The Prevalance of Trichiniasis in Swine in the United States, 1966-70

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THE pork industry of the United States, in 1966, requested the development of a program to eliminate *Trichinella spiralis* from pork (*1*). Attention since that time has centered on the development of procedures which could be used as epidemiologic tools for various facets of a trichinae elimination program. These included the pooled sample method (*2, 3*) and modifications of the fluorescent antibody test (*4, 5*). Coincidental with the development of such a program, several questions had to be answered regarding trichiniasis in swine.

1. Does the reservoir in swine constitute a public health hazard?
2. Will the disease be eliminated from swine without the benefit of a specific program?
3. Is the disease at a readily attackable level?
4. Will the number of infected carcasses retained for special processing disrupt the highly mechanized packinghouse operations?

To answer the aforementioned questions, an "apportioned" national trichiniasis study for swine was carried out from November 1966 through October 1970. The results of the study are reported in this paper and, when compared with earlier studies, will indicate possible trends in the extent of trichiniasis in swine.

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Review of Literature

Trichiniasis in the United States can be best reviewed by categorizing swine into two groups, namely farm-raised and garbage-fed swine. Farm-raised swine, which comprise 98.5 percent of swine raised, predominantly are grain fed in the North Central areas, but in other areas, they may subsist on other vegetative foods. Unfortunately, the vegetative diet in all areas occasionally may be supplemented by the addition of kitchen scraps containing pork or by wildlife carcasses. In contrast, garbage-fed swine, which comprise about 1.5 percent of marketed swine, originate from commercial garbage-feeding establishments usually centered around coastal metropolitan areas. Pork scraps in garbage are a significant part of the diets of these pigs.

Data on slaughter of swine for 1965 indicated that 89.5 percent of the swine marketed were farm-raised butcher swine, 9 percent were farm-raised breeder swine, and 1.5 percent were garbage fed. Butcher swine generally weigh 175 to

220 pounds and are marketed when they are 4½ to 6 months of age. Breeder hogs can weigh as much as 400 pounds or more and generally are kept until they are about 4 years of age.

Trichiniasis in farm-raised swine has decreased markedly since the beginning of the century. Trichinoscopic examination of 8 million swine for export, primarily farm raised, between 1898 and 1906 revealed a prevalence of 1.41 percent (*6*). Another 1.16 percent contained trichina-like bodies. These figures are minimal because the trichinoscopic method detects few light infections. The U.S. Department of Agriculture began a series of studies in 1933 to evaluate the prevalence of *T. spiralis* in swine using the artificial digestion-Baermann technique, which will detect most light infections.

Schwartz (*7*) found trichinae in 0.95 percent of more than 13,000 swine examined during the 1930's. The prevalence decreased to 0.63 percent in 3,031 farm-raised swine examined during 1948–52. More recent national studies by Zimmermann and Brandly (*8*) in 1961–65 revealed a prevalence of 0.12 percent in 9,495 butcher-weight swine and 0.22 percent in 6,881 breeder swine. Therefore, in 30 years the rate of trichiniasis in farm-raised swine decreased from 9.5 per 1,000 to about 1.2 per 1,000, a decrease of about 87 percent.

Garbage-fed pigs have been considered the primary source of trichinous pork. In an early study, Mark found trichinae in 12.9 percent of 3,064 swine which had been fed offal, garbage, and swill containing pork scraps in Massachusetts (*9*). Since Mark used a 1 grain (one sixteenth gram) sample as contrasted to a normal 1 gram or less sample for trichinoscopic examination and a 50- to 100-gm. sample for digestion, Hall (*10*) projected the actual prevalence to be between 25 and 50 percent. Schwartz (*7*) reported finding trichinae in 5.7 percent of 10,000 swine fed raw garbage in the 1930's and in 11.2 percent of 1,328 raw garbage-fed swine in 1950.

In 1952, vesicular exanthema spread rapidly from California through the swine population of the United States. Regulations requiring the cooking of garbage were passed by most States during 1953–54. Coincidental to this program, trichiniasis in garbage-fed swine decreased abruptly. Schwartz (*11*) examined 5,723 swine that were fed cooked garbage during 1954–59 and found only 2.2 percent infected. Zimmermann and Brandly (*8*) found trichinae in 2.6 percent of 5,041 swine fed cooked garbage examined during 1961–65. During 1961, however, prevalences of 6.3 and 5.1 percent were obtained from two States that are large producers of garbage-fed swine, indicating a decrease in garbage cooking efficacy after vesicular exanthema had been eradicated.

