

Pork Safety Fact Sheet

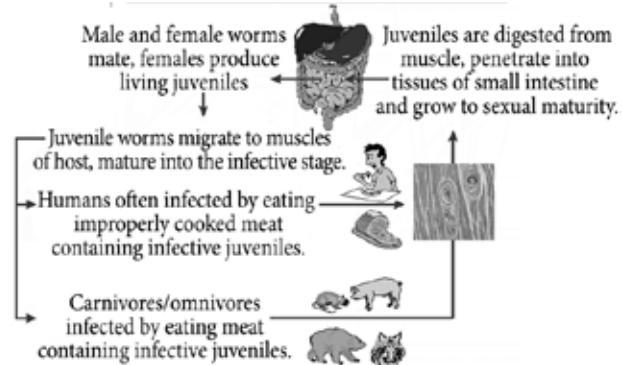


Trichinella

Introduction

Trichinella spiralis is a parasitic nematode (roundworm) which is found in many warm-blooded carnivores and omnivores, including pigs. *Trichinella* has a direct life cycle, which means it completes all stages of development in one host (Figure 1). Transmission from one host to another can only occur by ingestion of muscle tissue which is infected with the encysted larval stage of the parasite (Figure 2). When ingested, muscle larvae excyst and enter tissues of the host's small intestine, where they undergo development to the adult stage. Adult male and female parasites mate and produce newborn larvae which leave the intestine and migrate through the circulatory system to striated muscle tissue. There, the larvae penetrate a muscle cell, which is modified by the parasite into a unique cyst structure. In the muscle, *Trichinella* larvae mature to become infective for another host. The total time required for this development is from 17 to 21 days. Adult worms continue to produce larvae for several weeks before they are expelled. Once larvae encyst in musculature, they can remain alive and infective for years. An animal that is infected with *Trichinella* is at least partially resistant to a subsequent infection due to a strong and persistent immunity.

Figure 1. Life cycle of *Trichinella spiralis*.



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Trichinella and Pork

Trichinella was first recognized as a human parasite in 1835, but the source of human infection was not linked to pork until 1860. Soon after the discovery of pork as the source of human trichinellosis, countries in Europe implemented inspection programs, whereby tissue from pig carcasses was examined microscopically for *Trichinella*. These inspection methods originated in Germany and spread throughout most of Western Europe by the end of the 19th century. The U.S. did not implement slaughter inspection at the time because trichinellosis was not widely reported. However, the lack of testing soon became a trade issue for the U.S. and in 1892 testing was implemented for pork products that were exported to Europe. This testing continued until 1906, when it was determined that testing was no longer cost effective for the U.S. industry.

Slaughter testing and other surveillance studies performed in the early part of the 20th century demonstrated that *Trichinella* was present in approximately 1.5% of pigs slaughtered in the U.S. It is likely that the prevalence was even higher since the method used to test could only detect heavy infections.

Surveys conducted 30 years later (1933-1937) found prevalence in grain-fed pigs to be about 1%, but in garbage-fed pigs, the prevalence rate was 5.7%. A National Institute of Health report published in 1943 found 16.2% of the human population of the U.S. was infected (1 out of every 6 people). This information led to considerable publicity on the dangers of eating undercooked pork. Reports of high prevalence in garbage-fed pigs continued, reaching 11.2% in surveys conducted between 1948 and 1952. This substantial risk from *Trichinella* infection in pigs was responsible for USDA rules on methods used to prepare ready-to eat pork products.

Major changes have occurred in the management of pigs over the last 50-60 years which have resulted in a significant reduction of risk from *Trichinella*. Of great importance was the introduction of garbage cooking laws passed to eliminate vesicular exanthema in swine (1953-1954) and the hog cholera eradication program (1962). Of equal importance has been the movement to high levels of biosecurity and hygiene under which most pigs are now raised.

While the exact numbers of confinement-type pork production systems are not readily available, data on the size and management of swine herds demonstrates that the vast majority of U.S. pigs are produced under conditions where risk of exposure to *Trichinella* does not exist. The most recent USDA National Animal Health Monitoring Survey (2006) reported that only 1.0% of U.S. hogs are from herds of less than 100 head while 90% are from herds of 1000 hogs or more. Further, the percentage of operations using all in/all out management was 70.8% in 2006 as compared with 24.9% in 1990. Based on consolidation of pork production into large scale, intensively managed production systems, which preclude exposure of pigs to potential risk factors for *Trichinella*, the vast majority of U.S. hogs may be considered to be in the category of negligible risk. In fact, testing of large numbers of animals through national surveys and in-plant testing of pigs destined for export have failed to identify a single positive animal since 1994.

