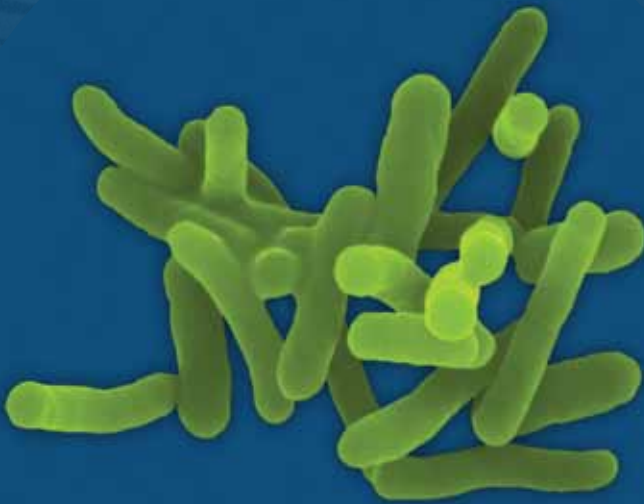


Risk-based Examples for Control of *Trichinella* spp. and *Taenia saginata* in meat



WHO



**Risk-based Examples
for
Control of *Trichinella* spp. and *Taenia saginata* in meat**

**Report of a Joint FAO/WHO Expert Meeting,
22-25 October 2013,
WHO Headquarters, Geneva, Switzerland**

**Food and Agriculture Organization of the United Nations
World Health Organization
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Declarations of interest

All participants completed a Declaration of Interest form in advance of the meeting. None were considered to present any potential conflict of interest.

Abbreviations used in the report

APHIS	Animal and Plant Health Inspection Service [of the USDA]
CAC	Codex Alimentarius Commission
CCFH	Codex Committee on Food Hygiene
CL	Confidence level
EFSA	European Food Safety Agency
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FSIS	Food Safety Inspection Service [of the USDA]
OIE	World Organisation for Animal Health
UECBV	European Livestock and Meat Trading Union
USDA	United States Department of Agriculture
WHO	World Health Organization

Preface

This report is a first edition being made available to facilitate ongoing discussions in this area. A more comprehensive second edition will be forthcoming.

Executive Summary

This expert meeting was implemented following the request of the Codex Committee on Food Hygiene (CCFH) which has been developing the Proposed Draft Guidelines for Control of Specific Zoonotic Parasites in Meat: *Trichinella* spp. and *Taenia saginata*. In November 2013, the 44th Session of the CCFH re-iterated the request of its 43rd session to FAO and WHO to develop risk-based examples for *Trichinella* spp. and *Taenia saginata* to illustrate the level of consumer protection likely to be achieved with different pre- and/or post-harvest risk management options, based on evaluation of slaughterhouse information and other data sources such as human illness. To facilitate the response, the CCFH requested the collection and review of existing information on risk-based examples for *Trichinella* spp. and *Taenia saginata*.

The proposed objectives of the meeting were:

- (i) To reach a common understanding of the risk management options that might be used for risk-based control of *Trichinella* spp. and *Taenia saginata* in meat.
- (ii) To analyse available data and information that contributes to establishing a risk-based approach to the control of these two zoonotic parasites.
- (iii) To develop risk-based examples (scenarios) for *Trichinella* spp. and *Taenia saginata* describing the likely levels of residual risk for consumers with different pre- and/or post-harvest risk management options.
- (iv) To provide an information resource for risk managers as an input to their risk management decisions.

The experts were presented with two different spreadsheet models, one for *Trichinella* spp. and the other for *Taenia saginata*, to respond to the requests from the Codex Committee.

***Trichinella* spp.**

The expert meeting aimed to provide examples for the confirmation of the establishment of a negligible risk compartment under controlled housing conditions, taking into account different assumptions relevant for the risk that *Trichinella* spp. might cause through the consumption of pork and pork-derived products.

A spreadsheet model was made available to the experts to develop the examples, which estimates the number of infected portions per million servings from pig populations in controlled housing compartments. The model applies an overarching assumption that every infected edible portion, independent of the number of larvae present in the meat, will cause human infection or illness. It also assumes that *Trichinella* larvae are uniformly distributed in an infected carcass, even though this is seldom the case in real life. Thus the model is very conservative in its outputs.

Using model input parameters to illustrate the different residual risks to consumers when different testing information is used to establish a negligible risk compartment, seven hypothetical examples were developed that simulated a range of scenarios. Conservative estimates are taken for the percentage of a carcass reaching the consumer as fresh pork, and the percentage that is consumed raw or undercooked.

The model showed that testing of a substantial number of pigs is needed to reduce residual risks to very low levels. However, there is a point where testing of additional pigs may not result in any further meaningful reduction in residual risk, and thus may not result in significant further improvement in public health benefit.

Once established, maintaining the controlled housing conditions, and thus the negligible risk status, is essential. Verification of the public health status resulting from maintenance can potentially be accomplished by using different approaches either separately or in combination:

- References to audit results at farm level, noting that audits will likely be the responsibility of a Competent Authority other than that responsible for public health.
- Surveillance in the live pig population under controlled housing conditions using test methods recommended by OIE (2013b).
- Surveillance of pigs outside the controlled housing compartment.

- Reporting of autochthonous human cases when robust public health surveillance and reporting systems are in place.

Demonstrating maintenance in a risk-based and cost-effective way is an essential part of the 'negligible risk compartment' approach and will be the subject of an Expert Meeting planned for 2014.

Taenia saginata

The purpose of the model used was to illustrate differences in *relative* risks (RR) to consumers when different intensities of postmortem meat inspection procedures are used, thereby informing decisions by risk managers on the most appropriate procedures to use in populations with different levels of infection. Thus the outputs of the model provided are very useful in 'modernization' of meat inspection.

A simple spreadsheet model was provided to estimate the residual level of risk to consumers following the application of specified postmortem meat inspection procedures to a slaughter population of a known size. Conservative model inputs were used. The model did not include a human dose response, but made use of the assumption that one residual cyst can lead to one tapeworm infection in humans. The final output of the model was the number of human infections that is expected to result from the slaughter population of known size.

The expert meeting provided examples of relative risks for four countries (W, X, Y, Z) with high, medium, low and very low number of cases of bovine cysticercosis as detected at abattoirs per year, respectively. Four model scenarios (A, B1, B2, C) were used with different sensitivity of inspection or viability of cysts.

The examples showed that the relative increase in human taeniosis cases associated with less intensive meat inspection was highly dependent on this change in postmortem inspection. In countries with a high prevalence of *Taenia saginata* in cattle, residual risks were relatively high irrespective of the postmortem inspection package used. Conversely, countries with a low prevalence of *Taenia saginata* in their slaughter populations had a very low level of residual risk for consumers and changes to the intensity of the postmortem inspection package had negligible impact on this risk estimate.

Conclusions

The application of simple spreadsheet models by the Expert Consultation resulted in effective generation of the quantitative risk-based information that is needed by public health officials when evaluating different meat hygiene programmes for *Trichinella* spp. and *Taenia saginata* in meat.

This innovative approach will significantly benefit from further work to generate more accurate estimates of relative risk, such as by:

- Using less conservative model inputs and perhaps different model structures
- Including a dose response module
- Illustrating differences in test regimes for *Trichinella* spp. when establishing a negligible risk compartment cf. verifying maintenance
- Utilizing evidence-based data on consumer cooking habits in relation to beef/pork in a population or country, as well as for meat treatments by food business operators
- Using Bayesian approaches to modelling different combinations of controls

1. Introduction

1.1 Background

Trichinella spp. cause human trichinellosis by consumption of raw or inadequately treated meat from domestic or game animals. *Taenia saginata* causes bovine cysticercosis, a parasitic disease of cattle, by the larval stage (*Cysticercus bovis*) of the human tapeworm *Taenia saginata*. Infection of humans with the adult tapeworm, known as taeniosis, occurs via the consumption of beef which has been insufficiently cooked or frozen to kill the cysticerci. Both are important for human and animal health and in meat trade. Traditionally, control of these parasites in host animals and their meat has been undertaken at some level within the food chain, e.g. biosecurity on-farm and inspection in a slaughterhouse.

The control of *Trichinella* spp. and *Taenia saginata* in meat has been ongoing work for the Codex Committee on Food Hygiene (CCFH), with the elaboration of Draft Guidelines for Control of Specific Zoonotic Parasites. In parallel, OIE revised and recently adopted Chapter 8.14 on Infection with *Trichinella* spp. from the OIE Terrestrial Animal Health Code (2013a), recommending control measures at the farm level to prevent food borne illness in humans. As a result, the importance of a risk-based approach to control *Trichinella* in meat through the complete farm-to-plate continuum was recognized by both organizations (OIE, 2012).