A national hog cholera eradication program was initiated in 1962 with emphasis again placed on thorough cooking of garbage. By 1963, the prevalences in these two States had declined from 6.3 and 5.1 percent to 0.4 and 0.5 percent. A statistically designed national study by Jefferies and co-workers (*12*) in 1964–66 confirmed the lower rate with a statistically weighted prevalence of 0.5 percent.

Material and Methods

This study was made cooperatively by the Meat and Poultry Inspection Program, Consumer and Marketing Service, USDA, and the Veterinary

Table 1. Prevalence of *Trichinella spiralis*

Area	Percent total hogs raised, 1965	Percent samples received	Butcher (farm-raised)				Breeder (farm-raised)	
			Number examined	Number positive	Percent positive	Rate per 1,000 swine	Number examined	Number positive
New England	0.32	1.45	91	0	0	0	47	0
Middle Atlantic	1.18	2.89	646	0	0	0	12	0
East North Central	31.92	29.81	5,947	21	.35	3.5	720	0
West North Central	47.78	41.85	8,598	3	.03	.3	696	0
South Atlantic	7.72	7.10	1,453	0	0	0	114	0
East South Central	6.80	5.94	1,096	0	0	0	130	0
West South Central	2.44	4.12	890	1	.11	1.1	31	0
Mountain	1.27	4.07	728	0	0	0	60	0
Pacific	.94	2.77	369	0	0	0	48	0
Unknown			185	0	0	0		
Total			20,003	25	0.125±0.049 [1]	1.25	1,858	0

[1] 95 percent confidence level.

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For purposes of sampling, the United States was divided into nine regions, similar to those used by the Public Health Service. These regions with States included are as follows.

Region	*State*
New England	Maine, New Hampshire, Vermont, Massachusetts, Rhode Island, Connecticut
Middle Atlantic	New York, New Jersey, Pennsylvania
East North Central	Ohio, Indiana, Illinois, Michigan, Wisconsin
West North Central	Minnesota, Iowa, Missouri, North Dakota, South Dakota, Nebraska, Kansas
South Atlantic	Delaware, Maryland, District of Columbia, Virginia, West Virginia, North Carolina, South Carolina, Georgia, Florida
East South Central	Kentucky, Tennessee, Alabama, Mississippi
West South Central	Arkansas, Louisiana, Oklahoma, Texas
Mountain	Montana, Idaho, Wyoming, Colorado, New Mexico, Arizona, Utah, Nevada
Pacific	Washington, Oregon, California, Alaska, Hawaii

To obtain a representative sample of U.S. swine, the sample was apportioned according to two factors: (*a*) relative production of swine by State in 1965 and (*b*) current marketing ratios of swine classified by weight and feedstuffs.

Apportionment by production was adhered to with minor variations (table 1). The largest variation was for the West North Central area which produced 47.78 percent of the swine in 1965 and was represented by 41.85 percent of the sample. The East North Central area submitted 29.81 percent of the sample compared to 31.92 of the production. Differences between the production percentage and sample percentage for other areas varied between +2.80 percent for the Mountain region and —0.84 percent for the East South Central region.

The largest discrepancy in sample size was for Iowa, which produced 24.09 percent of the swine but only submitted 20.60 percent of the sample. Some of the minor hog producing States did not have federally inspected swine slaughter plants at the time of this study. Unless swine from these States were slaughtered in other States, they were not included in the study. States not included were New Hampshire, Connecticut, Vermont, West Virginia, Louisiana, Wyoming, Nevada, Hawaii, and Alaska.

The swine diaphragms were collected at random during assigned collection periods by personnel of the Federal Meat and Poultry Inspection Program. Three collection cycles were carried out during the 4-year study. The swine were identified whenever possible as to farm of origin, size of animal, and type of feeding program. The crural portion of the diaphragm was the preferred tissue for examination, but occasionally the costal portion of the diaphragm was substituted.

