Cost of on-farm microbial testing for *Salmonella*: An application by farm size and prevalence level

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Summary

As the pork production industry moves closer to adopting and using Hazard Analysis and Critical Control Point (HACCP) management systems, effective pathogen identification becomes necessary. Additionally, relationships between management strategies and prevention and/or reduction of pathogens on the farm is needed. An important component of these systems is the associated economic costs and benefits. Studies have assessed the economic costs and benefits of HACCP management systems that target specific pathogen reduction, such as *Salmonella spp.* in food animals (Morales, 1995; Perrin, 1993). Morales' and Perrin's research lacked an analysis of HACCP's proactive approach to prevention of foodborne disease in the food chain. Existing research on economic analysis of HACCP has been limited. An application specific to the seafood and poultry industry was conducted by Martin (1993) and Curtin (1991)by Martin (1991)and for the food processing industry. Jensen and Unnevehr (1995) pointed out that "data on the incidence of pathogens in farm animals, the adoption of farm management practices, and the cost of these practices can be used to analyze the costs of reducing pathogens at the farm." It has been noted that HACCP plans are often made with limited knowledge of on-farm pathogen prevalence.

With the recent Pathogen Reduction Act of 1996 being put into law, the meat industry faces tighter scrutiny based on bacterial counts on meat products. USDA/FSIS efforts will be targeted at determining bacterial levels, including *Salmonella*, on meat products. Included in this law are specific goals or targets for the reduction of *Salmonella*. Tighter scrutiny and an increase in microbiological testing, first at the larger slaughter/processing facilities (500+ employees), will likely lead to industry adjustments.

Additionally, consumers, domestic and international, have become more health conscious and more informed about outbreaks of foodborne disease. The meat industry has a goal of increasing and maintaining consumer confidence and maintaining product integrity. These regulatory, social, and consumer changes shaping the meat and animal production industry likely will be felt throughout the industry, including at farm level.

This study evaluates the cost of on-farm *Salmonella* testing for selected prevalence levels and group sizes. Testing cost is size dependent; per pig cost declines as group size increases. Cost per pig in a group ranged from $5.37 for a 500-head group to $.49 per head for a 10,000 head group. Costs were projected with a 5% prevalence level and a 95% confidence interval.

Introduction

On-farm pathogen reduction management decisions often are made with a lack of knowledge regarding *Salmonella* prevalence levels. This approach allows for *Salmonella* testing costs to be projected based on selected confidence intervals and on selected margins of error of on-farm swine producers. It has been found that HACCP management strategies are often made without sufficient or prior knowledge of pathogen prevalence levels, thus the need for microbiological testing needs to be reconsidered.

Objectives:

1. The on-farm main objective of this study was to assess the costs of *Salmonella* testing at selected confidence intervals and margins of error with selected *Salmonella* prevalence levels of 5% and at 7%.
2. To develop a statistical approach that allows for further evaluation of data based on economic cost/benefits using swine production performance data.

Information gained in this report allows for further economic cost/benefit modeling to be made from baseline farm-level data. Information and statistical data is useful for management when scheduling groups of hogs into slaughter processing facilities. Industry personnel at slaughter/processing facilities have indicated a need and use for swine herd status information prior to receiving animals at slaughter facilities. This data can be used, for instance, in scheduling hogs based on herd health status. Hogs that exceed an upper control limit may be scheduled into a slaughter facilities at the end of a slaughter shift or end of a day. Animals with *Salmonella* levels at or below a given lower control limit may be scheduled into slaughter facilities early in a production shift. Issues regarding sourcing of product and cross-contamination remain to be worked out. At this point, it has not been determined whether a premium will be paid to producers for delivering groups of animals with pathogen prevalence levels at or below an established control limit. Intervention strategies on farm will likely be specific to the levels of *Salmonella*, such as in how hogs are handled to reduce trauma and prevention measures that limit cross-contamination. Measures are likely to be specific to the type of production system being used in producing swine; for example, three-site or multi-site swine production.