Applying a risk-based approach to meat hygiene requires re-evaluation of traditional practices and a re-focusing of regulatory and industry resources proportionate to risks. While this approach is now strongly advocated by national governments, there has been an uneven uptake on a global basis. As a consequence, the import requirements for meat and meat products of most countries represent a mix of “new” (risk-based) and traditional procedures and tests. Such is the case of *Trichinella* spp. and *Taenia saginata* in meat, where risk analysis principles can be applied to different types of traditional meat hygiene procedures. The development of this new approach calls for strong cooperation with OIE so as to facilitate a whole food-chain approach to risk reduction measures.

This expert meeting was implemented following the request of the Codex Committee on Food Hygiene (CCFH), which has been developing the Proposed Draft Guidelines for Control of Specific Zoonotic Parasites in Meat: *Trichinella* spp. and *Taenia saginata*. In November 2013, the 44th Session of CCFH reiterated the request of its 43rd session to FAO and WHO to develop risk-based examples for *Trichinella* spp. and *Taenia saginata* to illustrate the level of consumer protection likely to be achieved with different pre- and/or post-harvest risk management options, based on evaluation of slaughterhouse information and other data sources, such as human illness. To facilitate the response, the CCFH requested the collection and review of existing information on risk-based examples for *Trichinella* spp. and *Taenia saginata*. A call for data was issued to member countries and a summary of the information can be found in Annex 3. Risk profiles for these two parasites are available at <http://www.fao.org/food/food-safety-quality/a-z-index/foodborne-parasites/en/> and <http://www.who.int/foodsafety/micro/jemra/assessment/parasites/en/>.

1.2 Objectives

The proposed objectives of the meeting were:

- (i) To reach a common understanding of the risk management options that might be used for risk-based control of *Trichinella* spp. and *Taenia saginata* in meat.
- (ii) To analyse available data and information that contributes to establishing a risk-based approach to the control of these two zoonotic parasites.
- (iii) To develop risk-based examples (scenarios) for *Trichinella* spp. and *Taenia saginata* describing the likely levels of residual risk for consumers with different pre- and/or post-harvest risk management options.

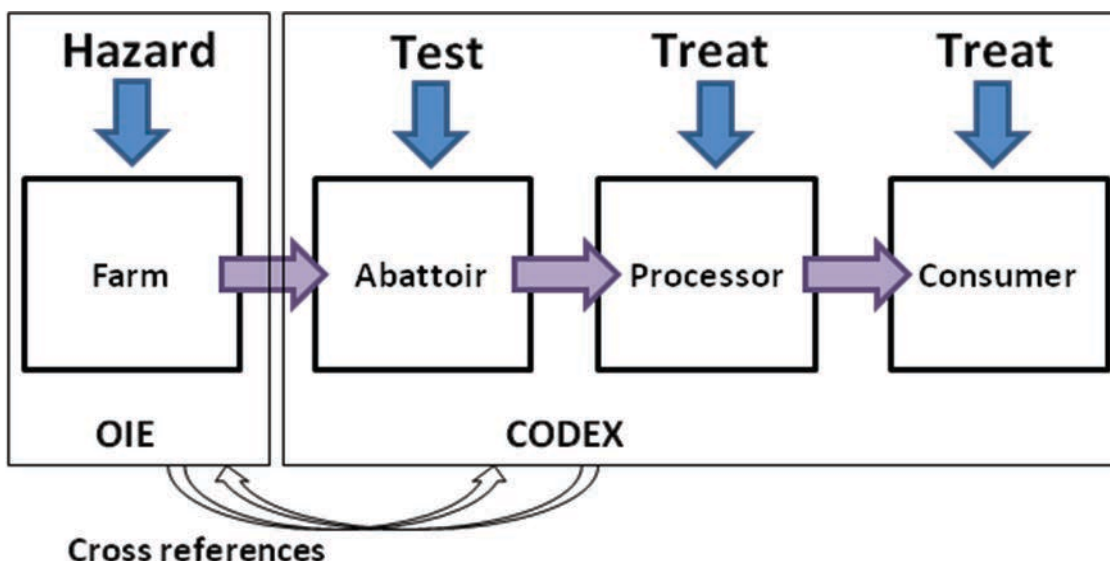
- (iv) To provide an information resource for risk managers as an input to their risk management decisions.

1.3 Context

The modernization of food safety systems has brought about a change from reactive to preventive food control activities, moving towards risk-based approaches that require all operators in the food chain to share responsibility for food safety. In the particular case of the parasites considered here, the linkage between control measures (pre-harvest and post-harvest) along the food chain continuum and the public health outcomes (illness in the consumer population) would aid risk managers to pinpoint the location (among the farm, abattoir, processor and consumer steps) for appropriate food safety interventions.

Controls for the parasites can be applied at several steps in the food chain, and those applicable at the pre-harvest (farm) and post-harvest (primary processing in the slaughterhouse) (Figure 1) are well described in the scientific literature and guidelines developed by international bodies such as OIE, FAO and WHO.

Figure 1. Steps in the food chain for application of control measures as described by OIE and the CAC (De Smet, EU, pers. comm.; Hathaway, in prep).



The OIE Terrestrial Animal Health Code provides guidelines for on-farm prevention of *Trichinella* infection in domestic pigs and includes requirements for establishing a compartment with a negligible risk of *Trichinella* infection for domestic pigs kept under controlled management conditions. OIE does not provide such guidance for *Taenia saginata*. The Codex Committee on Food Hygiene (CCFH) is currently developing guidance on the control of *Trichinella* spp. and *Taenia saginata* using a whole-food-chain approach (Proposed Draft Guidelines for Control of Specific Zoonotic Parasites in Meat: *Trichinella* spp. and *Taenia saginata*), including guidance to national governments on making public health decisions on the appropriate level of consumer protection

A negligible risk compartment refers to a compartment with a negligible risk of *Trichinella* infection (OIE, 2013a). This term, 'negligible risk of *Trichinella* infection', was amended from the former '*Trichinella*-free' because the determination of a 'free' status is not feasible given the sensitivity of currently available tests and the limited statistical power of most surveillance data (OIE, 2012).

1.4 Risk assessment

In responding to the above objectives, the experts were tasked with quantitatively illustrating the risks associated with selection of different risk management options by risk managers. Two spreadsheet risk models were provided to the experts as a baseline resource (Ryan and Hathaway, unpubl.; Van der Logt and Hathaway, unpubl.). The spreadsheet models are based on a relative assessment of the risk under different scenarios.

An important aspect of the task was the illustration of the residual risk to consumers following the implementation of selected control measures, especially in the context of different intensities of post-slaughter testing (*Trichinella* spp.) and postmortem inspection (*Taenia saginata*). It is important to note that it is not the role of the scientific expert to make the actual decision on what constitutes a negligible risk to the consumer.

1.5 Necessary inputs for modelling the food chain for control of *Trichinella* spp. and *Taenia saginata* in meat

1.5.1 *Trichinella* spp.

The components of relevance to a risk-based approach were defined by the experts at the meeting. On the farm, the focus was centred on domestic pigs under controlled housing conditions. Non-controlled housing status was considered in one scenario for comparison purposes only. A description of inputs required for modelling of the food chain for control of *Trichinella* spp. in pig meat is shown in Table 1. In addition, the experts mentioned that the exchange of food chain information with the abattoir stage was important to derive the necessary data.

At the abattoir level, there was agreement over the factors to consider, but there was some discussion on the test type, evidence of differences in current food safety systems.

The test method was selected in accordance with the diagnostic techniques recommended in Chapter 2.1.16 of the OIE Manual of Diagnostic Tests and Vaccines for Terrestrial Animals (2013b).

For the purposes of this expert meeting, risk modelling did not include serological testing as a possible control measure because of the lack of knowledge on performance characteristics (sensitivity and specificity).

Table 1. Inputs required for modelling of the food chain for control of *Trichinella* in pig meat

Stage	Factors	Values	Justification
Farm	Prevalence of carcasses that test positive post-slaughter as a determinant of negligible risk status (OIE) Population size of pigs in controlled housing compartments Age of the animals at slaughter		To establish and maintain negligible risk status
Abattoir	Prevalence of tests positive animals Performance characteristics of digestion test (sensitivity and specificity; detection limit) Sampling plan and sites sampled test Sample size	50-70%	To establish and maintain negligible risk status The limits of the model were 50-100% sensitivity in digestion testing.
Processing	Percentage of pig meat placed on the market as fresh meat or processed meat Processing treatments (freezing, heat treatment, drying, curing (cold and hot) and their validation	The limits of the model are 10-100% fresh pork	USA, Fresh: 25% EU, (UECBV) Fresh: 15-17% Processed: 60-66% Frozen: 15-17% As regards processing: 30% cooked sausages; 20% cooked ham; 15% dried sausages; 10% dried ham; 25% others, such as bacon (cured).
Consumer	Number of edible portions from 1 pig carcass Percentage of edible portions eaten raw or fresh	400 1-2%	Reference (USA) The model establishes between 50 and 150 meals/carcass. USA, 1%; NZ, 1%; EU, 5% The model sets a range of between 0 and 10% meals not rendered safe by cooking (undercooked or raw)

1.5.2 *Taenia saginata*

A description of inputs required for modelling of the food chain for control of *Taenia saginata* in beef meat is shown in Table 2.