The sample was coated with boric acid powder, placed in an individual plastic bag, and forwarded to the Veterinary Medical Research Institute for examination using the artificial digestion-Baermann method (*13*). The samples examined usually weighed about 50 grams, but occasionally larger or smaller samples were used.

in swine by geographic areas

Garbage-fed			
Number examined	Number positive	Percent positive	Rate per 1,000 swine
190	1	0.53	5.3
0	0	0	0
25	0	0	0
10	0	0	0
28	0	0	0
0	0	0	0
4	0	0	0
126	0	0	0
207	2	.97	9.7
590	3	0.508±0.572 [1]	5.08

Results

A total of 22,451 swine diaphragms were examined during the 4-year period, November 1966 through October 1970. Included were 20,003 farm-raised butcher hogs, 1,858 farm-raised breeder hogs, and 590 garbage-fed hogs. The swine originated from 41 States. Samples from farm-raised swine originated from all nine geographic areas while garbage-fed swine diaphragms were obtained from seven areas. Farm-raised butcher swine comprised 89.1 percent of the sample, farm-raised breeder swine 8.3 percent, and garbage-fed 2.6 percent.

Of the 20,003 farm-raised butcher swine examined, 25 were infected, giving a rate of 1.25 pigs

per 1,000 marketed (table 1). Statistical analysis at the 95 percent confidence level indicated a prevalence of 0.125 ± 0.049 percent. All but one of the 25 infected swine came from the North Central regions, which are the major hog producing areas of the United States. The States from which the infected swine originated were Iowa, three swine, three herds; Illinois, two swine, one herd; Indiana, eight swine, three herds; Ohio, 11 swine, two herds; and Texas, one swine, one herd (table 2).

A single infected butcher hog was found in 1967, 11 in 1968, and 13 in 1970. The prevalence rates per 1,000 were 1966, 0; 1967, 0.2; 1968, 1.9; 1969, 0; and 1970, 3.3.

In contrast to results of an earlier study (*8*), 1,858 farm-raised breeder swine diaphragms were examined with negative results (table 1).

Three of the 590 garbage-fed hogs were infected, giving an infective rate of 5.08 per 1,000. Because of the small sample size, the 95 percent confidence level includes zero (0.508 ± 0.572 percent). The three infected swine represented two garbage-feeding establishments, one in Massachusetts during 1968, the other in California in 1970.

Seventeen (68 percent) of the 25 infected farm-raised swine had less than one trichina per gram of diaphragm, three contained one to 50 per gram, while five contained more than 50 per gram. Four of the five swine in the most heavily infected group, with counts of 340, 306, 260, and 138 trichinae per gram, originated from a single Ohio herd. The fifth diaphragm, containing 82 trichinae per gram, was from an Iowa swine.

The three infected garbage-fed pigs had counts ranging from 1.2 to 7.8 trichinae per gram of diaphragm.

Discussion

If prevalence rates obtained two to three decades ago are used as base parameters, trichiniasis has decreased sharply in U.S. swine. The rate for farm-raised butcher swine, which comprise about 90 percent of marketed swine, decreased from 9.5

