT is the most sensitive test for the serodiagnosis of toxoplasmosis (Dubey and Beattie, 1988:

Dubey and Thulliez, 1989; Patton et al., 1991). A positive titer indicates that at some time in its life the pig has been infected with *T. gondii*.

Because some samples were of poor quality, and sampling error where less than 10 animals were sampled, not all farms were used in the analysis. If sow herds had less than 10 sows with test results and all tested negative, they were dropped from the analysis because the probability of all sows in the herd testing negative was considered too low to be labeled as a negative herd. Herds with at least one sow that tested positive were retained as a positive herd for analysis. The same convention was followed for finishers with less than 15 tested being the number that excluded a herd from advanced analysis when all animals were negative. A herd was considered positive if 1 or more animals tested positive. For both sow herds and market hog herds, all animals tested needed to be negative to be considered negative.
(Note: Economic info moved.)

Results

Eight percent of all swine tested for *T. gondii* antibodies were positive. Fifteen percent of the sows tested positive, while 3.2 percent of the market hogs tested positive (Table 1). The prevalence rate was significantly higher in the sow herd (about five times higher) than in the market hog herd. A NAHMS survey of sows compiled in 1990 showed that 20 percent of the sows were positive at that time. Market hogs were not surveyed in 1990.

Of the farms, 51 percent were positive for *T. gondii* (at least one positive animal). Of the sow herds tested, 56 percent were positive while 19 percent of the market hog herds tested were positive (Table 1). Again, about 5 times more farms than when compared across market hogs. In the 1990 NAHMS survey forty-nine percent of the sow herds tested positive (Kliebenstein et al., 1997). Thus, there is not much difference in the percent of sow herds testing positive between 1990 and 1995.

Table 2 provides information on prevalence level by state. For sows, the prevalence level ranges from a low of two percent for North Carolina to a high of 23 percent for Missouri. It should be noted that only 45 sows were tested in North Carolina. There were only three herds where sows were tested. North Carolina also had the lowest prevalence level for total swine: a level of .7 percent, while Wisconsin had the highest percent at 13 percent.

Information on percent of farms testing positive is provided in Table 3. The range of sow herds testing positive ranged from 33 percent in North Carolina to 82 percent in Indiana. Prevalence in total herds tested ranged from 20 percent of the herds in North Carolina to 79 percent of the herds in Wisconsin.

When comparisons were conducted by herd size it showed that negative sow herds were significantly larger than the positive herds. The negative herds averaged 647 sows, while the positive herds averaged 260 sows. Negative finisher herds averaged 3635 market pigs in inventory, while the positive herds averaged 2081 market pigs in inventory.

The analysis also focused on type of production facility and the type of rodent control used. For facility analysis, the swine herds were placed into two groups: those which had total confinement for all production phases and those which had at least one of the production phases in which pigs had access to the outside through open buildings or direct access to the outdoors. Of the sows, 58 percent were in total confinement in all production phases, while 67 percent of the finishers were in all total confinement systems.

The *T. gondii* status of sows and sow herds with all production phases in confinement (farrowing, nursery and finishing) was compared to herds that were not in total confinement in at least one of the phases. Twenty percent of the sows in facilities which were not all in total confinement were positive and were almost twice as likely to be infected than those in confinement: 12 percent infected (Table 4). This was significant at the .01 level. Additionally, sow farms which had facilities which were not all total confinement had a significantly higher percent (.01 level) of herds test positive than did the total confinement operations. Seventy one percent of the non-total confinement herds were positive compared to 49 percent of the total confinement herds.

Market hogs on farms that did not have all phases of the operation (farrowing, nursery, grower/finisher) in confinement were significantly more likely to be infected than those on farms that used total confinement throughout (Table 5). Of the finishers on farms that did not have all phases of the operation in confinement, 4.4% were positive for *T. gondii* compared to 2.3% on farms that used total confinement throughout. The prevalence level was essentially cut in half for the total confinement systems. Market hog herds with a farrow to finish operation not using total confinement throughout had a higher percent of market hogs testing positive (23.8%) than did the total confinement operations (16.3%).

Sows and market hogs exposed to cats in the production facilities were significantly more likely to be positive for *T. gondii* than sows and market hogs not exposed to cats (Table 6 and 7). About one-fourth (21%) of the sows in systems which had cat exposure were positive for *T. gondii*. This compared to only 6.7 percent of the sows in facilities which did not have cat exposure. The odds ratio test indicated sows in facilities with cat exposure were about four times more likely to be positive. For market hogs the odds are even greater. Odds ratio analysis

showed that market hogs produced in facilities with cat exposure were about 9 times more likely to be positive. Information in Table 7 shows that 5.5 percent of the market hogs in facilities with cat exposure were positive. This compared to 0.7 percent for those produced in facilities without cat exposure.