Table 2. Inputs required for modelling of the food chain for control of *Taenia saginata* in beef meat

Stage	Status (at farm level)	Factors	Values	Justification
Farm	“High prevalence” population	Prevalence positive at postmortem inspection	15%	From the scientific literature
	“Low prevalence” population or sub-population	Age of the animals at slaughter Sex Other risk factors such as type of breeding or management		Considered males and females
Abattoir		Prevalence positive at postmortem inspection	15%	From the scientific literature
		Designation of number of cysts constituting a lightly infected animal	4, 6 or 8	
		Performance characteristics of postmortem inspection (sensitivity and specificity)	2.0, 3.9, 4.7%	
		Regulatory action following positive test, e.g. require cooking of infected carcasses, trimming of lightly infected parts		
Processing		Distribution channels Processing treatments		
		Percentage of carcass, fresh after processing and distribution	90%, 95%	NZ 10%; EU 90%; USA 90%
Consumer		Number of edible portions from a carcass	1300 (150 g per portion)	
		Percentage of edible portions eaten raw or fresh	40%, 10%	
		Percentage of cysts viable/infective at point of consumption	100% infective	France: 1 infected and non-detected carcass could infect 10 people (estimate)

2. Development of the risk-based examples

2.1 *Trichinella* spp.

2.1.1 Establishing a negligible risk status

Purpose

The purpose of this section is to provide examples for the confirmation of the establishment of a negligible risk compartment under controlled housing conditions, taking into account different assumptions relevant for the risk that *Trichinella* spp. may cause through the consumption of pork and pork-derived products. It provides a tool for risk managers to decide on the acceptable residual risk for consumers. The main aim is to illustrate relative risk, depending on the scenarios being considered.

A negligible risk compartment refers to a compartment with a negligible risk of *Trichinella* infection (OIE, 2013a).

Model

A spreadsheet model (Annex 2) was made available to the experts to develop the examples. The model estimates the number of infected portions per million servings from pig populations in controlled housing compartments. The model does not include a quantitative description of the risk in terms of a human dose response model, so the overarching assumption is that every infected edible portion, independent of the number of larvae present in the meat, will cause human infection or illness. It also assumes that *Trichinella* larvae are uniformly distributed in an infected carcass, even though this is seldom the case in real life. Thus the model is very conservative in its outputs.

Model inputs

To illustrate the different residual risks to consumers when different testing information is used to establish a negligible risk compartment, the following model input parameters were used:

- Number of pigs slaughtered.
- Number of pigs tested within the controlled housing compartment.
- Number of pigs testing positive.
- Diagnostic sensitivity of testing under acceptable proficiency conditions.
- Percentage of fresh pork reaching the retail market.
- Number of edible portions per slaughtered pig.
- Percentage of undercooked or raw pork consumed.

Overview of examples

Seven hypothetical examples were developed that simulated a range of scenarios. All tests results for pigs from controlled housing are assumed to be negative. Conservative estimates are taken for the percentage of a carcass reaching the consumer as fresh pork and the percentage that is consumed raw or undercooked.

Example 1 is a population of 100 million pigs in a controlled housing compartment from which 1 million to 100 million are tested at slaughter. All tests results for pigs from controlled housing are assumed to be negative. The model produces results that are probably generated from near the upper bounds (50% of fresh meat at retail and 2% of undercooking or raw by consumers).

Example 2 (Reference example) represents a population of 10 million pigs in a controlled housing compartment in a farm/region/country. Of these pigs, a range of 1000 to 1 million are tested at slaughter, keeping all other parameters of Example 1 the same.

Example 3 represents a population of 1 million pigs, keeping all other parameters of Example

1 the same.

Example 4 is a small population of 100 000 pigs from which 1000 to 100 000 are tested, with all other parameters being the same as in Example 1.

Example 5 is the same as Example 2, which tests 1 million pigs but only 25% of the pork reaches the consumer fresh and only 1% is consumed raw or undercooked.

Example 6 is the same as Example 2, but testing all pigs, from which 1 was positive.

Example 7 considers a small population of pigs, which are not reared under controlled housing conditions, all tested at slaughter, in which 36 were positive. It illustrates the potential residual risk from small populations compared with much larger populations under controlled housing conditions.

Outcomes

The different scenarios and results of each example are presented in Table 3, and the model used for calculation of these outputs is presented in Annex 1.

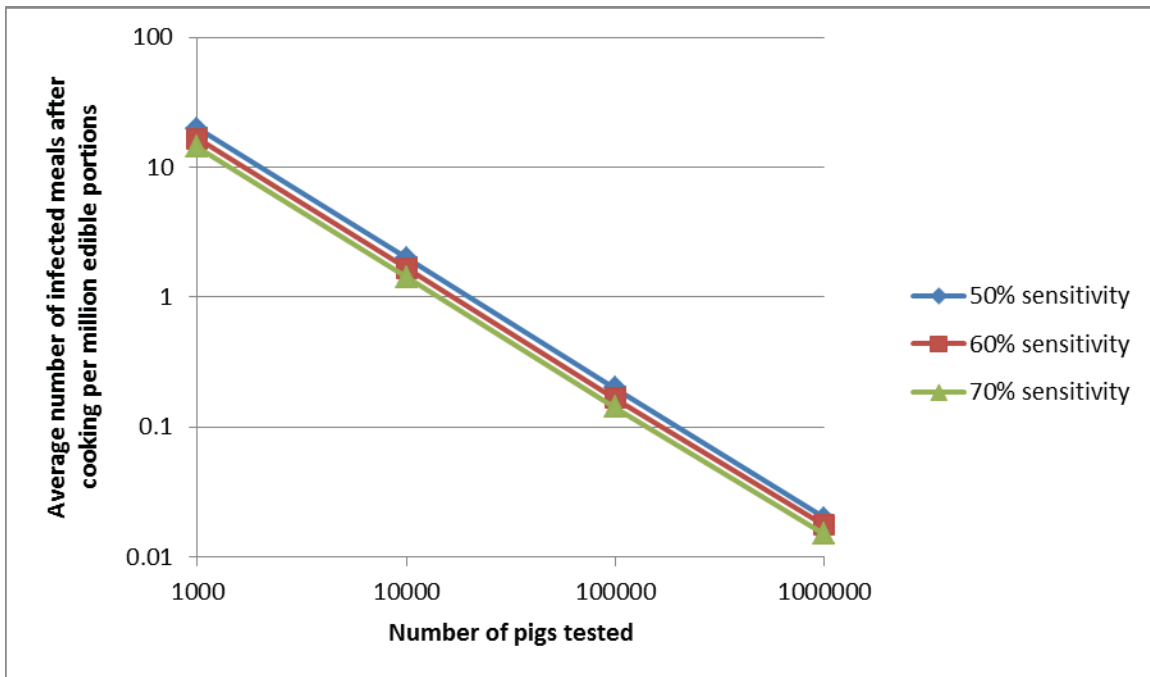
Table 3. Numbers of *Trichinella* spp. infected portions per million servings in seven scenarios

Example	No. of pigs slaughtered	No. of pigs tested	No. testing positive	% of fresh meat at retail	% of under-cooking by consumers	Residual infected portions	Infected portions per million servings
1	100 million	1 million to 100 million	0	50	2	666 000 – 7	16.7 – 0.017
2	10 million	1000 to 1 million	0	50	2	66 600 – 67	16.7 – 0.017
3	1 million	1000 to 1 million	0	50	2	6 660 – 7	16.7 – 0.017
4	100 000	1000 to 100 000	0	50	2	666 – 7	16.7 – 0.017
Example with low percentages of fresh meat at retail and undercooking by consumers, respectively							
5	10 million	1 million	0	25	1	17	0.00425
Example with 1 pig testing positive for <i>Trichinella</i> spp.							
6	10 million	1000 to 1 million	1	50	2	133 200 – 133	33.3 – 0.033
Example from non-controlled housing, pigs testing positive for <i>Trichinella</i> spp.							
7	13 000	10 000	36	50	2	321	61.7

The results for Examples 1 to 4 are presented in Figure 2 and Table 4. The model shows that the average number of infected meals after cooking drops proportionally as the number of animals in the population tested increases.

The model also shows that reducing the test sensitivity from 70% to 50%, using Examples 1 through 4, has little effect on the outcome for a given level of testing.

Figure 2. Variation in the average number of infected meals after cooking depending on the test sensitivity (50–70%) assuming no animals tested positive*



Notes: *Assuming 400 edible portions of pork from a carcass; 50% of the carcass used for fresh pork sales; 2% of meals that might not be rendered safe by cooking.