The decline and virtual disappearance of *Trichinella* from commercial pork is substantiated by reports of human infections. In the U.S., human trichinellosis is a notifiable disease reportable to the Centers for Disease Control. In the period from 2002 to 2007 an average of 1.7 cases per year were reported with domestic pork as the likely source of infection. Of these cases, only one case per year, on average, was linked to commercial pork (defined as "pork purchased at supermarkets, butcher shops, or restaurants"). Thus, based on the population of the U.S. and the number of cases reported to the CDC, the risk of acquiring human trichinellosis from commercial pork in the U.S. in the years between 2002 and 2007 was 1 in 285 million.

Epidemiology

Several species of *Trichinella* are found in warm-blooded carnivores, omnivores and raptorial birds. In North America, there are five known species or types of *Trichinella*. These include *Trichinella spiralis*, *T. nativa*, *T. pseudospiralis*, *T. murrelli*, and *Trichinella* T-6. *Trichinella spiralis* is a relatively recently introduced species which was brought to the U.S. in infected swine with European colonists. It is most commonly associated with domestic pigs, and is found in wildlife only where there is a current or historical occurrence of this parasite in pigs. The other species and types mentioned have low relative infectivity for pigs and are primarily of importance because they occur in game animals. Recent studies have shown that *T. murrelli*, and not *T. spiralis*, is the predominate species infecting sylvatic (wild) mammals in the U.S.; T-6 has been found in bears and other wildlife in the Northwestern U.S., while *T. nativa* has been found in a variety of carnivores in Alaska and northern New England. Both *T. nativa* and *Trichinella* T-6 are resistant to freezing. *Trichinella pseudospiralis*, a species that does not encyst in host musculature, has been reported infrequently from birds and wild mammals, but can also infect pigs.

Exposure of domestic pigs to *Trichinella* is limited to just a few risk factors which include: feeding of animal waste products contaminated with *Trichinella* larvae; exposure to and consumption of muscle tissue from living or dead rodents or other wildlife infected with *Trichinella*; or cannibalism among pigs within an infected herd. Other means of transmission such as tail biting or coprophagy are not important.

When transmission of *Trichinella* to pigs does occur, a simple evaluation of farm management practices can determine the way in which pigs have become infected. Since it is illegal to feed raw garbage to pigs, this source of infection should never be an issue. Feeding of any raw or undercooked meat scraps, including table waste, could pose a risk, but it is unlikely as *Trichinella* occurs so rarely in U.S. pigs. Exposure of pigs to infected rodents and wildlife poses the highest risk of infection. Rats, in particular, serve as both a reservoir host and as a bystander host for *Trichinella* infection on infected pig farms. Rodents can pick up infection from landfills, carrion, or from infected pig carcasses. When rat populations are in close contact with pigs, it is possible that either dead or live rats will be caught and eaten. If the rat is infected with *Trichinella*, then *Trichinella* infection of the pig will occur. The same type of risk holds true for other small mammals. Pigs that have access to the outdoors will occasionally encounter animal carcasses which they might eat. Raccoons, skunks, and opossums which frequent the environment near pig farms can have high prevalence rates for *Trichinella*. By taking the following steps, risk of exposure of pigs to *Trichinella* will be greatly reduced:

- Do not feed uncooked waste products, table scraps or animal carcasses to pigs. This is particularly important in the case of carcasses from hunted or trapped wildlife.
- Eliminate or minimize exposure of pigs to live wildlife. Create barriers which are effective in separating pigs from skunks, raccoons and other small mammals.
- Implement and maintain an effective rodent control program. Biosecurity, maintaining perimeters, baiting and trapping are all part of rodent control. See "An Overview of Rodent Control for Commercial Pork Production Operations" (<http://www.pork.org/filelibrary/Biosecurity/BiosecurityBook.pdf>)
- Maintain good hygiene. Remove dead pigs as soon as they are found. Keep barns free from clutter and feed stored securely. The use of good production/management practices for swine husbandry will preclude most risks for exposure to *Trichinella* in the environment.

Control

There are a variety of ways in which *Trichinella* control is approached. Many countries require slaughter testing of individual carcasses. For pork exported to the European Union, Russia, and some other countries, U.S. packers are

required to test carcasses using the same slaughter testing methods employed by European and Russian meat inspectors. This testing is performed through the USDA Agricultural Marketing Service's Trichinæ Export Testing Program.