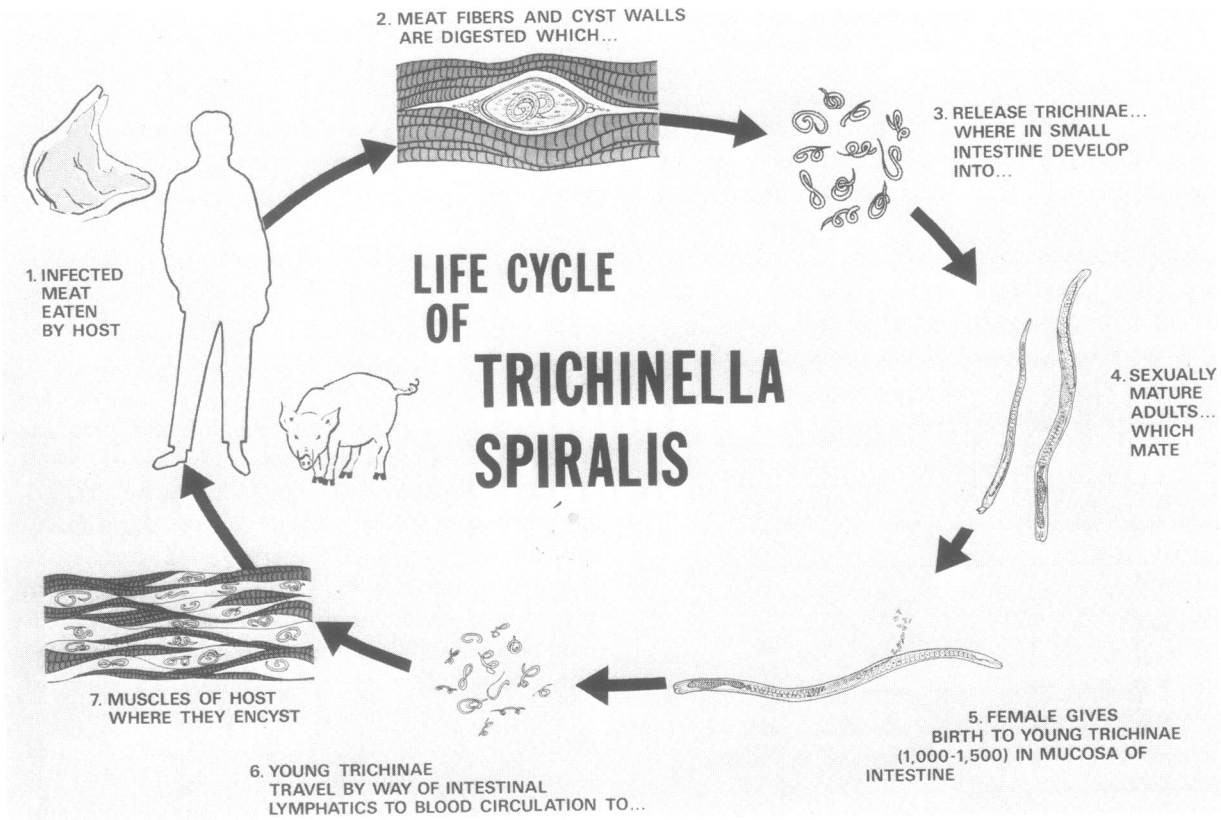
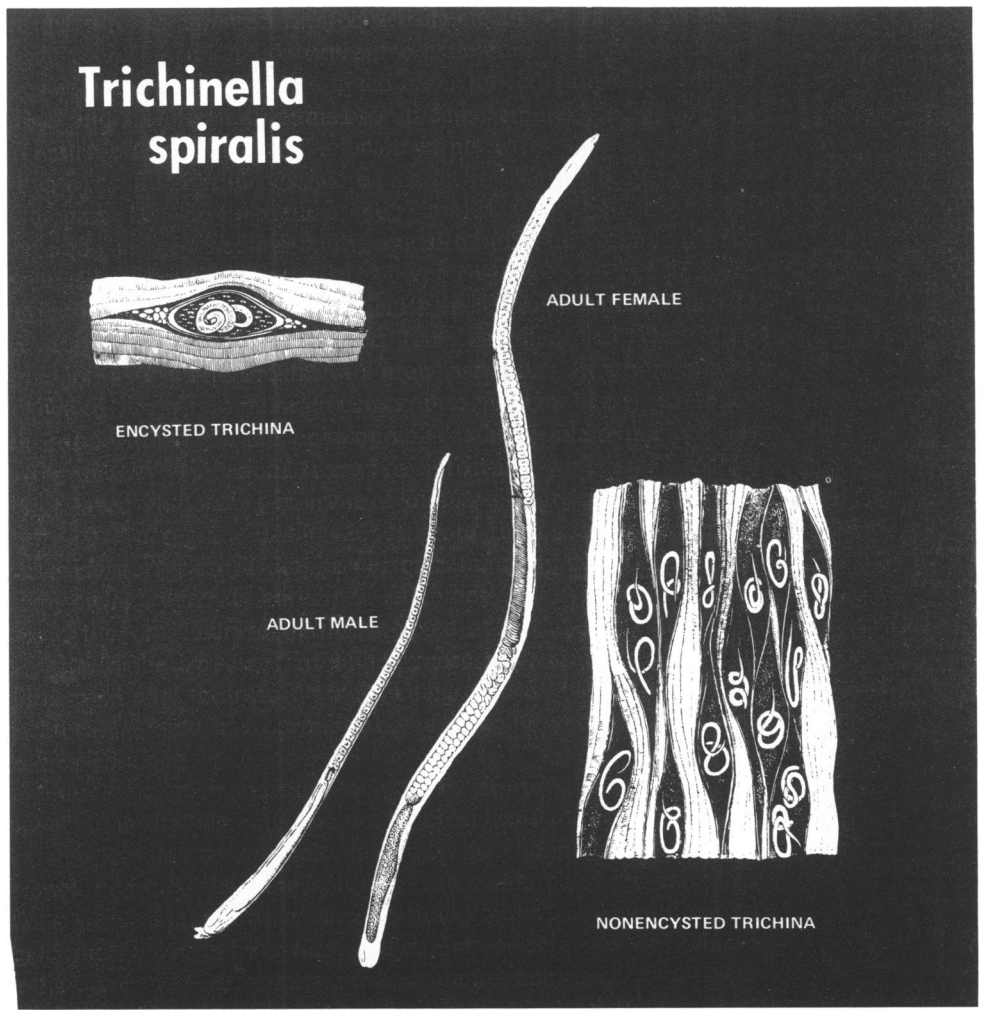