Table 4. Variation in the average number of infected meals after cooking depending on the test sensitivity (50–70%) assuming no animals tested positive.*

Number of animals tested	Test sensitivity		
	50%	60%	70%
1 000	19.98	16.65	14.2725
10 000	1.99975	1.6675	1.4275
100 000	0.2	0.16675	0.1425
1 000 000	0.02	0.0175	0.015

Notes: *Assuming 400 edible portions of pork from a carcass; 50% of the carcass used for fresh pork sales; 2% of meals that might not be rendered safe by cooking.

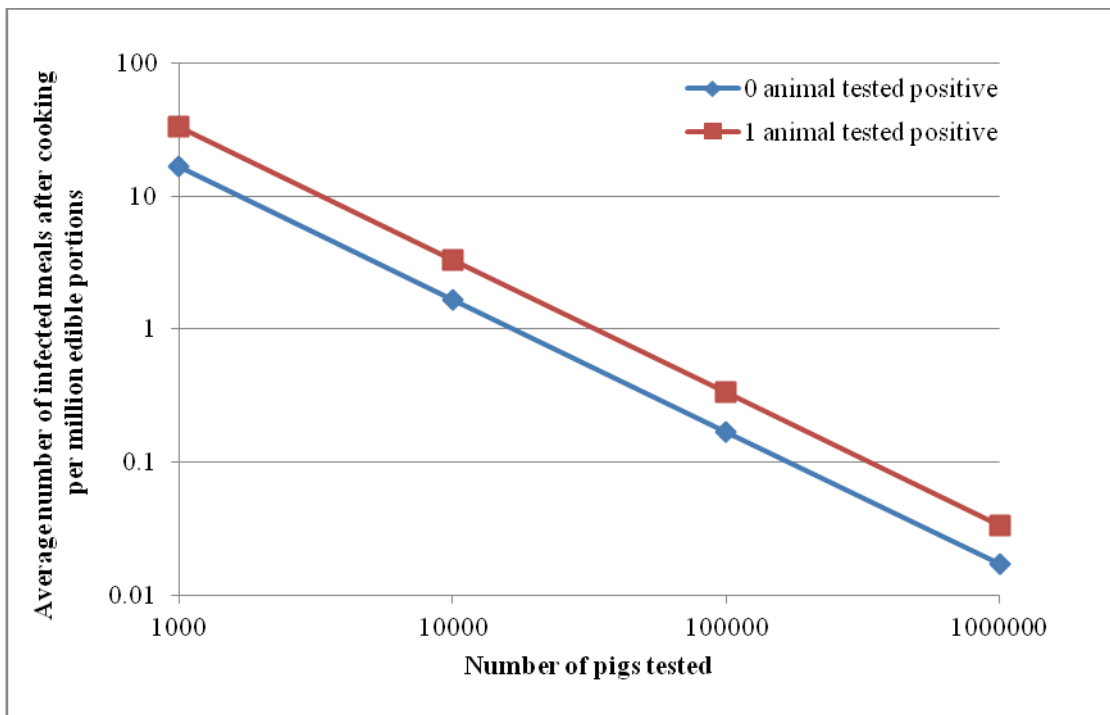
Table 5. Variation in the average number of infected meals after cooking depending on the number of animals tested, assuming one animal tested positive*

No. of animals tested	Test sensitivity 60%	
	0 animal positive	1 animal positive
1 000	16.7	33.3
10 000	1.67	3.33
100 000	0.167	0.333
1 000 000	0.017	0.033

Notes: *Assuming 400 edible portions of pork from a carcass; 50% of the carcass used for fresh pork sales; 2% of meals that might not be rendered safe by cooking, test sensitivity 60%.

The results for the comparison of having one animal tested positive (Example 6) versus zero animals tested positive (Example 5) are shown in Figure 3 and Table 5. The values indicate that if a large number of animals is being tested (100 000 – 1 000 000), there may not be a large difference in the average number of infected edible portions at 60% sensitivity of testing.

Figure 3. Variation in the average number of infected meals after cooking depending on the number of animals tested, assuming one animal tested positive*



Notes: *Assuming 400 edible portions of pork from a carcass; 50% of the carcass used for fresh pork sales; 2% of meals that might not be rendered safe by cooking, test sensitivity 60%.

The output of the model estimates the average number of infected edible portions reaching the consumer. The average number of infected animals that may persist in the tested population can also be reported as an output of the model. The model should also show the number of potentially infected carcasses, as the number of portions as well as the number of preparations per carcass may vary.

2.1.2 Ongoing verification for the maintenance of the compartment with a negligible risk

Once established, maintaining the controlled housing conditions, and thus the negligible risk status, is essential. Verification of the public health status resulting from maintenance can potentially be accomplished by using different approaches either separately or in combination:

- References to audit results at farm level, noting that audits will likely be the responsibility of a Competent Authority other than that responsible for public health.
- Surveillance in the live pig population under controlled housing conditions using test methods recommended by OIE (2013b).
- Surveillance of pigs outside the controlled housing compartment.
- Reporting of autochthonous human cases when robust public health surveillance and reporting systems are in place.

Different approaches to verification of the maintenance of a negligible risk compartment were not evaluated by this Expert Meeting. Demonstrating maintenance in a risk-based and cost-effective way is an essential part of the “negligible risk compartment” approach and will be the subject of a further Expert Meeting.

In this context, prior knowledge (for example: number of animals tested in the past, the quality of test performance, test results and incidence of trichinellosis in the human population)

may potentially be used to reduce the number of carcass tests that might be needed to verify the ongoing success of the negligible risk compartment.

2.1.3 Conclusions

By referring to the outputs from different control scenarios, risk managers can choose the control measures for *establishment* of a negligible risk compartment that deliver the level of consumer protection that is required at the national level.

1. It is clear that testing of a substantial number of pigs is needed to reduce residual risks to very low levels. However, there is a point where testing of additional pigs may not result in any further meaningful reduction in residual risk, and thus may not result in significant further improvement in public health benefit.

2. More work is needed to complement the outcomes of this Expert Consultation. The model is conservative in use of input parameters (e.g. one larva in an edible portion causes human illness), additional modelling will provide clearer indications of the merits of an agreed level of testing relative to residual risk. Further, additional investigation and modelling is needed to support public health decisions on assurance of maintenance of a negligible risk compartment according to different measures (e.g. slaughterhouse testing, audits, human surveillance and other parameters).

2.2 *Taenia saginata*

Purpose

The purpose of the model used was to illustrate differences in relative risks (RR) to consumers when different intensities of postmortem meat inspection procedures are used, thereby informing decisions by risk managers on the most appropriate procedures to use in populations with different levels of infection.

Model

This is a simple spreadsheet model that estimates the residual level of risk to consumers following the application of specified postmortem meat inspection procedures to a slaughter population of a known size. The model can be found in Annex 2.

For input parameters for which there is a paucity of available data, conservative point estimates were used. The model does not consider the human dose response but makes use of the assumption that ingestion of one viable cyst in an edible portion of meat can lead to one tapeworm infection.

Based on the risk assessment model by van der Logt, Hathaway and Vose (1997), the primary model parameters are the particular set of meat inspection procedures that are being evaluated and the number of infected and detected animals. Each set of procedures will have an estimated sensitivity for detecting infected animals. Those infected animals that are detected on inspection will be removed and those infected animals that are not detected will remain in the food supply chain. The model applies estimates of the average number of cysts present in infected animals in the slaughter population (for example in one year), the percentage of viable cysts per infected animal, and the percentage of infected meat not processed or treated to inactivate the parasite, to generate an estimate of the total burden of cysts in fresh meat.

Subsequent steps in the model represent interventions that sequentially reduce the number of viable cysts. Each viable cyst that is ingested is assumed to result in infection (a conservative assumption) and the final output of the model is the number of human infections that is expected to result from a slaughter population of a specific size.

The primary value of the model is to illustrate the residual risk that results from 'high prevalence' compared with 'low prevalence' slaughter populations. (A low-prevalence sub-population might also consist of specific animals within herds, such as calves or males.) Model outputs demonstrate that when low intensity inspection procedures compared with high

intensity procedures are used in 'low prevalence' populations, there is negligible difference in residual risks.

Overview of examples

Countries W, X, Y and Z were chosen as examples to represent different prevalence situations (Table 6). For each of these examples, model parameters were based on available data or reasonable assumptions relevant to each scenario. Model parameters varied between countries to best reflect the 'real-life' situation, including processing and consumption habits. Model outputs are shown in Table 6.

In scenario set A, the overall sensitivity of inspection is determined from published scientific information on the sensitivity of detecting a single cyst (Kyvsgaard *et al.*, 1990, 1996) and expert opinion on the average number of cysts likely to be present in a 'lightly infected' population.

In scenario set B, overall sensitivity of inspection is determined from a theoretical stepwise increase in sensitivity according to the number of incisions performed. B1 and B2 scenario sets are based on 7 and 4 cysts per infected animal, respectively, to assess the influence of varying, plausible cyst burdens.