Swine producers who produce and send to market (or to the slaughter facility) a safer product (swine with reduced or nondetectable levels of *Salmonella*) can gain advantages in the market. The potential exists for scheduling swine into slaughter/processing facilities based on criteria of herd health status at close-out time; herds of swine having low versus high levels of *Salmonella* is currently being evaluated. Swine herds having low or nondetectable levels of pathogens would be scheduled into a slaughter facility early in the day. Given management justifications regarding cross-contamination of bacteria in slaughter facilities overall levels of *Salmonella* on pork products may remain lower for a particular production shift. Groups of swine with high levels of pathogens (*Salmonella)* would be scheduled into facilities at the end of day. The value of these hogs may be reduced or discounted because of high pathogen levels. Alternatively, groups of swine with excessive levels of *Salmonella* may be sent to a processing facility where pork products from this herd will be made into cooked products. Here too, hogs will be of lower value.

Established relationships among producers/slaughter/processing personnel will be impacted by recent regulatory changes facing the pork industry specific to acceptable standards for foodborne contamination and the safety of meat products. This is due, in part, to recent changes in governmental regulations targeting slaughter facilities. Compliance to the Pathogen Reduction Act of 1996 may affect supplier/slaughter/processor relationships.

Export demand for pork products,that have low or zero pathogen levels is likely to increase. Overall export demand for US pork products is projected to double over the next five years, according to the US Meat (Pork) Export Federation in 1996. As the volume of pork products going through slaughter/processing facilities increases, cross-contamination resulting from foodborne bacteria, *Salmonella*, becomes a growing concern for management. The quality of meat products and product safety have become important to market assess issues and to the increasing competitiveness in international trade in meats (Caswell and Hooker, 1996). Products free of pathogens or of having a low level of pathogens have become a necessary ingredient to enter the market. Demand for safer and higher quality pork is likely to filter backward from consumer to producer. This will impact relationships existing in the swine/pork industry. Recent outbreaks of foodborne disease, such as *E Coli O157:H7* in Japan in June 1996, though not yet traced to meat products, are likely to cause importing countries to take a closer look at product safety and quality issues.

Consumers of pork products can benefit from purchasing products with zero or low levels of pathogens. Sickness would be reduced. Societal costs caused by foodborne pathogens are estimated in the range of $6 to $22 billion annually. This represents the value of medical costs and of lives saved from reducing eight foodborne pathogens (Roberts and Unnevehr, 1994). Consumers have a large potential benefit from *Salmonella* reduction, which is estimated at a cost of $1 to $2 billion per year. Growing concerns by consumers pertaining to the availability of alternative choices for safer food products indicate that consumers are willing to pay a premium for meat products (pork products) that have reduced risk for spreading foodborne disease. Through willingness-to-pay experiments, (Hayes et al. 1995; Fox et al. 1995; Shogren et al., 1994; Shin et al., 1992) have shown that consumers are willing to pay a premium to enhance the food quality through the reduced prevalence of pathogens.

Materials and Methods

One technique used in this study for estimation of costs and verification of existing baseline *Salmonella* data was elicitation of expert opinion, a method used by Martins (1993) and Anderson (1994). Using this technique allowed for gaining further input on estimating *Salmonella* prevalence levels by industry personnel having expertise in swine production and slaughter/processing personnel. When food safety and meat quality personnel at slaughter processing facilities were asked to estimate an upper boundary regarding the percentage of *Salmonella* infected swine upon receipt at the facility and/or in the holding area prior to entering the slaughter facility, they indicated that the range was 8.0 to 8.5%. A mean prevalence level above 8 to 8.5% is considered to be above the upper boundary for acceptance by industry personnel. Additional intervention actions likely are required for these hogs to be slaughtered and processed into pork products.