Table 2. Epidemiologic data for infected swine

Infected lot	State	Date	Type	Number samples per lot	Number positive	Trichinae counts per gram
1	Texas	November 1967	Farm-raised	98	1	8.9
2	Ohio	December 1967	Farm-raised	104	6	.42, .28, .25, .19 .12, .06
3	Massachusetts	March 1968	Garbage-fed	10	1	7.8
4	Indiana	December 1968	Farm-raised	33	4	20.2, .11, .08, .02
5	Indiana	December 1968	Farm-raised	20	1	.02
6	Indiana	January 1970	Farm-raised	50	3	.06, .06, .01
7	Ohio	February 1970	Farm-raised	5	5	340, 306, 260, 138, 10.2
8	Illinois	March 1970	Farm-raised	4	2	.53, .27
9	Iowa	June 1970	Farm-raised	2	1	.10
10	Iowa	June 1970	Farm-raised	2	1	.06
11	Iowa	June 1970	Farm-raised	2	1	82
12	California	August 1970	Garbage-fed	8	2	4.1, 1.2

infected swine per 1,000 in the 1930's to only 1.25 per 1,000 currently. The rate for garbage-fed swine similarly declined from 110 per 1,000 in 1950 to only 5.1 per 1,000 presently. Adding to the significance in the 5.1 per 1,000 rate is a 60 percent reduction in garbage-fed swine since 1955. As of January 1971, only 615,500 swine were being fed garbage and only 7,700 of these were fed raw garbage. Assuming that the lifespan of a garbage-fed swine approximates 6 months,

