The Current Status of Trichiniasis in U.S. Swine

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ALTHOUGH *Trichinella spiralis* was first recognized in man by Paget in 1835 and in swine by Leidy in 1844, trichinae in swine were not recognized as a human health hazard until 1859 when Zenker traced the source of a human outbreak to pork. Since that time, much attention has been given to *T. spiralis* and its eventual elimination as a human pathogen. It has long been recognized that the disease in swine results primarily from the feeding of raw or improperly cooked garbage to hogs. The role of rats in the trichiniasis cycle, once considered of primary importance, is now considered insignificant by some workers (*1*, *2*). The widespread occurrence of *T. spiralis* in wildlife has received increasing attention in the past two decades (*3*, *4*).

Trichiniasis has long been considered a public health problem in the United States. Frequent reference has been made to the 16.1 percent incidence in humans reported in studies from 1937 to 1944 (*4*). There are indications, however, of a decreasing prevalence of the disease in the U.S. human population since these studies. This paper reports current findings on the incidence of *T. spiralis* in U.S. swine and discusses other recent findings that may indicate a decrease of incidence in man.

Review of Literature

In trichinoscopic examinations of 8 million swine for export from the United States from 1898 to 1906, 1.41 percent (infective rate of 141 per 10,000 swine) were found infected with live *T. spiralis* larvae while another 1.16 percent contained trichina-like bodies (*5*). These swine were primarily grain fed. Routine trichinoscopic examinations of swine have not been made in the United States since 1906. However, periodic studies using the artificial digestion method have been made to determine the incidence in swine. (In trichinoscopic examinations, the sample size is generally 1 gram whereas in artificial digestion techniques the samples generally vary from 45 to 100 grams or more.) Schwartz began a series of studies in 1933 (*6*). Trichinae were found in 126 (0.95 percent) of more than 13,000 farm-raised pigs examined, giving an infective rate of 95 per 10,000 swine. The larvae counts were generally low, with nearly two-thirds of the infected samples containing 1 to 5 trichinae per 100 grams of muscle. Less than 25 percent contained 1 or more per gram. Schwartz, in later studies (*7*), found trichinae in only 0.63 percent of 3,031 diaphragms from midwestern swine. This was an infective rate of 63 per 10,000 swine.

Schwartz reported an incidence of 11 percent for 1,325 swine fed raw garbage, which were examined during 1950, while the incidence was 2.2 percent for 5,723 diaphragms from swine fed cooked garbage during 1954–59. The infective rates were 1,100 and 220 per 10,000 pigs respectively. In other studies, Kerr (*8*), in California, reported incidences of 0.5 percent in grain-fed swine, 6.4 percent in raw garbage-fed swine, 8.3 percent in swine fed raw offal, and 5.4 percent in swine fed cooked offal. McNaught and Zapata (*9*) found trichinae in 4 percent of 495 garbage-fed pigs in San Francisco. Turner, in Alabama, reported an in-

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cidence of 0.51 percent from 791 garbage-fed swine, while 381 nongarbage-fed pigs were negative (*10*). Peres (*11*) examined 516 pigs from southern United States with negative results.

Studies were conducted by Zimmermann and associates (*12*) to determine the incidence in Iowa swine during 1953–57. Six (0.17 percent) of 3,597 swine diaphragm samples were found to contain trichina larvae. Two of the infections were heavy, containing 1,289 and 467 larvae per gram of diaphragm. A third contained 1.3 larvae per gram while the other three samples contained less than 1 larva per gram.

A recent report by Rothrock (*13*) revealed a major trichiniasis problem in an Iowa swine herd. In special trichinoscopic examination of pork to be exported to Portugal, 3 of 482 swine slaughtered on June 15, 1964, were found infected with *T. spiralis*. Subsequent examination of the three infected samples by the artificial digestion-Baermann method revealed trichinae per gram counts of 4,561, 255, and 18.9. (These examinations were made at the Veterinary Medical Research Institute, Iowa State University of Science and Technology. They are not included in the studies presented in this report, however, since only those samples positive by trichinoscopic examination were sent for evaluation. Inclusion of these selected positive samples would, therefore, have distorted the results of the study.) An extensive followup investigation by the Animal Disease Eradication Division, Agricultural Research Service, U.S. Department of Agriculture, included visits to 35 farms. Extremely poor sanitation and swine-management practices were found on one farm. Subsequent examinations of eight swine from this farm revealed three infected animals with trichinae per gram counts of 1,451, 190, and 2,400. Limited examination of rats and mice from the premises yielded negative results.