Information provided in Tables 8 and 9 shows similar results when evaluated by method of rodent control. Sows and market hogs produced in systems that relied on traps and/or bait only as the method of rodent control had significantly lower prevalence levels of *T. gondii*. This is likely an issue of the exclusion of cats. For example, seven percent of the sows on farms which used traps and/or bait only for rodent control were positive, as compared to 20.1 percent which had other rodent control methods incorporated. For market hogs, 26.9 percent of the farms using more than traps and/or bait for rodent control were positive for *T. gondii*, compared to only 10 percent of those using traps and/or bait only.

Economics of Alternative Production Systems

Results have shown that pig herds in confinement have lower levels of *Toxoplasma gondii* infection than pig herds in non-confinement facilities. A recent study has shown that there is little evidence that *T. gondii* is associated with decreased pig productivity in sow operations (Kliebenstein et al., 1997). A conclusion here is that sow productivity impacts would not represent an economic incentive to incorporate management strategies that would lessen the incidence of *T. gondii*.

Given the lack of productivity impacts on sow herds, *T. gondii* would not impact the cost of production of feeder pigs. To our knowledge, productivity impacts in market hogs is not known. With this information on economics, and the absence of regulation, decisions which will drive adoption of production systems will be based on any differences in pork production cost between the systems. Direct economic incentives related to productivity that are associated with *T. gondii* appear to be limited for pork producers. Given this, it is necessary to evaluate production between alternative production systems. Information in Table 10 provides a comparison of the cost of producing market hogs in two alternative systems (Brewer et al., 2000). The hoop system is a system which is open on both ends of the pig containment facility. The confinement system is totally enclosed, with no access of cats, birds, etc. Information for the cost comparisons was obtained from a side-by-side system comparison.

The cost of production provided in Table 10 is based on a facility cost of $180 per pig space for a confinement building and $55 per pig space for the hoop structure with feed and

manure equipment being the same for both systems. Fixed costs are calculated at 13.2% of total investment for confinement and 16.5% for hoops. Confinement facilities are depreciated over 15 years (6.7% annually), whereas hoops are depreciated over 10 years (10% annually). Insurance and taxes represent 1.5% of fixed investment. Ten-percent interest is assumed for both systems. Fuel, repairs, utilities, vet, medical, marketing and miscellaneous are based on Iowa State University livestock enterprise budgets (Lawrence and Vontalge, 1998; Otte, 1997; Brümm et. al., 1997). The bedding cost is for 195 pounds of cornstalks per pig; with a 1,200 lb bale valued at $20 per bale. Labor was valued at $10/h with .20h/head and .27h/head needed, respectively, for confinement and hoop pigs.

Feed efficiency was 2.98 lb of feed per pound of gain for confinement and 3.05 for hoop pigs. With a feed cost of $.06/lb, the resulting feed costs for confinement and hoops are $40.07 and $41.11, respectively.

Overall, the cost of production was comparable between the two systems. The confinement system showed a slight cost advantage of $.31 per cwt market weight sold. The main cost differences in the two systems were housing cost, feed, and bedding. Hoop systems require more feed and bedding, while facility costs are higher for confinement systems.

Given similar economic results, operator preference and available resources will guide the production system choice and production decision. Decisions will depend upon such factors as management style, preferences, availability of capital, and availability of bedding. Additionally, information on parasite loads in the system, as well as potential food safety issues and impacts, should also be considered. This can be difficult, as the pork production industry is not set up to effectively transfer a number of the food safety impacts to the point of origination.

Summary and Conclusions

Results from this and other studies have shown a clear association between pork production systems which are accessible to *Toxoplasma gondii* vectors, such as cats, and seropositivity of hogs for *T. gondii*. Sows and market hogs in pork production systems which had total confinement facilities in phases (farrowing, nursery, finishing) were significantly less likely to be seropositive for *T. gondii*. Of the market hogs tested, 4.4 percent from non-confinement facilities were positive, as compared to 2.3 percent of the hogs from all confinement facilities. Pigs produced in systems that used bait and/or traps as the only method of rodent control had significantly fewer animals seropositive for *T. gondii*. Additionally, it was shown that there is little evidence that *T. gondii* is associated with decreased pig productivity. Thus, there is little

direct economic incentive for producers to use production strategies which would lead to reduced *T. gondii* levels in pigs. Furthermore, a recent study has shown similar pig cost of production between confinement and hoop systems.