In the U.S. domestic market, the traditional approach for *Trichinella* control has been strict requirements for post-slaughter processing of ready-to-eat products to inactivate *Trichinella* larvae and guidance to consumers regarding the proper temperature to cook fresh pork. Pending changes in food safety regulations (9 CFR 318.10) may soon require packers to include *Trichinella* as a hazard in their HACCP plan. Packers will then have the option of further processing if *Trichinella* is considered a risk in pigs that are slaughtered in their plant. Alternatively, pork from pigs that have tested negative for *Trichinella*, or from pigs that come from *Trichinella*-free herds, will be exempt from further treatment.

The following discussion summarizes individual pig carcass testing and processing methods that are used to prevent risk of human exposure to infected pork post-slaughter, followed by a section describing how documenting good management practices can be used to demonstrate absence of risk for exposure to *Trichinella* during pork production.

Post-Harvest Testing

Despite the very low prevalence of *Trichinella* in pigs in most developed countries, considerable energy goes into individual carcass inspection. These efforts are largely a continuation of measures implemented when *Trichinella* was a serious problem. In countries where slaughter inspection programs are required, these requirements are often used as trade barriers against countries that do not inspect for *Trichinella*.

It is not possible to see *Trichinella* cysts within meat tissue by macroscopic examination, so inspection of meat requires a laboratory test which allows microscopic visualization. The method of choice, and that approved in many regulations governing inspection of pork, is the pooled sample digestion method. Samples of tissue collected from sites where parasites concentrate, such as the diaphragm, masseters or tongue, are subjected to digestion in acidified pepsin. Larvae, which are freed from their muscle cell capsules by this process, are recovered by a series of settling steps, then visualized and counted under a microscope. Requirements for performing the digestion test are found in the Directives of the European Economic Community, in the U.S. Code of Federal Regulations, and various other publications.

Since 1994, the USDA Agricultural Marketing Service has managed a slaughter testing program for pork exports. Trading partners who require testing for *Trichinella* include the EU, Russia and Singapore. In the period from 1984 to 2012, over 43 million pigs were tested using the pooled sample digestion method, with no positive findings for *Trichinella* infection.

An alternative method of testing pigs for *Trichinella* infection is an indirect method which looks for antibodies to the parasites in pig blood. This test, called the ELISA, has been used extensively for testing in both pre- and post-slaughter applications and is an extremely useful tool for determining or monitoring infection in herds, but is not recommended for slaughter testing since infection can be present in the pig for several weeks before antibodies are present in the blood.

Post-Harvest Processing

Where fresh pork is not tested for *Trichinella*, as is the case in the U.S., alternative methods are used to prevent exposure of humans to potentially contaminated product. Companies who produce ready-to-eat (RTE) pork products must take steps to mitigate this potential hazard. Treatment of RTE products must be validated for their effect on *Trichinella* larvae. Many treatments including cooking, freezing, and curing have already been validated for commercial processors, and these methods are in common use. For fresh pork, guidance is provided to consumers by the USDA on proper handling and cooking to ensure safety.

Cooking - Commercial preparation of pork products by cooking requires that meat be heated to internal temperatures that have been shown to inactivate *Trichinella* larvae. For example, *Trichinella spiralis* is killed in 47 minutes at 52° C (125.6° F), in 6 minutes at 55° C (131° F), and in < 1 minute at 60° C (140° F). It should be noted that these times and temperatures apply only when the product reaches and maintains temperatures evenly distributed throughout the meat. Alternative methods of heating, particularly the use of microwaves, have been shown to give variable results, with parasites not completely inactivated when product was heated to reach a prescribed end-point temperature. The U.S. Code of Federal Regulations for processed pork products (9CFR318.10) is based on scientific data, and requires pork to be cooked for 2 hours at 52.2° C (126° F), for 15 minutes at 55.6° C (132° F), and for 1 minute at 60° C (140° F).

The U.S. Department of Agriculture recommends that consumers of fresh pork cook the product to an internal temperature of 63.8° C, or 145° F followed by a 3 minute rest. Ground product requires higher temperatures - 71.1° C or 160° F. Although these temperatures are higher than temperatures at which *Trichinella* larvae are killed (about 55° C or 131° F), they allow for different methods of cooking which do not always result in even distribution of temperature throughout the meat. It should be noted that heating to 77° C (171° F) or 82° C (180° F) was not completely effective when cooking was performed using microwaves.