Methods

A study was initiated in April 1961 to determine the incidence of *T. spiralis* in U.S. swine. The study was a cooperative project between the Meat Inspection Division, Consumer and Marketing Service, U.S. Department of Agriculture, and the Veterinary Medical Research Institute, College of Veterinary Medicine, Iowa State University of Science and Technology. Swine diaphragms were collected by personnel of the Meat Inspection Division. The crural portion of the diaphragm was obtained when available. Swine were identified, where possible, as to origin and type of feeding program. The swine diaphragms were coated with boric acid powder, placed in individual plastic bags, and forwarded to the Veterinary Medical Research Institute for examination by the artificial digestion-Baermann method (*14*). The preferred sample size was 45 grams, although occasional smaller samples were examined.

The swine were classified as (*a*) farm-raised butcher hogs, (*b*) farm-raised breeder hogs, and (*c*) garbage-fed hogs. The garbage-fed hogs, which came from areas where cooked garbage is the predominant swine feed, consisted of both butcher type and breeder type. Farm-raised swine are generally grain fed in the Midwest swine-raising area, but may subsist on other feeds in other U.S. areas. Butcher hogs generally weigh 175–220 pounds and are 4½ to 6 months of age. Breeder hogs are generally 1½ to 5 years of age. The national marketing ratio for the three groups of swine in 1963 was approximately 89.5 percent farm-raised butcher, 9.0 percent farm-raised breeder, and 1.5 percent garbage-fed.

Results

A total of 21,417 swine diaphragms were examined from April 1961 through March 1965: 9,495 farm-raised butcher hogs, 6,881 farm-raised breeder hogs, and 5,041 garbage-fed hogs. The swine originated from at least 24 States in all 9 geographic areas. However, not all types of hogs were obtained from each geographic area.

The results of these examinations indicate that the current incidence of *T. spiralis* in farm-raised swine is low (table 1). Of the 9,495 diaphragms from farm-raised butcher hogs, only 11 (0.12 percent) were infected with *T. spiralis*. This is an infective rate of 12 per 10,000 pigs. The five infected samples (1.1 percent) from the Pacific States came from one farm, and two of three lots of pigs examined from this farm were infected. The majority of U.S. pigs are raised in the West North Cen-

tral and East North Central Regions, and the incidences for these regions are 0.06 percent and 0.08 percent respectively.

A slightly higher incidence was obtained for the 6,881 farm-raised breeder swine: 15 (0.22 percent) were infected (table 1). Infected breeder swine were obtained from five of eight geographic areas. The maximum incidence was 0.39 percent from the East North Central Region, followed by 0.36 percent from the Middle Atlantic Region. No infected breeder diaphragms were obtained from the West North Central Region.

In contrast to the relatively low incidence of trichinae in farm-raised swine, a markedly higher incidence was observed among the 5,041 garbage-fed swine; 2.6 percent (table 1). By area, the incidences were: Pacific, 4.1 percent; West South Central, 2.9 percent; New England, 2.7 percent; and Middle Atlantic, 2.7 percent.

The larvae per gram counts for the infected farm-raised swine were generally low (table 2). All the 11 infected butcher swine diaphragm samples contained less than 1 larva per gram, as did 12 of the 15 positive breeder swine samples. Of the remaining three infected breeder samples, one contained 167 larvae per gram; one, 68.9 larvae per gram; and one, 1.3 larvae per gram.

The concentration of trichina larvae in diaphragms of garbage-fed swine was heavier than in those of farm-raised swine. Of the 131 infected samples, 79 (60.2 percent) contained less than 1 larva per gram, 30 contained 1–10, 10 contained 11–50, and 9 contained 50–500. The remaining three samples had 866, 912, and 2,800 larvae per gram.

Although the overall incidence rate of *T.*

Table 1. Incidence of Trichinella spiralis in swine, April 1961 through March 1965, by geographic areas

Area	Farm-raised								Garbage-fed			
	Butcher				Breeder							
	Number examined	Number positive	Percent positive	Rate per 10,000 swine	Number examined	Number positive	Percent positive	Rate per 10,000 swine	Number examined	Number positive	Percent positive	Rate per 10,000 swine
New England	0	0	0	0	0	0	0	0	2,292	63	2.7	270
Middle Atlantic	55	0	0	0	550	2	.36	36	1,114	30	2.7	270
East North Central	2,556	2	.08	8	2,547	10	.39	39	0	0	0	0
West North Central	3,400	2	.06	6	2,026	0	0	0	0	0	0	0
South Atlantic	992	0	0	0	687	1	.15	15	0	0	0	0
East South Central	700	0	0	0	128	0	0	0	300	0	0	0
West South Central	823	2	.24	24	516	1	.19	19	68	2	2.9	290
Mountain	503	0	0	0	397	1	.25	25	395	0	0	0
Pacific	466	5	1.1	110	30	0	0	0	872	36	4.1	410
Total	9,495	11	0.12	12	6,881	15	0.22	22	5,041	131	2.6	260