Data collected (NAHMS, 1995) in a national swine baseline study showed that the *Salmonella* prevalence level on farm was 6.2%. As a result of employing expert elicitation, along with using baseline data made available for this research, the likely prevalence of *Salmonella* on swine is presumed to fall between a range of 6.2% to 8.5%. To reflect today's condition of swine in production facilities, a mean prevalence level of 7% for *Salmonella* will be used. A prevalence level of 5% also will be evaluated, as this level of prevalence (5%) has been identified as a goal by key industry personnel.

Testing costs are determined for different swine farm sizes and for different confidence intervals and margins of error. Costs are calculated at the group level as well as for cost per hog in a group sizes to determine any costs associated with production size relationships. Costs are impacted by production size, number of tests required per group, and testing costs per hog tested. Testing costs per pound of pork (carcass) is impacted by hog selling weight. The number of animals tested was determined first by finding the infinite population size and then calculated based on selected prevalence levels, confidence intervals, and margins of error (1993) Ott.

Testing cost per pig of $11.25 was calculated by determining the number of samples collected per hour and processed per hour, $3.25, average cost for rapid test $7.50, recordkeeping, etc. at $.50 per sample. Researchers averaged the number of samples collected per hour, handling and preparation, rapid testing costs, data analysis costs, etc. in deriving the $11.25 figure.

Testing cost per pound of carcass pork also was calculated. This was accomplished through the use of the conversion factor based on the Chicago Board of Trade standard method: (live animal weight *.74 yields the carcass weight). Using the average hog live market weight of 250 pounds at close-out and the .74 conversion factor provides a carcass weight of 185 pounds per animal. Testing costs per pound have been calculated using both live animal weight and carcass weight.

Results and Discussion

Tables 1 through 3 show *Salmonella* testing cost projections by group size for selected confidence intervals (95% and 98%), for selected prevalence levels (5% and 7%), and for a margin of error of 2%. The number of animals tested per group, as well as the cost per group size and cost per hog are provided.

Data in table 1 is based on baseline data and expert opinion provided and indicates where the swine production industry is today regarding *Salmonella* prevalence levels (around 7%). Thus, the number of tests required for detection of the prevalence of *Salmonella* are based on *Salmonella* prevalence levels of 7 %. A 95% confidence interval has been selected with a margin of error at 2%.

Table 2 represents a targeted goal for *Salmonella* reduction (by 2%) and overall prevalence levels of (5%). This target was provided by key personnel in the swine industry. This figure was derived by asking key industry personnel where swine producers would like to be in one to three years regarding overall on-farm prevalence levels of *Salmonella*. As compared with industry data available today, at the 7% level, the number of tests required for group validation is lower. The targeted goal and range for reduced *Salmonella* levels on swine thus becomes 3% to 7% using a mean prevalence level of 5%. Table 3 represents the same scenario as table 2, except that a 98% confidence interval was used for the projections shown.

Figure 1 graphs *Salmonella* testing costs per hog in selected groups for selected prevalence levels of 5% and 7%, and a margin of error of 1%, 2% and 3%. A 95% confidence interval was used for projecting each cost shown. In figure 2, *Salmonella* testing costs per hog per group are shown for selected confidence intervals of 95% and 98%, and amargin of error of 1%, 2% and 3% each for prevalence levels of 5%.

Observation clearly show that a strong relationship exists between testing costs per pig and group size. This is especially so for the comparison with a 1% margin of error. Costs for the 3% margin of error begin to level out at the 2,000 to 3,000 group size. Table 1 shows that the per pig costs decline from $6.26 for the 500 animal group size to $.66 for the 10,000 group size. With 5% prevalence level the per pig costs range from $5.37 to $.49, from the smallest group size to the largest group size.

Comparing figure 1 to figure 2 shows that the per pig costs for the 7% prevalence level with a 95% confidence interval was essentially the same as the per pig cost for the 5% prevalence level with a 98% confidence interval scenario. This is true for all selected margins of error (1%, 2%, and 3%). The figures can be used to track how large the group size would need to be to have similar per pig testing costs under selected scenarios.