In scenario set C, the effect of subjecting only the high-risk subpopulation to traditional meat inspection was assessed. In this scenario the probability of a cyst being viable was increased to 11% from 10% in the basic model.

Model inputs

Sensitivity of inspection

The prevalence of infected animals and the number of cysts present in an infected animal are known to be highly variable. There are several published sources of information that *assign* an average sensitivity of 'traditional' postmortem inspection (a combination of visual inspection of all muscle surfaces and organs, palpation of predilection sites and a series of incisions of predilection sites) of 15%.

The sensitivity of detecting one *Taenia saginata* cyst in an infected animal is very low and Kyvsgaard *et al.* (1990) found this to be 4% in experimentally infected calves. As the number of cysts increases in an infected animal, the sensitivity of infection obviously increases. In heavily infected animals, the sensitivity is likely to be above 50%.

Scenario set A uses 4.7% as the sensitivity of detecting one cyst (Hathaway, in prep.).

If the slaughter population is 'lightly infected', the average number of cysts assigned in the model to infected animals is small. Model A assigns this point estimate as 4 and the average sensitivity of inspection for such a population is about 15%. Thus 85% of infected animals go undetected and enter the food chain.

When the set of procedures used for postmortem inspection is altered by the exclusion of the incisions of masseter and pterygoid, the sensitivity drops from 4.7% to 3.9%. Such changes in model inputs are the prime determinant in generating the relative risks that result from the different inspection packages.

Scenario set A can also be used to model 'heavily infected' slaughter populations. In such a situation, the sensitivity assigned to inspection will be higher and the average number of cysts that is assigned to an infected animal will be higher than in the scenario described above.

In Scenario set B, overall sensitivity of inspection is determined from a *theoretical* stepwise increase in sensitivity according to the number of incisions performed. (This model does not include the outcome of visual examination and palpation or the relative value of different types and sequences of incisions in different predilection sites). In Scenario set B, the average number of cysts in infected animals is assigned as 4 or 7, the latter assumption results in a more conservative estimate for the mitigation of residual risk.

This is combined with the sensitivity of meat inspection, the probability of a cyst being viable, and the proportion of beef meat being subjected to a treatment that would inactivate cysts.

Viability of cysts

The user of the model can assign a value appropriate to the baseline scenario. An estimate of 10 % was used for the first three examples that are presented below (Scenario sets A, B1 and B2). This estimate of 10% cyst viability is based on studies entailing complete carcass dissection of naturally and experimentally infected cattle.

In Scenario set C, the parameter representing probability of a cyst being viable was increased from 10% in the basic model to 11% in this model, reflecting that in young infected male cattle, cysts might have developed but not calcified to the same extent as in adult cattle. It would be of interest to study further to which degree the assumed higher proportion of viable cysts is compensated by a lower number of cysts in younger cattle compared with adult cattle that through a longer life have had more probability of getting infected not just once but several times.

Outcomes

The outcome of these models is shown in Table 6. Across all country and model scenarios, the increase in the annual number of human tapeworm carriers expressed in absolute numbers differed across countries depending on the baseline cysticercosis prevalence.

The model also provides the opportunity to compare the residual risk that results from “high prevalence” and “low prevalence” slaughtered populations using the same and/or different set of inspection procedures. The last scenario (Scenario set C) is an example of the above. This scenario was only run for a country with a low number of human cases. The input data were based on Calvo-Artavía *et al.* (2013a, b), who showed that male cattle could have a much lower prevalence than female cattle, probably as a result of being slaughtered at a younger age. Moreover, male cattle are most often raised indoors. Hence, only subjecting female cattle to traditional meat inspection only lowered the number of cattle identified at meat inspection from 44 to 36. When these figures were entered into the model, the estimated number of human cases increased from 36 to 42 – a very small increase in residual risk.

Table 6. Summary of various estimates of the residual risk of taeniosis in four example countries with different prevalences of *Taenia saginata* in slaughter populations according to current and alternative postmortem meat inspection regimes (the diagram for calculation is in Annex 2)

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Country "W"												
A ⁽¹⁴⁾	6633	4	4.70%	4	10%	95%	40%	100%	18%	4748		
	6633	4	3.90%	4	10%	95%	40%	100%	15%	5845	1097	23%
B1 ⁽¹⁵⁾	6633	8	2.00%	4	10%	95%	40%	100%	15%	5748		
	6633	6	2.00%	4	10%	95%	40%	100%	11%	7824	2076	36%
B2 ⁽¹⁵⁾	6633	8	2.00%	7	10%	95%	40%	100%	15%	10058		
	6633	6	2.00%	7	10%	95%	40%	100%	11%	13691	3633	36%
C ⁽¹⁶⁾	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—
Country "X"												
A ⁽¹⁴⁾	1500	4	4.70%	4	10%	90%	40%	100%	18%	1017		
	1500	4	3.90%	4	10%	90%	40%	100%	15%	1252	235	23%
B1 ⁽¹⁵⁾	1500	8	2.00%	4	10%	90%	40%	100%	15%	1231		
	1500	6	2.00%	4	10%	90%	40%	100%	11%	1676	445	36%
B2 ⁽¹⁵⁾	1500	8	2.00%	7	10%	90%	40%	100%	15%	2155		
	1500	6	2.00%	7	10%	90%	40%	100%	11%	2933	778	36%
C ⁽¹⁶⁾	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—
Country "Y"												
A ⁽¹⁴⁾	44	4	4.70%	4	10%	90%	40%	100%	18%	30		
	44	4	3.90%	4	10%	90%	40%	100%	15%	37	7	23%
B1 ⁽¹⁵⁾	44	8	2.00%	4	10%	90%	40%	100%	15%	36		
	44	6	2.00%	4	10%	90%	40%	100%	11%	49	13	36%
B2 ⁽¹⁵⁾	44	8	2.00%	7	10%	90%	40%	100%	15%	63		
	44	6	2.00%	7	10%	90%	40%	100%	11%	86	23	36%
C ⁽¹⁶⁾	44	—	—	4	10%	90%	40%	100%	15%	36		
	36	—	—	4	11%	90%	40%	100%	12%	42	6	16%
Country "Z"												
A ⁽¹⁴⁾	44	4	4.70%	4	10%	90%	10%	100%	18%	7		
	44	4	3.90%	4	10%	90%	10%	100%	15%	9	2	23%
B1 ⁽¹⁵⁾	44	8	2.00%	4	10%	90%	10%	100%	15%	9		
	44	6	2.00%	4	10%	90%	10%	100%	11%	12	3	36%
B2 ⁽¹⁵⁾	44	8	2.00%	7	10%	90%	10%	100%	15%	16		
	44	6	2.00%	7	10%	90%	10%	100%	11%	22	6	36%
C ⁽¹⁶⁾	—	—	—	—	—	—	—	—	—	—	—	—
	—	—	—	—	—	—	—	—	—	—	—	—

Key and Notes: (1) Scenario (Overall sensitivity of inspection);

(2) Infected and detected animals;

(3) No. of cuts OR no. of cysts;

(4) Probability of detecting an infected animal per cut OR probability of detecting one cyst;

(5) Estimated no. of cysts in non-detected animals; (6) Estimated probability of cyst viability;

(7) Proportion of meat not being subjected to cyst killing processes;

(8) Proportion of meat not cooked or undercooked;

(9) Probability of infection;

(10) Carcass-level sensitivity;

(11) People infected with *T. saginata* tapeworms;

(12) Risk difference = Difference in (11) due to (10); (13) % Increase in risk associated with applying 15% vs 18% carcass level sensitivity;

(14) Scenario A = Detection of 1 cyst and Average number of cysts in lightly infected population;

(15) Scenario B = No. of cysts or incisions performed; B1 = 4 cysts per infected animal, and B2 = 7 cysts per infected animal;
(16) Scenario C = Only high risk sub-populations will be subjected to traditional meat inspection; Viability of a cyst = 11%

Remarks

Initially, the case countries were compared based on the number of infected carcasses detected at meat inspection. Thereby the ranking of risk was made from high risk down to very low risk. However, the size of the slaughter population varied considerably between the four case countries: from 0.5 to 4.5 million. The true prevalence varied even more: from 0.007% to 2%, implying a factor of close to 300. In fact, the country with the highest number of infected carcasses (and expected human cases) turned out to have half as high a true prevalence as the case of the country believed to represent medium risk. To take this into account, the true prevalence and the human incidence calculated as human cases per 100 000 inhabitants or 1 million inhabitants should be calculated.

The model assumptions would benefit from investigating the parameters related to post-harvest processes (consumer habits in eating beef, whether raw or undercooked versus properly cooked) in order to improve confidence in the results. Therefore, the results presented in Table 6 should be interpreted with care. Attention should be paid to the difference in number of cases found when comparing the current scenarios with alternative scenarios.