Table 2. Degree of infection in diaphragms of swine examined for Trichinella spiralis

Type of swine	Number examined	Number positive	Trichinae per gram				
			<1	1–10	11–50	50–500	>500
Farm-raised:							
Butcher	9,495	11	11	0	0	0	0
Breeder	6,881	15	12	1	0	2	0
Garbage-fed:							
Butcher and breeder	5,041	131	79	30	10	9	3

spiralis is high in garbage-fed swine, certain trends were noted during the years of this study. Three sampling periods were used for State A in the New England area (table 3). During the initial sampling period of March–June 1961 (*15*), an incidence of 6.3 percent was observed. Subsequent samplings revealed a sharply declining incidence: 1.9 percent from November 1962 through January 1963, and only 0.4 percent from November 1963 through February 1964.

A similar decline was noted for State B in the Middle Atlantic Region. The initial sampling during May to July 1961 yielded a 5.1 percent incidence, while a second sampling 1½ years later, December 1962 to January 1963, revealed only a 0.5 percent incidence.

Table 3. Trends in incidence of Trichinella spiralis in garbage-fed swine of two States

Sampling dates	Number sampled	Number positive	Percent positive
State A (New England area):			
March–June 1961	800	50	6.3
November 1962–January 1963	421	8	1.9
November 1963–February 1964	991	4	.4
State B (Middle Atlantic area):			
May–July 1961	505	26	5.1
December 1962–January 1963	560	3	.5

Discussion

The presence of *T. spiralis* in U.S. swine has long been a major problem from both the economic and the public health standpoint. Importation of U.S. pork products has been prohibited by many countries, partially because of the stigma that the possible presence of *T. spiralis* has produced. Only since 1963 has the market for pork expanded outside the United States; then only after the pork has undergone trichinoscopic inspection. The finding of the 16.1 percent incidence in the U.S. human population during 1937 to 1944 and the statement by Stoll (*16*) that the United States has three times as many cases of trichiniasis as the rest of the world combined, has helped to underline the public health aspects of the problem.

There are indications, however, that the public health aspects of this problem have decreased markedly since 1937–44. This viewpoint is supported by several reports and findings. During the 5-year period, 1944–48, 1,999 cases of human trichiniasis were reported for the United States (*17*) while during 1959–63, only 1,065 cases (excluding Hawaii and Alaska) were reported (*18*). This is nearly a 50 percent reduction. A marked reduction has been noted for the prevalence of *T. spiralis* in pork products available in Iowa. Zimmermann and associates (*14*) reported an incidence of 12.4 percent in bulk pork sausage during 1944–46, while 1953–60 studies revealed only a 1.0 percent incidence.

A comparison of the results obtained in the study reported here with some of the previously cited earlier studies on the incidence in swine will give additional credence to the thought that strides are being made in decreasing the problem in swine and thus decreasing the public health aspects of the disease. This is especially applicable to the decrease in prevalence in farm-raised pigs. The current infective rate of 12 per 10,000 farm-raised butcher pigs is more than a 90 percent decrease from the trichinoscopic findings obtained during 1898–1906 when the infective rate was at least 141 per 10,000 pigs. Also, most trichinoscopic methods use a 1-gram or smaller sample; therefore, samples containing less than 1 larva per gram may not be detected by trichinoscopes. In the current series, all of the farm-raised butcher samples contained less than 1 larva per gram.

The current infective rate of 12 per 10,000 farm-raised butcher swine indicates a marked decrease, even when compared with the recent infective rates of 95 and 63 per 10,000 in farm-raised swine reported by Schwartz (*6*, *7*).

In the study reported here, 2,281 Iowa swine had an incidence of 0.044 percent. This infective rate of just over 4 pigs per 10,000 indicates more than a 70 percent decrease from the 1953–57 series when the infective rate was 17 per 10,000 pigs. This finding is counteracted somewhat by the previously cited report of Rothrock (*13*), who reported a major trichiniasis focus in an Iowa swine herd. The finding of 4,561 larvae per gram in one sample is more than 1½ times the maximum of 2,800 found in garbage-fed

swine. Problem herds such as this, primarily the result of poor management, point up the need for more thorough education of the swine producer in regard to the potential danger of the disease. The probable primary reason for the trichinae buildup in the Iowa swine was that they were allowed to feed on swine carcasses. The potential danger of swine feeding on wildlife carcasses should also be emphasized, since studies have shown that at least 14 species of wildlife native to Iowa are reservoirs for the disease (*3*, *19*).