Cost differences exist between the alternative scenarios. The scenarios can reflect the producers level of risk acceptance. For example, a 1% margin of error has less risk than a 3% margin of error. Likewise, a 98% confidence interval has a lower level of risk than a 95% confidence interval. Tables 4 and 5 provide a side-by-side comparison for *Salmonella* testing costs per hog for selected prevalence levels, selected margins of error, and for selected confidence intervals. The *Salmonella* prevalence levels selected are 5% and 7%. Cost comparisons are provided for the selected margins of error of 1%, 2%, and 3%. For example, it shows that the costs for testing at the 1% margin of error is significantly higher than at the 2% or 3% margin of error. Table 5 shows a side-by-side comparison for *Salmonella* testing costs per hog for selected confidence intervals, selected margins of error, for a 5% *Salmonella* prevalence level. Each series of costs are listed with a margin of error of 1%, 2%, and 3% respectively.

Comparison of *Salmonella* testing cost savings for selected confidence intervals and prevalence levels are summarized. These comparisons allow for the determination of cost savings for group of swine resulting from reduced *Salmonella* prevalence levels on farm. Cost savings are realized when HACCP management strategies can reduce *Salmonella* prevalence levels effectively, for example from 7% to 5%. There is little economic incentive, however, for the producer who cannot manage and reduce *Salmonella* levels on farm.

Testing cost reductions per hog within group size are achieved by reducing prevalence levels and are shown in table 6 for a margin of error of 2%, and *Salmonella* prevalence levels of 5% and 7%. Confidence intervals of 95% and 98%, respectively, are used in cost projections. Economic incentives and benefits for producers who can manage to reduce *Salmonella* level exist. For example, for the 500-animal group size the per hog testing cost decreases by $.88 by reducing prevalence from 7% to 5%. For the 10,000 animal group size the cost reduction is $.17. Other performance factors, such as shorter time to market, improved average daily gain and feed efficiency, and annual turn ratio, will be evaluated over the next year to show if further economic benefits exist for producers who have adopted a proactive philosophy in pathogen prevention and reduction.

Information in tables 7 and 8 provide the incremental cost or change in per-pig testing cost as animal group size increases from one size to the next. Table 7 shows the reduction in per-pig testing cost when the prevalence level is 5%. Table 8 provides similar information using a 7% prevalence level.

Cost reductions decline as animal group size increases. This is shown with the numbers on the diagonal for tables 7 and 8. For example, in table 7, per pig testing cost declines by $1.85 per pig in the group for 1,000 head as compared to a 500-head group. Costs decline by $.25 per pig if group size is 3,000 animals as compared with 2,500 animals. Going from 4,500 to 5,000 animals reduces costs by $.10 per pig. Similarly, the same column in table 7 provides information on reduced costs between the alternative group sizes. For example, testing costs for a producer with an animal group size of 3,000 hogs has a per pig testing cost of $3.89 lower than the producer with a group size of 500 hogs.

As producers adopt pathogen reduction strategies such as HACCP management strategies, good management practices (GMP), or related heard health management programs, and build into their practice a mechanism for making scientific decisions based on current and historical data, on-farm management efforts for *Salmonella* reduction will be based on scientific data. Detailed economic data, production data, and epidemiologic data will be needed for effective on-farm analysis and effective management decision-making, (Gorton et al., 1996; and Kliebenstein et al., 1995). On-farm evidence suggests that HACCP's procedures that reduce prevalence of *Salmonella* may enhance pig growth and feed conversion efficiency, and lower production costs. Additionally, a HACCP-based management system may increase the livestock turn ratio, providing a shorter time to market for finishing swine. Further research on economic costs and benefits for effective on-farm analysis is needed. This study provides a framework for analysis of on farm testing costs for the benefit of swine producers, slaughter/processors, regulators, scientific researchers, and consumers.