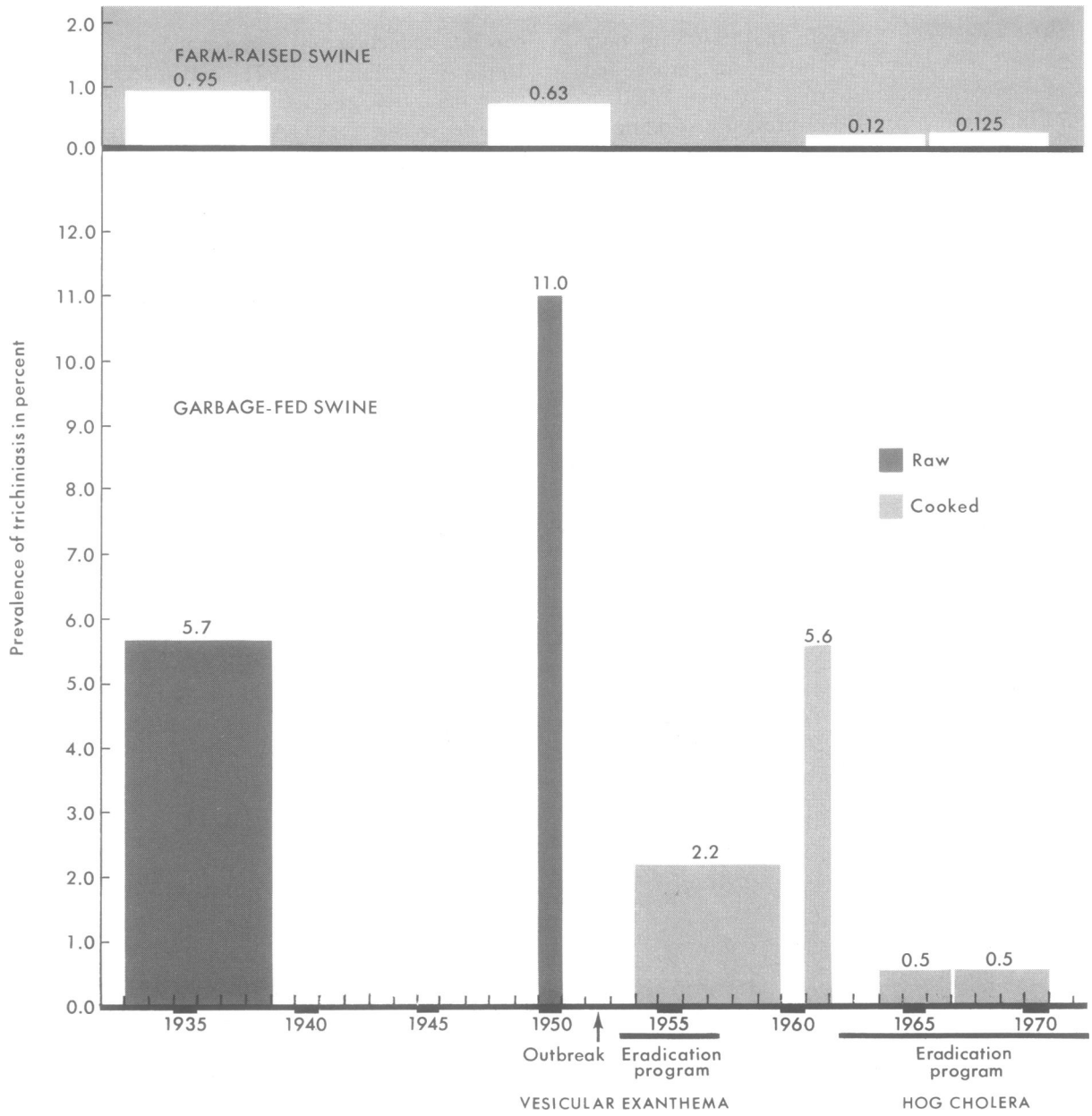


only 1,250,000 of the 85 million swine raised in the United States in 1971 were being fed garbage. At least six States—Wisconsin, South Dakota, Iowa, Illinois, Louisiana, and Alabama—have banned or soon will ban all feeding of garbage to swine.

Although major strides have been made in lessening the risk of the disease, certain aspects are still disturbing. First, the prevalence level apparently has reached a plateau during the past decade. The current infective rates are similar to those obtained during the first half of the decade (*8*). Even more disturbing is the infective rate for 1970, 3.3 pigs per 1,000, the highest of the decade. If this level is maintained, the potential health hazard to human beings would markedly increase.

Undoubtedly the greatest impact on the disease occurred in the 1940's and 1950's, when major decreases occurred as side effects of nontrichina-oriented programs. The primary effects resulted

Trends in the prevalence of trichiniasis in swine with relationship to swine disease eradication programs



from the vesicular exanthema eradication program in the 1950's which resulted in establishment of garbage cooking regulations (see chart). Other favorable changes resulted from development of swine management and feeding programs, widespread use of commercial and home freezers, and the decrease in home and noninspected commercial processing of pork.

The hog cholera eradication program started in the early 1960's, accompanied by reemphasis on garbage cooking, has been reflected in a further decline in trichiniasis. With the current evidence of a leveling off or possible upswing in prevalence, however, it is apparent that a specific trichina-oriented program will be necessary to eliminate the disease from swine and thus from man.