The results from the model might be validated in some circumstances through a comparison with data representing recorded human cases in a particular country/region. Unfortunately, human prevalence data is not available for most countries, and where it is available it applies to a very small sample size. However, data indicating an approximate number exist in various countries. For example, in Denmark (6 million inhabitants), Statens Serum Institute reported 38 persons suspected to be infected by *Taenia saginata* in 2011, and between 2 and 8 cases per year were diagnosed as *Taenia saginata* positives by examination of faecal material. Hence, the outcome of the model for Denmark was confirmed by this report.

The included models are merely examples to demonstrate the concept of 'risk-based' control. These models are a first attempt to address this concept and as such, the models will undergo further improvements or changes. In general, any model should be accompanied by a clear and transparent narrative description. This description should include at least the assumptions behind the model and the rationale for the applied model parameter values or distributions. As far as possible, the model structure and parameter values should be based on scientific evidence. Reference should be made to the applied evidence base.

Uncertainty issues should be considered in the development and description of the model. At least two main sources of uncertainty can be distinguished: model uncertainty and parameter uncertainty. Model uncertainty relates to a lack of knowledge or controversy regarding the model structure. It can be dealt with through scenario analyses, in which different plausible model structures are implemented and compared. Parameter uncertainty relates to a lack of knowledge or controversy regarding the true value of model parameters. It can be dealt with through uncertainty analysis (a.k.a. uncertainty propagation or probabilistic sensitivity analysis), in which model parameters are represented by probability distribution functions that reflect their uncertainty, and by repeatedly running the model starting from different randomly selected parameter values, a distribution of output values will be generated reflecting the uncertainty in each of the input parameters. Alternatively, parameter uncertainty can be dealt with through non-probabilistic approaches, such as one-way sensitivity analyses or the use of conservative estimates for each of the uncertain parameters.

There is model uncertainty regarding the estimation of the animal-level sensitivity (i.e. the probability of detecting a truly infected individual). Two approaches are implemented and compared in a scenario analysis: (1) the modelling of the animal-level sensitivity based on the number of cysts per animal and the probability of detecting one cyst; and (2) the modelling of the animal-level sensitivity based on the number of cuts performed on the carcass and the probability of detecting a truly infected animal per cut.

2.3 Conclusions

1. The spreadsheet model demonstrated the expected changes in residual human risks under different prevalence scenarios when different sets of meat inspection procedures were used at postmortem inspection. Thus the model can be effectively used to provide examples to support public health decisions on 'modernization' of meat inspection. If the difference in residual risk is very small when different sets of inspection procedures are used, then those that represent the best use of meat inspection resources and create the least contamination can be justifiably implemented.

2. The output of the examples showed that the relative increase in human taeniosis cases associated with less intensive meat inspection was only dependent on the evaluated change in inspection practices, and did not depend on the country-specific risk mitigation profiles. However, given the different baseline burdens, there was a marked difference in residual human risks between countries with a low versus high prevalence of *Taenia saginata* in their slaughter populations. In countries with a high prevalence of *T. saginata*, residual risks were relatively high irrespective of the inspection package used, with reduced inspection resulting in an expected increase in the number of human cases of the order of thousands. Conversely, countries with a low prevalence of *T. saginata* in their slaughter populations had a very low human residual risk, and changes to the inspection package had very little impact on model outputs.

3. Overall Conclusions and Recommendations

3.1 Conclusions

1. The application of simple spreadsheet models by the Expert Consultation resulted in effective generation of the quantitative information that is needed by public health officials when evaluating different postmortem meat hygiene programmes for *Trichinella* spp. and *Taenia saginata* in meat.
2. Notwithstanding differences in model inputs, the changes in relative risks in different risk management scenarios are important information for the risk managers in the design or review of their risk management activities.
3. The Expert Consultation showed, by using the risk-based examples for *Trichinella* spp. and *Taenia saginata*, the value of a 'fit-for-purpose' risk modelling approach to support modernization of meat inspection.
4. The models enabled the development of science-based risk scenarios to assess the effect of various changes to digestion testing and meat inspection for *Trichinella* spp. and *Taenia saginata*, respectively, on the residual risk of human trichinellosis and taeniosis, respectively, whereby the outcome is based on changes in relative risks rather than specific estimates of risk.
5. The models used provide examples to demonstrate the concept of 'risk-based' control. They are a first approach to this concept and will undergo further improvement.

3.2 Recommendations

1. More work is needed to further advance this innovative approach, e.g. when using a combination of risk management measures to assure maintenance of a negligible risk compartment. Therefore, further development of the spreadsheet model, such as using a Bayesian approach, might allow integration of other inputs to support public health decisions.
2. Further work could be undertaken to improve the spreadsheet model, e.g. to include other information, such as the dose-response model developed for *Trichinella* spp. (Teunis *et al.*, 2012) and consumer behaviour.
3. Evidence-based data on consumer cooking habits in relation to beef/pork in a population or country will improve the confidence of the output from the model(s). Evidence-based data on meat treatments by food business operators are also necessary.

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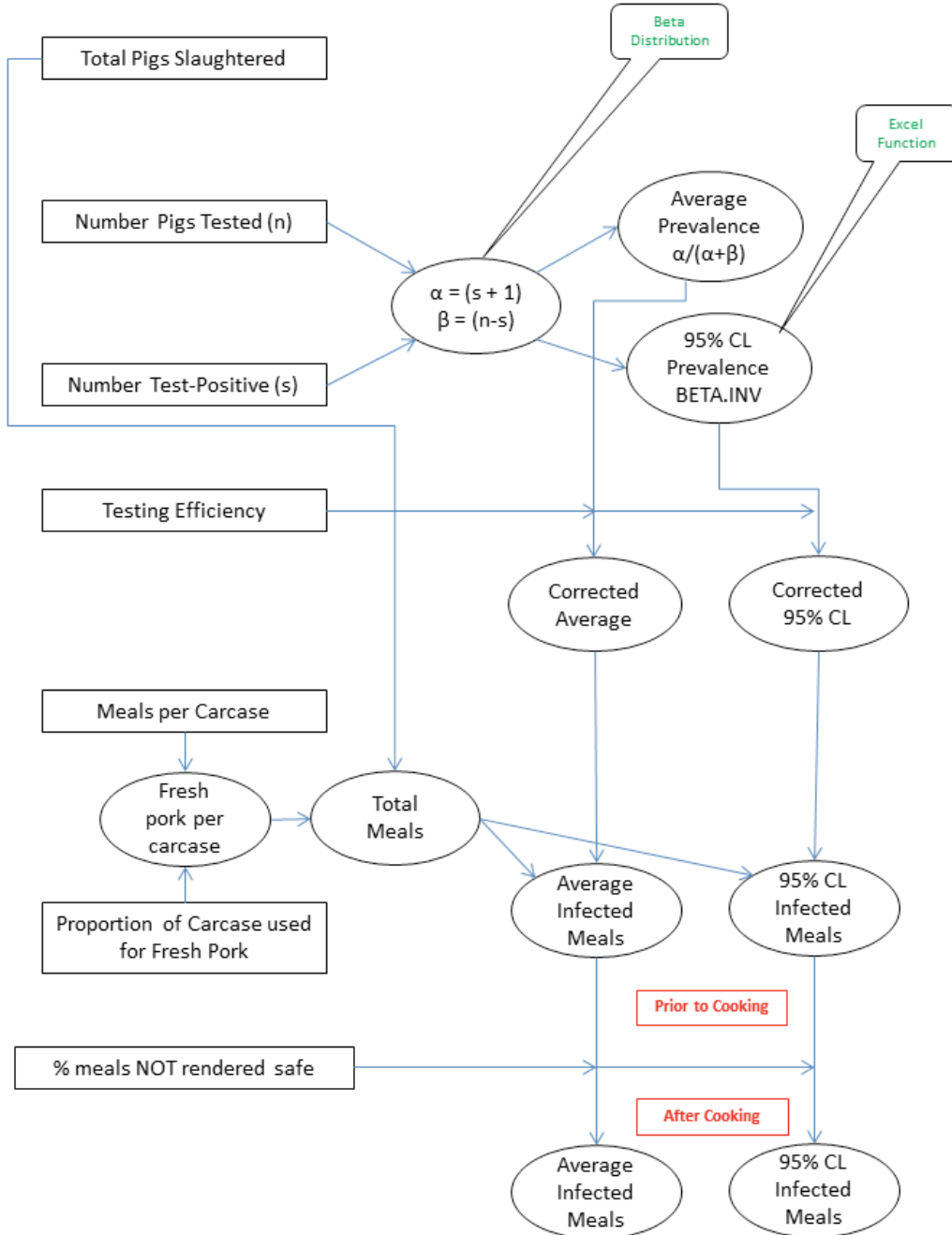
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Annexes

Annex 1. Flow diagram for *Trichinella* spp. model (base model provided by Ryan and Hathaway, unpubl.).

Output: Number of infected portions per million servings



Annex 2. Spreadsheet diagram for the *Taenia saginata* model (base model provided by van der Logt and Hathaway, unpubl.).