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Table 1. *Salmonella* testing costs by group size with a given confidence interval of 95%, margin of error at 2%, and *Salmonella* prevalence level at 7%.

Number of animals per group	Number of tests required per group	Cost per group	[a] Cost per hog in group	[b] Cost per lb. - carcass weight	Cost per lb. average live animal weight of 250 lb.
500	278	$3,127.78	$6.26	$0.034	$0.025
1,000	385	4,329.59	4.33	0.023	0.017
1,500	441	4,965.57	3.31	0.018	0.013
2,000	476	5,359.18	2.68	0.014	0.011
2,500	500	5.626.80	2.25	0.012	0.009
3,000	517	5820.57	1.94	0.010	0.008
3,500	530	5,967.36	1.70	0.009	0.007
4,000	541	6,082.40	1.52	0.008	0.006
4,500	549	6,174.99	1.37	0.007	0.005
5,000	556	6251.11	1.25	0.007	0.005
10,000	588	6,618.27	0.66	0.004	0.003

[a] The test cost per hog tested is $11.25.
[b] Cost per lb. carcass weight = live weight (250 lb.)* conversion factor .74 (Chicago Board of Trade).

Table 2. *Salmonella* testing costs by group size with a given confidence interval of 95%, margin of error at 2%, and *Salmonella* prevalence level at 5%.

Number of animals per group	Number of tests required per group	Cost per group	[a] Cost per hog in group	[b] Cost per lb. - carcass weight	Cost per lb. average live animal weight of 250 lb.
500	239	$2,685.86	$5.37	$0.029	$0.021
1,000	313	3,527.77	3.53	0.019	0.014
1,500	350	3,936.06	2.62	0.014	0.010
2,000	371	4,179.23	2.09	0.011	0.008
2,500	386	4,340.10	1.74	0.009	0.007
3,000	396	4,454.41	1.48	0.008	0.006
3,500	404	4,539.82	1.30	0.007	0.005
4,000	409	4,606.06	1.15	0.006	0.005
4,500	414	4,658.93	1.04	0.006	0.004
5,000	418	4,702.11	0.94	0.005	0.004
10,000	436	4,906.74	0.49	0.003	0.002

[a] The test cost per hog tested is $11.25.
[b] Cost per lb. carcass weight = live weight (250 lb.)* conversion factor .74 (Chicago Board of Trade).

Table 3. ***Salmonella*** **testing costs by group size with a given confidence interval of 98%, margin of error at 2%, and *Salmonella* prevalence level at 5%.**

Number of animals per group	Number of tests required per group	Cost per group	[a] Cost per hog in group	[b] Cost per lb. - carcass weight	Cost per lb. average live animal weight of 250 lbs.
500	282	$3,171.44	$6.34	$0.034	$0.025
1,000	392	4,413.78	4.41	0.024	0.018
1,500	451	5,076.67	3.38	0.018	0.014
2,000	488	5,488.84	2.74	0.015	0.011
2,500	513	5,769.92	2.31	0.012	0.009
3,000	531	5,973.86	1.99	0.011	0.008
3,500	545	6,128.59	1.75	0.009	0.007
4,000	556	6,250.00	1.56	0.008	0.006
4,500	564	6,347.81	1.41	0.008	0.006
5,000	571	6,428.29	1.29	0.007	0.005
10,000	606	6,817.22	0.68	0.004	0.003

[a.] The test cost per hog tested is $11.25.
[b.] Cost per lb. carcass weight = live weight (250 lb.)* conversion factor .74 (Chicago Board of Trade).