However, the importance of the issue to the industry should not be overlooked, as the indirect impacts can be great. Roberts and Frenkel have shown that for the U.S., estimates of income and other preventable costs caused by toxoplasmosis range from $.4 billion to $8.8 billion annually. Reducing the level of toxoplasmosis can have a direct impact on consumers. Given this, and the lack of direct economic incentives for pork producers, industry programs would be helpful in assisting consumer and producer benefits to better match. Moreover, consumer assurance of the safety of pork is vital to continued and enhanced demand for pork, both domestically and internationally. Moreover, there is an increased consumer awareness of food-borne pathogens. The demand for safe food products is increasing. A *T. gondii* food-safety incident related to pork would erode the consumer image, potentially leading to reduced demand, at least in the short term. The industry needs to evaluate methods of reducing cat accessibility to pig production systems.

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Table 1. Seroprevalence of *T. gondii* in Sows and Finisher Pigs in the 1995 NAHMS Survey

	Animals		Herds	
Swine Type	Positive/ Total	% Positive	Positive/ Total (a)	% Positive
Sows	488/3236	15	126/226	56
Finishers	153/4712	3.2	53/282	19
Unknown	3/13	10	-	-
Total	644/7979	8	144/285	51

(a) Adding number of sow herds and finisher herds will be more than the total herds, as some farms had both sows and finishers tested.

Table 2. Sows and Finisher Pigs Positive for *T. gondii* - by State

State	Positive Sows/ Total Sows	% Positive Sows	Positive Finishers/ Total Finishers	% Positive Finishers	Positive Swine/ Total Tested	% Positive Total Animals
Georgia	4/74	5	1/75	1	5/149	3
Illinois	48/324	15	15/380	4	63/704	9
Indiana	27/162	17	13/315	4	40/477	8
Iowa	160/895	18	48/1061	5	208/1957	11
Kansas	18/140	13	3/162	2	21/302*	7
Kentucky	8/67	12	3/89	3	14/186**	8
Michigan	24/147	16	14/201	7	38/348	11
Minnesota	47/429	11	2/613	0.3	49/1042	5
Missouri	32/140	23	7/184	4	39/324	12
Nebraska	29/175	17	18/323	6	47/498	9
North Carolina	1/45	2	1/255	0.4	2/300	0.7
Ohio	20/161	12	4/386	1	24/547	4
Pennsylvania	6/103	6	2/167	1	8/270	3
South Dakota	5/65	8	13/127	10	18/192	9
Tennessee	14/105	13	0/165	0	14/270	5
Wisconsin	45/204	22	9/209	4	54/413	13
Total	488/3236	15	153/4712	3	644/7979	8

*1 animal of unrecorded age not included in later analysis

** 30 animals of unrecorded age not included in later analysis

Table 3. Sow and Finisher Farms Positive for *T. gondii* - by State

State	Positive Sow Farms/ Total Sow Farms	% Positive Sow Farms	Positive Finisher Farms/ Total Finisher Farms	% Positive Finisher Farms	Number Farms Tested	% Positive Total Farms
Georgia	2/5	40	1/5	20	3/5	60
Illinois	12/22	55	6/24	25	12/24	50
Indiana	9/11	82	4/16	25	11/16	69
Iowa	33/59	56	17/67	25	38/68	56
Kansas	7/11	64	1/12	8	7/12	58
Kentucky	2/5	40	2/6	33	4/7**	57
Michigan	7/11	64	3/12	25	7/13	54
Minnesota	14/31	45	2/39	5	16/39	41
Missouri	5/11	46	3/13	23	6/13	46
Nebraska	8/13	62	3/18	17	9/18	50
North Carolina	1/3	33	1/10	10	2/10	20
Ohio	6/11	55	3/21	14	8/21	38
Pennsylvania	3/7	43	1/9	11	3/9	33
South Dakota	3/6	50	2/7	29	3/7	43
Tennessee	4/7	57	0/9	0	4/9	44
Wisconsin	10/13	77	4/14	29	11/14	79
Total	126/226	56	53/282	19	144/285	51

** one farm with incomplete data not included in later analysis

Table 4. Comparison of *Toxoplasma gondii* Seropositivity in Sows by Production Facility

Facility Type	Number	Percent Negative	Percent Positive	P
		Sow Comparison		
Total Confinement in All Phases	1884	88.4	11.6	<0.01
Not all Total Confinement	1149	79.8	20.2	
		Farm Comparison		
Total Confinement in All Phases	128	50.8	49.2	<0.01
Not All Total Confinement	79	29.1	70.9	