Such findings indicate that isolated major problem herds can exist even in areas where the prevalence of trichinae in swine is extremely limited. This emphasizes the importance of the regulations of the Meat Inspection Division in order to assure the consumer that ready-to-eat products from infected animals are safe. Most outbreaks of trichiniasis are traced to home processed or locally processed pork products. There is a need for re-evaluating regulations for the processing of pork destined for intrastate commerce which is generally not under the Meat Inspection Division.

Although the incidence obtained in this study for swine fed cooked garbage is similar to that obtained by Schwartz in 1954–59, there are indications that the role of garbage-fed swine in the perpetuation of trichiniasis is declining. One indication is a decline in the number of garbage-fed pigs. In January 1955, 374,213 pigs were being fed raw garbage and 1,009,830 pigs were being fed cooked garbage in the 48 States. Ten years later, in January 1965, these totals had declined to approximately 10,795 swine fed raw garbage and 860,576 swine fed cooked garbage. The January 1965 total includes estimates for Texas. These totals represent an approximate reduction of 97 percent in raw garbage feeding and a 15 percent reduction in cooked garbage feeding during the 10-year period.

In addition to the declining number of pigs being fed garbage, the trends noted during the nearly 4 years of the study indicate that progress is being made in decreasing the incidence of trichiniasis in garbage-fed swine. The marked decline in incidence, from 6.3 percent in March–June 1961 to 0.4 percent during November 1963 to February 1964, for garbage-fed swine of State A (table 3) probably reflects rigid enforcement of State regulations. Although the cooking of garbage fed to swine in State A has been required since 1954, rigid enforcement did not begin until 1961. Since that time, compliance with the requirement has gradually improved, and at present it is generally good throughout the State. The decline in State B is attributed to improved methods of cooking garbage, better equipment, improved sanitation, and a continuing education program to emphasize the importance of cooking garbage properly (personal communication, J. C. Jefferies, staff veterinarian, U.S. Department of Agriculture, March 4, 1965).

To evaluate these downward trends more fully, a statistically designed study to determine the current national incidence of *T. spiralis* in garbage-fed swine was started in July 1964. This cooperative project of the Animal Disease Eradication Division, the Meat Inspection Division, and the Animal Disease and Parasite Division of the U.S. Department of Agriculture with the Veterinary Medical Research Institute, is still in progress.

Although the elimination of garbage feeding entirely would probably reduce the prevalence of *T. spiralis* in swine, this would be difficult to enforce and would lead to major problems in garbage disposal for metropolitan areas. This would also place economic sanctions on the garbage feeding segment of the swine industry. If the relatively small number of pigs listed as being fed raw garbage is used as an indicator, this would indicate that most garbage feeding establishments are generally complying with the State and Federal garbage cooking regulations. This indicates a need for re-evaluation of cooking procedures as well as intensive studies to determine the role of wildlife and other possible sources of infection in perpetuating the disease in garbage-fed swine.

A study of the concentration of larvae per gram is also of value in evaluating the trends in trichiniasis. Schwartz considered trichinae counts of less than 1 per gram as relatively insignificant. All of the infected farm-raised butcher diaphragms and 12 of 15 farm-raised breeder samples fell in this category or, conversely, only 3 (0.018 percent) of 16,376 farm-raised swine examined in this study had "significant" infections, and 1 of these 3 swine had

only 1.3 larvae per gram. Schwartz obtained a significant infection rate of about 0.15 percent.

A higher rate of significant infections was noted for garbage-fed swine, with 39.8 percent of the positive samples containing 1 or more per gram. On a total sample basis, 52 (1.03 percent) of 5,041 garbage-fed swine had significant infections. Schwartz obtained a rate of about 1.1 percent for swine fed cooked garbage.

Summary

A total of 21,417 swine diaphragms were examined for *Trichinella spiralis* from April 1961 through March 1965. The swine were from all geographic areas of the United States.

Results of the examinations indicated that the current incidence of *T. spiralis* in farm-raised pigs is low; only 0.12 percent of 9,495 butcher swine and 0.22 percent of 6,881 breeder swine were infected. The incidence in garbage-fed pigs is markedly higher; 2.6 percent of 5,041 diaphragm samples contained trichinae. Although the overall incidence for garbage-fed swine is high, trends were noted which may indicate a decline in incidence. During this approximately 4-year study, the incidence for garbage-fed swine in a New England State declined from 6.3 percent to 0.4 percent, and in a Middle Atlantic State it decreased from 5.1 percent to 0.5 percent.

The larvae per gram counts for the farm-raised pigs were low; 23 of 26 infected diaphragm samples contained less than 1 larva per gram. For garbage-fed swine, the concentration of larvae per gram was higher; only 79 of 131 infected samples contained less than 1 larva per gram. Each of three diaphragms from garbage-fed swine contained more than 500 larvae per gram; the maximum was 2,800.

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