Table 4. ***Salmonella*** **testing cost per hog for selected prevalence levels and selected margins of error for a 95% confidence interval.**

Number of animals per group	5% prevalence			7% prevalence		
	Margin of error			Margin of error		
	1%	2%	3%	1%	2%	3%
500	$8.83	$5.37	$3.25	$9.38	$6.26	$4.02
1,000	7.27	3.53	1.90	8.04	4.33	2.45
1,500	6.18	2.62	1.34	7.03	3.31	1.76
2,000	5.37	2.09	1.04	6.25	2.68	1.37
2,500	4.75	1.74	0.84	5.63	2.25	1.13
3,000	4.26	1.48	0.71	5.12	1.94	0.95
3,500	3.86	1.30	0.62	4.69	1.71	0.83
4,000	3.52	1.15	0.54	4.33	1.52	0.73
4,500	3.25	1.04	0.49	4.02	1.37	0.65
5,000	3.01	0.94	0.44	3.75	1.25	0.59
10,000	1.66	0.49	0.22	2.25	0.66	0.30

Table 5. *Salmonella* testing cost for selected confidence intervals and selected margins of error for 5% prevalence level.

Number of animals per group	95% confidence interval, Margin of error			98% confidence interval, Margin of error		
	1%	2%	3%	1%	2%	3%
500	$8.83	$5.37	$3.25	$9.43	$6.34	$4.11
1,000	7.27	3.53	1.90	8.11	4.41	2.51
1,500	6.18	2.62	1.34	7.11	3.38	1.81
2,000	5.37	2.09	1.04	6.34	2.74	1.41
2,500	4.75	1.74	0.84	5.71	2.31	1.16
3,000	4.26	1.48	0.71	5.20	1.99	0.98
3,500	3.86	1.30	0.62	4.77	1.75	0.85
4,000	3.52	1.15	0.54	4.41	1.56	0.75
4,500	3.25	1.04	0.49	4.10	1.41	0.67
5,000	3.01	0.94	0.44	3.83	1.29	0.61
10,000	1.66	0.49	0.22	2.31	0.68	0.31

Table 6. Comparison of *Salmonella* testing cost savings for selected confidence intervals and prevalence levels by group sizes with a margin of error = 2%.

Nbr. of animals per group	95% confidence interval, Prevalence levels of			5% prevalence level, Confidence intervals of			98% confidence interval to 95% confidence interval		
	7%	5%	cost savings	98%	95%	cost savings	98% p=5%	95% p=7%	cost savings
500	$6.26	$5.37	$0.88	$6.34	$5.37	$0.97	$6.34	$6.26	$0.08
1,000	4.33	3.53	0.80	4.41	3.53	0.88	4.41	4.33	0.08
1,500	3.31	2.62	0.69	3.38	2.62	0.76	3.38	3.31	0.07
2,000	2.68	2.09	0.59	2.74	2.09	0.65	2.74	2.68	0.06
2,500	2.25	1.74	0.51	2.31	1.74	0.57	2.31	2.25	0.06
3,000	1.94	1.49	0.46	1.99	1.49	0.50	1.99	1.94	0.05
3,500	1.71	1.30	0.41	1.75	1.30	0.45	1.75	1.71	0.04
4,000	1.52	1.15	0.37	1.56	1.15	0.41	1.56	1.52	0.04
4,500	1.37	1.04	0.34	1.41	1.04	0.37	1.41	1.37	0.04
5,000	1.25	0.94	0.31	1.29	0.94	0.35	1.29	1.25	0.04
10,000	0.66	0.49	0.17	0.68	0.49	0.19	0.68	0.66	0.02

Table 7. Incremental testing cost reduction per hog in group by group size with a given confidence interval of 95%, margin of error at 2%, and *Salmonella* prevalence level at 5%.