Second, although the prevalence rate and number of garbage-fed swine has decreased markedly, the potential for a major reversal still exists. Although the 95 percent confidence level for garbage-fed swine includes zero, the similarity of results to the larger and statistically valid 1964–66 study (*12*) would indicate that the current prevalence rate for garbage-fed swine is about four times that for farm-raised swine. This difference would indicate some garbage is not being cooked sufficiently to destroy all trichinae. Soon after vesicular exanthema was eradicated in 1957, the prevalence rate for garbage-fed swine increased nearly threefold. This upswing could occur again after hog cholera is eradicated if garbage cooking regulations are not strictly enforced. This reassertion could then produce a spillover into any farm-raised swine which are unofficially fed commercial garbage or table scraps.

Third, even with the current relatively low level of infection in swine, the risk still constitutes a hazard for man. This risk can be illustrated in two ways. Using current prevalences of 0.125 percent for farm-raised swine and 0.508 percent for garbage-fed swine with a marketing base of approximately 85 million swine indicates that about 105,000 farm-raised and 6,000 garbage-fed swine are infected with *T. spiralis* when marketed each year. If the 1970 rate of 0.33 percent for farm-raised swine is used, the infected reservoir would nearly triple.

The musculature of swine constitutes about 43 to 46 percent of the body weight of a 198-pound swine (*14*). Therefore, an average butcher-weight swine would have about 90 pounds of muscle. Assuming that a typical serving of pork contains one-fourth pound of muscle, an average infected market hog could expose about 360 human beings. This potential exposure level would increase if the pork were used in commercially prepared sausage where it is diluted with other pork or beef. Even at the exposure level of 360 meals per hog, the estimated current reservoir of 111,000 infected swine could cause about 40 million exposures per year.

Fortunately, home cooking, freezing, and processing under government inspection devitalizes most trichinae. Based on a recent national study of human beings, it is estimated that 120,000 to 300,000 persons are infected yearly in the United States (unpublished data by W. J. Zimmermann, J. H. Steele, and I. G. Kagan).

The risk of acquiring trichiniasis will persist until the disease is eliminated from swine. A recent outbreak in Missouri of 76 confirmed and 16 suspected cases indicates the potential health hazard (*15*).

The perpetuation of a reservoir of *T. spiralis* in swine is almost entirely dependent upon man. All the primary sources of infection, namely commercial garbage, household garbage, and wildlife carcasses usually must be made available to swine by man. This fact can be illustrated by the results of epidemiologic studies for the pilot study of the pooled sample method in Iowa which revealed probable sources of infection for six infected herds (*3*). These were table scraps, three herds; restaurant meat scraps and possible migration of dump rats to farm, one herd; and wildlife carcasses, two farms, including one belonging to a fur buyer. Thus, if all swine producers could be educated as to the hazard, trichiniasis would immediately lose its public health significance without the need to expend time and money for a specific elimination program.

Unfortunately, regulatory and education programs, as exemplified by current prevalences, have not proved entirely effective. Therefore, slaughterhouse detection of the disease in swine is the most logical, and from a public health standpoint, the safest approach to the problem.

At the current relatively low but still significant level, this disease is readily attackable. An effective elimination program, including slaughterhouse diagnosis, special processing of infected carcasses, and traceback to farm of origin should rapidly reduce trichiniasis to a level where the disease would no longer be considered a public health

problem. With the existence of a wildlife reservoir (*16*), it is recognized that continual followup monitoring of some type would be necessary to prevent a reoccurrence.

Several decades ago, with relatively high prevalence rates, trichinae inspection procedures may have interfered with efficiency of slaughterhouse operations because of necessary retainment and special processing for infected carcasses. The current low level only occasionally should cause operational difficulties. This lack of interference has been demonstrated by the pilot study of the pooled sample method in which up to 4,000 swine were slaughtered daily over an 8-month period with no interference of normal operations (*3*).

Although the prevalence rates are similar for the 1961–65 and 1966–70 studies, certain other dissimilarities are evident. In the current study, 24 of the 25 infected farm-raised swine originated from the North Central regions, although in the earlier study only 14 of 26 were from these regions. Thus, the disease is now centered in the major swine-producing areas of the United States where "official" garbage feeding is minimal. The four States from which the 24 infected swine originated produce about 50 percent of the nation's pork.