Freezing – Scientific studies have been conducted to determine the effect of cold temperatures on the survival of *T. spiralis* in pork. Predicted times required to kill *Trichinella* larvae were 8 minutes at -20° C (-4° F), 64 minutes at -15° C (5° F), and 4

days at - 10° C (14° F). *Trichinella* were killed instantaneously at -23.3° C (-10° F). The U.S. Department of Agriculture requires that RTE pork products be frozen at -17.8° C (0° F) for 106 hours, at - 20.6° C (-5° F) for 82 hours, at -23.3° C (-10° F) for 63 hours, at -26.1° C (-15° F) for 48 hours, at -28.9° C (-20° F) for 35 hours, at - 31.7° C (-25° F) for 22 hours, at -34.5° C (-30° F) for 8 hours, and at -37.2° C (-35° F) for 0.5 hours. These extended freezing times take into account the amount of time required for temperature to equalize within the meat along with a margin of safety. It should be noted that species of *Trichinella* other than *T. spiralis*, particularly those found in wildlife, may have greater resistance to cold temperatures. Therefore, freezing guidelines for inactivating *Trichinella* larvae in pork cannot be applied directly to game meats.

Curing - There are a great variety of processes used to prepare cured pork products (sausages, hams, pork shoulder, and other RTE products). All processes currently approved for commercial use have been tested to determine their efficiency in killing *Trichinella*. In the curing process, product is coated or injected with a salt mixture and allowed to equalize at refrigerated temperatures. Following equalization, product is dried, or smoked and dried, at various temperature/time combinations. The curing process involves the interaction of salt, temperature and drying times to reach a desired water activity, percent moisture, or brine concentration. Unfortunately, no single or even combination of parameters achieved by curing has been shown to correlate definitively with *Trichinella* inactivation. All cured products should be processed by validated methods such as those published in the U.S. Department of Agriculture's Code of Federal Regulations (9CFR318.10).

Irradiation - Treatment of fresh pork with 30 krad (0.3kGy) of cesium-137 has been proven to render *Trichinella* completely non-infective. Irradiation with cobalt-60 or high energy x-rays at this same level should also be effective for inactivating *Trichinella*.

Pre-Harvest Control and Herd Certification

Trichinella infection is extremely rare in domestic pork in the U.S. due to improvements in the management of pigs. Grain-fed pigs raised in biosecure housing are not at risk for exposure to *Trichinella*. Regulations are in place in the U.S. and Europe to document pig management systems which eliminate the risk of exposure to *Trichinella*.

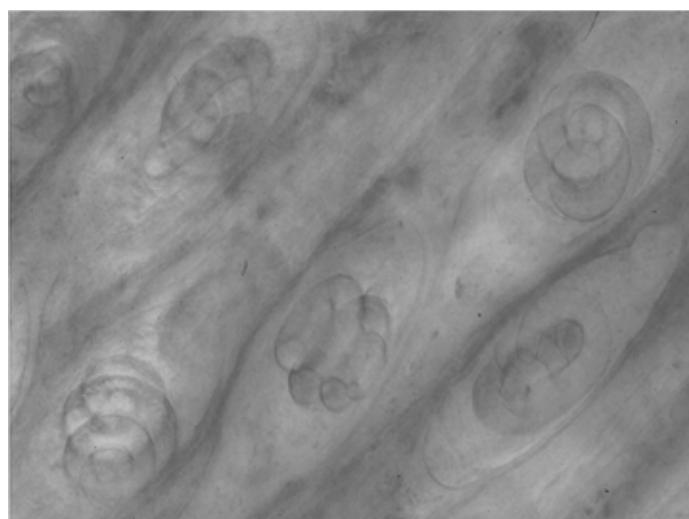
In the U.S., the principles of *Trichinella*-free pig production were studied for several years and then a formal program of certification was launched by the USDA in 2008 (National Trichinae Certification Program, USDA Farm Bill, May 2008). The European Union has similar legislation (SANCO/2075/2005) which allows for exemption from required testing of pigs originating from pork production sites that meet certain criteria for good hygiene as well as from regions that have demonstrated negligible risk for exposure of domestic pigs to *Trichinella*.

Under the USDA's National Trichinae Certification Program, U.S. pork producers can qualify for *Trichinella*-free herd status by documenting that their production practices conform to program standards. In the program, Good Production Practices (GPP's) prevent exposure of pigs to risks for *Trichinella* infection along with systematic monitoring of the product (*Trichinella*-free pigs).