Nbr of animals per group	Group size 500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000
500	-	-	-	-	-	-	-	-	-	-
1,000	$1.85	-	-	-	-	-	-	-	-	-
1,500	2.75	$0.90	-	-	-	-	-	-	-	-
2,000	3.28	1.44	$0.54	-	-	-	-	-	-	-
2,500	3.64	1.79	0.89	$0.35	-	-	-	-	-	-
3,000	3.89	2.04	1.14	0.61	$0.25	-	-	-	-	-
3,500	4.08	2.23	1.33	0.79	0.44	$0.19	-	-	-	-
4,000	4.22	2.38	1.47	0.94	0.59	0.33	$0.15	-	-	-
4,500	4.34	2.49	1.59	1.05	0.70	0.45	0.26	$0.12	-	-
5,000	4.43	2.59	1.68	1.15	0.80	0.54	0.36	0.21	$0.10	-

Table 8. Incremental testing cost reduction per hog in group by group size with a given confidence interval of 95%, margin of error at 2%, and *Salmonella* prevalence level at 7%.

Nbr of animals per group	Group size 500	1,000	1,500	2,000	2,500	3,000	3,500	4,000	4,500	5,000
500	-	-	-	-	-	-	-	-	-	
1,000	$1.93	-	-	-	-	-	-	-	-	
1,500	2.95	$1.02	-	-	-	-	-	-	-	
2,000	3.58	1.65	$0.63	-	-	-	-	-	-	
2,500	4.01	2.08	1.06	$0.43	-	-	-	-	-	
3,000	4.32	2.39	1.37	0.74	$0.31	-	-	-	-	
3,500	4.55	2.63	1.61	0.98	0.55	$0.24	-	-	-	
4,000	4.74	2.81	1.79	1.16	0.73	0.42	$0.18	-	-	
4,500	4.88	2.96	1.94	1.31	0.88	0.57	0.33	$0.15	-	
5,000	5.01	3.08	2.06	1.43	1.00	0.69	0.45	0.27	$0.12	