The findings for breeder swine are another major contrast. Since risk of exposure increases with age, it is common to find higher prevalence rates in older animals. This higher prevalence was evident in the 1961–65 study as farm-raised breeder swine had a prevalence of 0.22 percent, nearly double the 0.12 percent for the younger butcher swine (*8*). This relationship was not apparent in this study; in fact, no infected breeder animals were detected in the 1,858 examined. This variance may be due to the smaller size of the sample or to a quirk in sampling, since current swine management practices give no logical reason for this difference.

The intensity of infection in an animal, as indicated by trichina counts per gram of diaphragm, shifted upward in the current study. Levels of one trichina per gram or greater are considered significant since these levels produce clinical infection most often in man (*11*). During 1961–65, 11.5 percent of the infected farm-raised swine attained this level of infection (*8*), while currently this increased to 32 percent of the infections in farm-raised swine. Similarly, 40 percent of the detectable infections in garbage-fed swine examined during 1961–65 contained one or more trichinae per gram as compared with 100 percent discovered currently, although the 100 percent value represents only three animals. Thus more than 30,000 swine with significant infections may be marketed yearly.

Although current marketing procedures indicate that many of the sample lots examined in this study originated from two or more farms, therefore making interpretation of the data difficult, the results tend to indicate that swine trichiniasis is infecting fewer herds but that there is greater herd involvement. During the 1961–65 study, 26 farm-raised swine were infected. These were from 19 lots of pigs, 13 of which had a single infected pig, four had two positive samples, while one farm with two positive lots had five infected pigs. Although the infected animals in lots having many infected swine may have originated from more than one farm, this probability is minimal and the assumption can be made that the 26 swine positive for trichinae originated from about 18 farms. In contrast, the 25 infected farm-raised swine in this study represented only 10 lots, five with one positive, while the other lots contained two, three, four, five, and six infected animals each. This apparent reduction in farms with infected swine together with a reduction in positive lot size, two to 104 (median, 10) in this study and 11 to 110 (median, 55) in the 1961–65 study, tends to indicate greater herd involvement.

The finding of 100 percent prevalence in a lot of five samples from an identified Ohio herd (table 2, lot 7) drew particular attention because of the health hazard to human beings presented and the opportunity for an epidemiologic study. Four of the five infected swine had trichina counts of more than 100 per gram of diaphragm, the fifth, 10.2 per gram. Using an estimate that each trichina per gram of diaphragm of a butcher-weight swine represents about 9,000 other trichinae in the musculature of the infected swine (*17*), four of the carcasses contained more than a million trichinae, the fifth 90,000. Thus, any of these carcasses could have produced a major outbreak of trichiniasis.

Epidemiologic study indicated no garbage feeding of swine on the farm but two pet raccoons had died. Their carcasses had been laid next to the fence enclosing the swine and had been eaten. The raccoons were assumed to be the possible source of infection. Two months later, when 34 hogs from the same herd were marketed, examination revealed only one infected animal with 0.24 tri-

china per gram of diaphragm. The difference in prevalence and intensity between the two groups would probably substantiate the probability of a single or limited exposure of the swine herd to trichiniasis.

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A total of 22,451 swine diaphragms were examined for *Trichinella spiralis* from November 1966 through October 1970. The swine originated from all geographic regions of the United States. The sample was apportioned by (*a*) type of feeding program, (*b*) animal age, and (*c*) by State according to swine production. Results of the examinations revealed trichinae in 25 of 20,003 farm-raised butcher swine, none of 1,858 farm-raised breeder swine, and three of 590 garbage-fed swine.

Although the prevalences represent a marked decrease from those obtained in studies two to three decades ago, they are similar to those obtained in a 1961–65 study, indicating a possible leveling off of prevalence rates. The prevalence of 0.33 percent obtained during 1970 was the highest yearly rate of the decade.

Comparison with the 1961–65 study does indicate an increase in intensity of infection, more herd involvement, and increased concentration of the disease in the North Central regions.

Based on current production data, about 105,000 farm-raised swine and 6,000 garbage-fed swine may be marketed yearly with trichinae infections, giving about 40 million potential exposures for human beings.