Output: Number of people infected with *Taenia saginata* tapeworms

		Number of cattle slaughtered per year	4,476,989	animals		
4	number of cysts		6,633	Infected and detected animals	0.148%	Observed prevalence
4.7%	probability of detecting an infected animal per cyst					
17.5%	Sensitivity of inspection					
82.5%	Probability of not detecting an infected animal		31,236	Infected and non-detected animals	0.698%	Percentage of the population that is infected and not detected
			37,869	Infected animals	0.846%	True prevalence
Estimated number of cysts in non-detected animals						
4	cysts		124,944	Number of undetected cysts		
Estimated probability of cyst viability	10%		12,494	Number of viable cysts		
	<i>Processor</i>					
eing subjected to processes which kill the cysts	95%		11870	Number of surviving viable cysts		
	<i>Consumer</i>					
Proportion of meat not cooked or undercooked	40%		4748	Number of surviving viable cysts		
	Probability of infection	100%	4748	People infected with <i>T. saginata</i> tapeworms		

Annex 3. Summary of the Call for Data on the Control of *Trichinella* spp. and *Taenia saginata* in meat

A3.1 Background

The 44th session of the Codex Committee on Food Hygiene (CCFH) held in November 2012 refined its earlier request at the 43rd CCFH to FAO/WHO to develop risk-based examples for *Trichinella* spp. and *Taenia saginata* to illustrate the level of consumer protection likely to be achieved with different post-harvest risk management options. With regard to addressing this work, the CCFH also requested FAO/WHO to focus on the collection and review of existing information and examples and use this to guide further work. According to the request, FAO/WHO issued the call for data in January 2013 to collect relevant information.

A3.2 Response to call for data

There were ten countries (Argentina, Australia, Croatia, Cyprus, Dominican Republic, Netherlands, New Zealand, Peru, Sweden and United States of America), one region (EU) and one international organization (the Center for Science in the Public Interest) that responded to the call for data for *Trichinella* spp., and eleven countries (Australia, Cyprus, Denmark, Dominican Republic, Netherlands, New Zealand, Peru, Swaziland, Sweden, Sudan and United States of America) and one region (EU) for *Taenia saginata*.

A3.3 Results

A3.3.1 *Trichinella* spp.

A3.3.1.1 Public health data on the burden of disease in a country or region

(i) Prevalence of human cases

Eight of the 12 respondents reported the prevalence of human trichinellosis. Argentina reported a higher prevalence compared with Europe. No occurrences were reported for Australia, Dominican Republic, New Zealand (as of 2011) and Peru. (Cyprus: no information provided.)

Table A3.1 Summary of cases reported in response to Call for Data

Argentina (cases per 100 000 people)	Croatia ⁽¹⁾ (cases)	EU ⁽²⁾ (case-reporting countries)	Netherlands (cases)	New Zealand (cases)	Sweden ⁽³⁾ (cases)	CSPI (case from database)	USA (cases)
0.98 (2012)	8 (2011)	363-26 (2011)	1 (2009)	1 (1992),	2 (since	258 of 26	17 (2011)
1.17 (2011)	7 (2010)	(confirmed: 268)	without travel	suspected	1997)	outbreaks	(median of
1.63 (2010)		394-25 (2010)	history	overseas			11 cases
		(confirmed: 223)	reported	source of			per year
		1073-25 (2009)		infection			reported
		(confirmed: 748)		2 (2001),			during
				endemic			2002–2011)
				source			
				0 (2011)			

Notes: (1) Population: approximately 4.5 million. (2) Population of 27 countries (excluding Croatia, including Sweden): 50.25 million. (3) Population: 9.5 million. (4) Center for Science in the Public Interest (CSPI).

(ii) Notification status

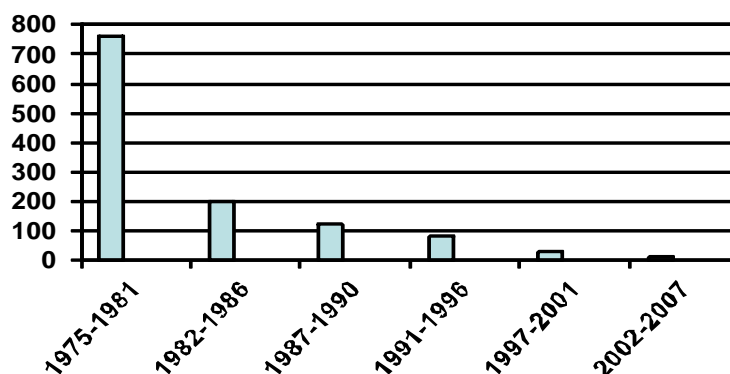
Argentina, Croatia, EU, Netherlands, Sweden and the United States of America dealt with trichinellosis as a notifiable disease. In New Zealand, organisms in pigs are also notifiable to the Ministry for Primary Industries.

(iii) Source attribution

Argentina, EU and New Zealand reported that the major source of the hazard related to human cases was pig meat. At the same time, data from Center for Science in the Public Interest (CSPI) showed that 20 of 26 outbreaks were associated with game meat (bear, walrus and cougar). The United States of America reported game meat, such as bear, boar, deer, pork and beef meat as sources of infection.

Figure A3.1 demonstrates the decline in total number of cases of human trichinellosis attributed to pork or pork products over the past 35 years in the United States of America. As can be seen, pork is no longer a significant source of human infection in the United States of America. In the period since 2002, an average of 1.7 cases per year were reported with pork as the source. Of these only one case per year, on average, has been linked to commercial pork. Thus, the risk of acquiring human trichinellosis from commercial pork in the United States of America in the years between 2002 and 2007 was 1 in 285 million.

Figure A3.1. Human trichinellosis caused by pork (all sources) from 1975 to 2007 in the United States of America



(iv) Types of human illness or clinical symptoms

Argentina reported that symptoms might range from very mild to severe, with gastrointestinal disorders (firstly) and muscle pain, fever, etc. (secondly). EU evaluated that (1) case fatality of confirmed cases associated with pig was <math><0.1\%</math>; (2) incidence associated with soliped meat was 0.05–0.15 cases per 100 000 EU population; and (3) result of evaluation of severity in humans was low. New Zealand reported patients' symptoms, including myalgia, fever, periorbital oedema, and photophobia. In the United States of America, eosinophilia, fever, periorbital oedema and myalgia have been observed. The number of reports of human trichinellosis in the United States of America have declined from approximately 500 cases annually in the 1940s and 1950s to an average of 14.2 cases annually in the period 2000–2009.

A3.3.1.2 Trade-related information

(i) Detections at port-of-entry inspection

There was no country reporting the detection of *Trichinella* spp. at port-of-entry point (including no testing conducted). Argentina reported that it has not been subjected to product rejection caused by *Trichinella spiralis* from countries which import livestock-derived products from

Argentina. The United States of America reports that *Trichinella* control in the foreign producing country is addressed during United States Department of Agriculture Food Safety Inspection Service (USDA FSIS) equivalence determinations and verified in the audit process. FSIS does not perform re-inspections for trichinae at port of entry. New Zealand also mentioned that most of the risk mitigation measures are applied and certified offshore due to New Zealand's geographic isolation and that most imported meat is frozen.

(ii) Risk management response to detection

EU applies the relevant regulation (Articles 18 and 19 of EC No 882/2004) to any detection. Peru reported that in the event of finding a product with deficiencies, the respective lot was destroyed.

A3.3.1.3. Performance of post-harvest control measures

(i) Prevalence of detection in domestic pigs

Argentina, Croatia, EU, New Zealand and the United States of America reported the prevalence of detection of *Trichinella* (see Tables A3.2A & B). There is no report or detection in Australia, Cyprus, Dominican Republic, Peru and Sweden. New Zealand reports that routine monitoring of domestic pigs continued until 2007, but all samples tested were negative.

Table A3.2A. Reported prevalence of *Trichinella* spp. in domestic swine

Argentina	EU	New Zealand
52 positive out of 3 643 538 slaughtered swine (2012)	Frequency of detection in pork carcasses after chilling: <0.1% For solipeds: 3 per 775 762 single samples (2007–2011)	Summary of recorded porcine and equine <i>T. spiralis</i> infections in New Zealand: 1965 – 4 pigs; 1968 – 3 pigs; 1997 – 4 pigs; 2001 – 16 pigs; 2004 – 1 horse.

Table A3.2B. Reported prevalence of *Trichinella* spp. in swine and game in Croatia, 2010–2012

	No. of positive cases in domestic pigs and game					
	Tested in approved slaughterhouses			Tested in authorized veterinary establishments		
	Domestic	Wild boar	Other species	Domestic	Wild boar	Bear
2010	2	2		66	53	2
2011	4	4		39	41	
2012	4	7		34	28	2

The United States of America reports that sera collected for the USDA's National Swine Survey in 1990 and 1995 demonstrated a continued decline in prevalence on a national basis (0.16% and 0.013% positive, respectively). Positive animals identified in the 1990 and 1995 NAHMS were sows; no market hogs were found positive in the 1990, 1995, 2000 or 2006 NAHMS Swine Surveys.