Exclude 12 sow farms with incomplete facility information

Table 5. Comparison of *Toxoplasma gondii* Seropositivity in Market Hogs by Production Facility

Facility Type	Number	Percent Negative	Percent Positive	P
		Market Hog Comparison		
Total Confinement in All Phases	2096	97.7	2.3	<0.01
Not all Total Confinement	1334	95.6	4.4	
		Farm Comparison		
Total Confinement in All Phases	129	83.7	16.3	0.17
Not All Total Confinement	84	76.2	23.8	

Exclude 46 finisher farms with incomplete facility information

Table 6. Comparison of *Toxoplasma gondii* Seropositivity in Sows by Cat Access to Production Facilities

Item	Number	Percent Negative	Percent Positive	P
		Sow Comparison		
Cat Access	1917	79.0	21.0	<0.01
No Cats	1241	93.3	6.7	
		Farm Comparison		
Cat Access	132	31.8	68.2	<0.01
No Cats	84	59.5	40.5	

Exclude 3 farms with incomplete rodent control information

Table 7. Comparison of *Toxoplasma gondii* Seropositivity in Market Hogs by Cat Access to Production Facilities

Item	Number	Percent Negative	Percent Positive	P
		Market Hog Comparison		
Cat Access	2469	94.5	5.5	<0.01
No Cats	1943	99.3	0.7	
		Farm Comparison		
Cat Access	148	72.3	27.7	<0.01
No Cats	108	89.8	10.2	

Exclude 3 farms with incomplete rodent control information

Table 8. Comparison of *Toxoplasma gondii* Seropositivity in Sows Where Traps and/or Bait Are the Only Rodent Control Method

Item	Number	Percent Negative	Percent Positive	P
		Sow Comparison		
Traps and/or Bait Only	1137	93.0	7.0	<0.01
Others	2021	79.9	20.1	
		Farm Comparison		
Traps and/or Bait Only	77	58.4	41.6	<0.01
Others	139	33.8	66.2	

Exclude 3 farms with incomplete rodent control information

Table 9. Comparison of *Toxoplasma gondii* Seropositivity in Market Hogs Where Traps and/or Bait Are the Only Rodent Control Method

Item	Number	Percent Negative	Percent Positive	P
		Market Hog Comparison		
Traps and/or Bait Only	1808	99.3	0.7	<0.01
Others	2604	94.7	5.3	
		Farm Comparison		
Traps and/or Bait Only	100	90.0	10.0	<0.01
Others	156	73.1	26.9	

Exclude 3 farms with incomplete rodent control information

Table 10. Swine Market Hog Cost of Production

Item	Hoop System	Confinement System	Difference
Facility Investment			
Building (per pig space) (8ft^2/pig confinement; 12ft^2/pig hoop)	$55.00	$180.00	$125.00
Feed & manure handling equipment (per pig space)	$36.00	$ 36.00	
Total initial investment (per pig space)	$91.00	$216.00	$125.00
Days from 35-260 lbs + 10 days (based on relative average daily gain)	142	141	-1
Total investment per pig marketed (based on relative average daily gain +10 days)	$35.28	$83.15	$47.87
Fixed Cost			
Interest, taxes, depreciation, insurance (13.2% for confinement; 16.5% for hoops) (per cwt, 35 lbs to market)	$ 5.82	$10.98	$ 5.15
Operating cost			
Feeder pigs (30-40 lb pig)	$30.00	$30.00	
Interest on feeder pig (10% for 4 months)	$1.00	$1.00	
Fuel, repairs, utilities	$1.00	$1.50	$0.50
Bedding (1200lb bale @ $20.00 each)	$3.25		-$3.25
Feed ($.06/lb feed)	$41.11	$40.07	-$1.03
Vet/medical	$1.50	$1.50	
Marketing/misc.	$1.50	$1.50	
Interest on fuel, feed, etc. (10% for 2 months)	$0.81	$0.74	-$0.06
Labor (0.20 hrs conf; .27 hrs hoops @10/hour)	$2.70	$2.00	-$0.70
Death loss cost	$1.19	$1.06	-$0.12
Total operating cost	$84.05	$79.38	-$4.67
Total cost (per pig marketed)	$89.87	$90.36	$0.49
Grade Premium (per pig marketed)	$1.30	$2.60	$1.30
Net cost (per pig marketed)	$88.57	$87.76	-$0.81
Net cost per cwt market weight live (260 lb market hog)	$34.07	$33.75	-$0.31