Documentation of GPPs for risk-reduced pork production is accomplished by completion of a farm audit, administered by a trained veterinarian. The audit takes into account all production practices that impact the *Trichinella* status of market animals. Audits consider adherence to: 1) feed integrity, source and storage; 2) building construction and condition as it pertains to biosecurity; 3) integrity of rodent control programs; and 4) general management and hygiene issues as they pertain to rodent control, cannibalism and other issues. In addition, the producer assumes responsibility for maintaining the integrity of good production practices between audits. The process of raising pigs under GPPs to prevent *Trichinella* infection requires documentation in the form of the audit and verification. Herds which meet GPPs, and thus receive certification, are monitored periodically (by testing pigs at slaughter) to verify the absence of infection. Since the system is based on a pre-harvest HACCP approach, only a sample of production needs to be tested.

Certified pork can be exempt from individual carcass testing when required in domestic and export markets and certification can exempt pork from further processing. Importantly, certified pork is a way of documenting the safety of fresh pork to consumers and assuring that domestic pork continues to be free from *Trichinella*.

Figure 2. *Trichinella spiralis* larvae in pig muscles.



Documenting Negligible Risk through Surveillance

The various programs (slaughter testing and certification of management) and processes (cooking, freezing and curing) that are followed to protect the consumer from infection with *Trichinella* in pork are costly to the industry. In defined populations of pigs where *Trichinella* is known to be absent or to occur very rarely, a case for negligible risk can be built on knowledge of low risk management, surveillance data in pig populations, and human health data. Some countries in Europe have been designated as having negligible risk for *Trichinella* in pigs by the European Union, but international standards for negligible risk have not been developed as yet.

Populations of pigs that might be described as having negligible risk could include a collection of herds identified by a packer, a region, or an entire country. In defining a population to be described as having negligible risk, the management of all pigs in that population must be known. Pigs must originate from confinement management systems and a statistically valid sampling program must be in place to

demonstrate that infection is not present. Surveillance in pigs can be supplemented with public health data demonstrating that human infection has not occurred as a result of pork originating from that population of pigs.

This approach is reasonable for countries or segments of the pork industry where *Trichinella* is absent or extremely rare. Development of international guidelines for negligible risk populations is ongoing.

While bio-secure management will prevent risk of exposure of pigs to *Trichinella*, pigs managed in outdoor or partial confinement systems will always remain at risk. *Trichinella* circulates in wildlife and all species of carnivores and omnivores are at risk of exposure. Unless extensive wildlife surveys are conducted, it is impossible to assess the potential risk to pigs that may come in contact with a wild animal. Therefore, pigs raised in non-confinement systems must be considered at risk and pork must be tested, processed, or handled accordingly by consumers.

Selected References

The following web resources provide additional information on *Trichinella* and trichinellosis:

International Commission on Trichinellosis web pages - <http://www.trichinellosis.org/>

Centers for Disease Control web pages - <http://www.cdc.gov/parasites/trichinellosis/> and <http://www.cdc.gov/mmwr/preview/mmwrhtml/ss5809a1.htm>

FAO Guidelines for the Surveillance, Management, Prevention and Control of Trichinellosis - http://www.trichinellosis.org/uploads/FAO-WHO-OIE_Guidelines.pdf

European Union Regulations for *Trichinella* Control. - <http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2005:338:0060:0082:EN:PDF>

USDA Code of Federal Regulations - <http://www.gpo.gov/fdsys/pkg/CFR-2001-title9-vol2/pdf/CFR-2001-title9-vol2-sec318-10.pdf>

USDA, Agricultural Marketing Service Trichinae Export Program - <http://www.ams.usda.gov/AMSV1.0/ams.fetchTemplateData.do?temp late=TemplateC&navID=TrichinaeExportProgram&rightNav1=Trich inaeExportProgram&topNav=&leftNav=&page=TSBTrichinaeExport Program&resultType=&acct=stgeninfo>

USDA, Animal and Plant Health Inspection Service Trichinae Certification Program - <http://www.gpo.gov/fdsys/pkg/FR-2008-10-10/pdf/E8-23678.pdf> and <http://www.aphis.usda.gov/vs/trichinae/>

Status of *Trichinella* Infection in U.S. Commercial Pork and its Safety for International Trade in Pork and Pork Products - <https://webadmin.pork.org/filelibrary/Gamble%20Paper%20on%20Trichinella.pdf>