By far the largest data set of testing for *Trichinella* in pigs comes from hog slaughter plants that test for export under the Agricultural Marketing Service (AMS) Trichinae Export Program (unpublished data, AMS).

All testing performed in the AMS programme was by digestion and was performed as described in EU Regulations and OIE guidelines. Some participating slaughter plants have been in the programme since 1996, while others came and went as the market changed. Nevertheless, the numbers of tests conducted from slaughter plants in the Midwestern United States of America (n = 38 755 374, with all negative results since 1996) comprise a data set that clearly demonstrates the lack of *Trichinella* infection in commercial pigs from this region.

(ii) Prevalence of detection in game

Argentina, Croatia, EU and New Zealand reported the prevalence of detection of *Trichinella* as below. There is no report or detection in Australia, Cyprus, Dominican Republic, New Zealand,

Peru, Sweden and the United States of America.

Table A3.3. Reported prevalence of *Trichinella* spp. in game

Argentina	EU
13 from wild boars (2008–2012)	2011: farmed boars (115/25 996 (0.4%)), wild boars (EU 831/700 289 (0.12%), Non-EU 0/1919) 2010: farmed boars (26/36 871 (0.07%)), wild boars (EU 988/72 4640 (0.14%), Non-EU 0/2448) 2009: farmed boars (8/27 591 (0.03%)), wild boars (EU 959/580 841 (0.2%), Non-EU 0/2558)

For Croatia, see Table A3.2B.

For New Zealand, Clear and Morris (2004) stated:

Since 1990, more than 17 500 feral pigs have been processed. Many have come from the wilderness areas of the South Island. The last testing of feral pigs for export was in April 2002, as none have been exported since then. Feral pigs heavier than 68 kg continue to be tested for the local market, but as few reach this size most are not tested. There have been no positive *T. spiralis* findings in feral pig samples tested.

As of 12 April 2013, no infections had been detected in pigs since that article was published.

(iii) Test methodology applied

EU, including Croatia, Cyprus, The Netherlands and Sweden, reported that testing according to Commission Regulation (EC) No 2075/2005 was conducted, which recommends the magnetic stirrer method for pooled-sample digestion. Argentina and Australia also apply a digestion method, which is described in their own regulations. New Zealand also applies this method, set by OIE. All testing in the United States of America is done according to US test licensure, OIE guidelines and EU regulations.

A3.3.1.4. Availability of risk models

Table A3.4 shows the results of qualitative risk ranking for pork and horsemeat for *Trichinella* spp. for the EU.

The Netherlands reported models based on the risk of transmission, and development of a dose response model in rats, swine and humans. A scenario analysis of a risk-based approach has also been published (van der Giessen *et al.*, 2013). See also Teunis *et al.* (2012) and Takumi *et al.* (2009, 2010).

Table A3.4. EU qualitative risk ranking (Source: EFSA)

Pork	Horsemeat
<ul style="list-style-type: none"> • Frequency of detection: low <ul style="list-style-type: none"> • Severity: low • Source attribution: high <ul style="list-style-type: none"> • Final medium risk 	<ul style="list-style-type: none"> • Human incidence: low <ul style="list-style-type: none"> • Severity: low • Prioritization: low.

New Zealand provided a *Trichinella* model used for the expert meeting as the basis for the development of risk-based examples.

The United States of America provided a reference for *Trichinella* (Gamble, 2011).

A3.3.2 *Taenia saginata*

A3.3.2.1. Public health data on the burden of disease in a country or region

(i) Prevalence of human cases

Australia reported 12 human cases of *Taenia saginata* in 2000, of which 10 were imported (2 were unknown). In Sudan, 6932 cases (0.018% of the population) were reported in 2011. In New Zealand, 10 cases of taeniasis were notified in 2011 (0.2 per 100 000 population). United States of America reports about 2000 cases/year. There was no information from the other responding countries.

(ii) Notification status

All countries reported that human taeniasis is not notifiable (or reported "no information"), except New Zealand, where it is notifiable under human health legislation.

(iii) Types of human illness and clinical symptoms

EU, including Denmark, reported that severity of disease was unknown from EU-wide data, and considered to be 'Low'.

A3.3.2.2. Trade-related information

All countries reported that either that there was no detection of the parasite at port-of-entry or that no information was available.

A3.3.2.3. Performance of post-harvest control measures

(i) Prevalence of detection in cattle

Australia, Denmark, EU, New Zealand, Sweden, Sudan and Swaziland reported the prevalence of detection of *Taenia saginata* (Tables A3.5A & B). Swaziland reported 482 cases for the year 2012. There was no report or detection reported from the rest of countries. In the United States of America, the Animal and Plant Health Inspection Service (APHIS) has not recorded or compiled national-level information on *Taenia saginata* since 2005, when OIE removed it from the OIE list of diseases.

Table A3.5A. Reported prevalence of detection of *Taenia saginata*

Australia	Denmark	EU	Sweden	Sudan	Swaziland
<i>Taenia saginata</i> is present in the cattle population at a very low prevalence (Pearse <i>et al.</i> , 2010).	348/4 090 661 (2004–2011) The true animal level prevalence was estimated to be 0.06%	between 0.007% and 6.8% (Dorny and Praet, 2007; SCVMPH, 2000)	Approx. 1/year for the last three years. (Total slaughter of cattle ca. 400 000/year.)	Infection rate in different parts of Sudan: 0.06-2.7% by region (6 regions)	482 cases (2012)

Table A3.5B. New Zealand – Number and prevalence of cases of *Taenia saginata* per year from 2000 to 2012

Year	<i>Taenia saginata</i> confirmed	Possible <i>Taenia saginata</i>	Total	Annual kill (1000s)	Prevalence %
2000	1	5	6	2206	0.000272
2001	4	6	10	2146	0.000466
2002	19	22	41	2226	0.001842
2003	13	16	29	2556	0.001135
2004	6	5	11	2632	0.000418
2005	1	5	6	2443	0.000246
2006	1	3	4	2373	0.000169
2007	0	4	4	2232	0.000179
2008	1	4	5	2429	0.000206
2009	8	8	16	2373	0.000674
2010	11	4	15	2432	0.000617
2011	7	8	15	2275	0.000659
2012	4	0	4	2263	0.000177
Total	76	90	166	30 586	Av. 0.000543

(ii) Inspection methodology in national legislation

Australia, Denmark, Dominican Republic, EU, New Zealand, Peru, Sudan and Swaziland reported routine meat inspection associated with *Taenia saginata*, including EC No 854/2004 applied by EU member states. In the United States of America, APHIS currently does not have national legislation regarding beef cysticercosis, but FSIS legislation exists (9CFR 311.23 Tapeworm cysts in cattle; 9CFR 325.7, FSIS directive 6100.2; FSIS training materials). In Swaziland, postmortem inspection includes palpation, incision of parts of the carcass and offal, with laboratory tests to reach a definitive diagnosis.

(iii) Epidemiological information on the level of infection

Australia reported a sporadic case, which was probably caused by imported copra meal contaminated with human faeces. Denmark also reported that the level of infection was low and infected cases were only observed sporadically. EU estimated 0.17% (0–0.29) in fresh bovine meat out of 1 386 366 samples. New Zealand reported that generally a low level of infection exists where one cyst from one animal from one farm is detected, but that over the last ten years three instances of clustering have occurred. Sudan regarded the level of infection as medium. The Netherlands reported low to very sporadic levels of infection, high in veal calves mostly due to contamination of food. In the United States of America, state-level information on clusters and sporadic outbreaks is held by the State.

A3.3.2.4. Availability of risk models

Denmark reported two studies, namely Calvo-Artavia *et al.* (2013) and Calvo-Artavia, Nielsen and Alban (2013). The EU-provided qualitative risk ranking based on notification rate in humans and severity was given as ‘low’.

New Zealand reported that various unpublished *Taenia saginata* models have been developed by MPI. Relevant references are van der Logt, Hathaway and Vose (1997), and Richardson *et al.* (2009).

A3.4 Sources for Annex A3

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Microbiological Risk Assessment Series

This report documents the development of risk-based approaches for *Trichinella* spp. and *Taenia saginata* to illustrate the level of consumer protection likely to be achieved with different pre- and/or post-harvest risk management options, based on evaluation of slaughterhouse information and other data sources such as human illness. Simple spreadsheet models were used to generate quantitative risk-based information that is needed by public health officials when evaluating different meat hygiene programmes for *Trichinella* spp. and *Taenia saginata* in meat.

This volume and others in this *Microbiological Risk Assessment Series* contain information that is useful to both risk assessors and risk managers, the Codex Alimentarius Commission, governments and regulatory agencies, food producers and processors and other institutions or individuals with an interest in *Trichinella* spp. and *Taenia saginata* in meat.

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