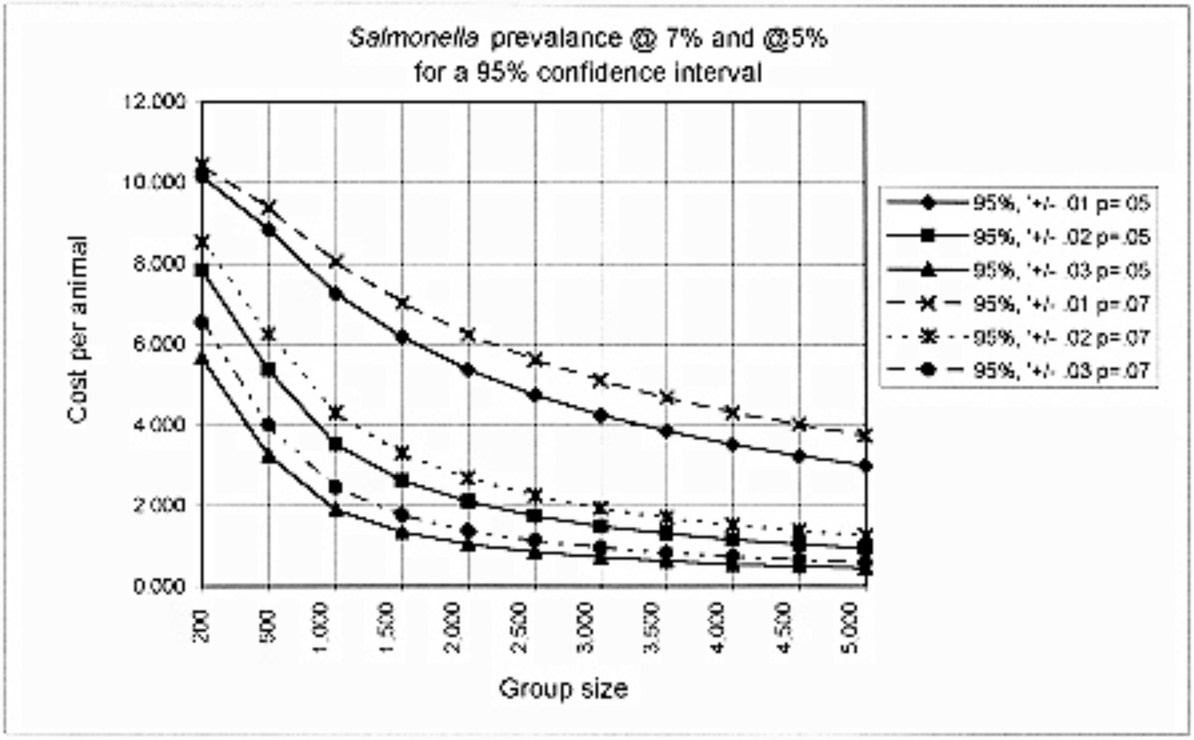

Figure 1. Salmonella testing cost per hog for selected prevalence levels and margins of error by group size for a 95% confidence interval.

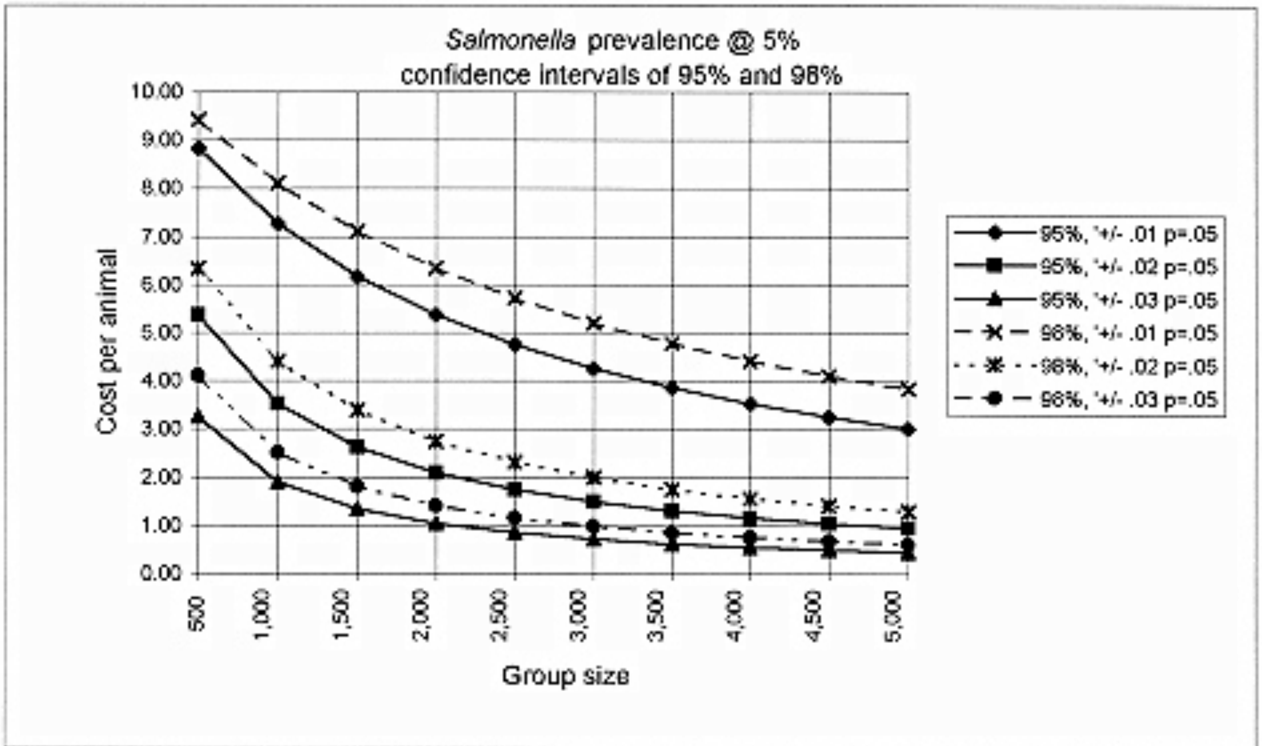

Figure 2. ***Salmonella*** **test costs for selected confidence intervals and margins of error for a 5% prevalence level.**