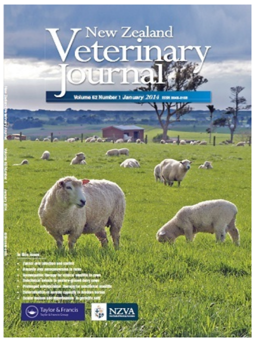

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Review Article

Taenia ovis infection and its control: a Canadian perspective

BD DeWolf*[§], AS Peregrine[†], A Jones-Bitton*, JT Jansen[‡] and PI Menzies*

Abstract

Distributed worldwide, *Taenia ovis* infection is responsible for the condemnation of sheep carcasses in many countries. This review highlights the programme used in New Zealand to successfully control *T. ovis* in sheep, and discusses how similar approaches may be modified for use in Canada, given what is currently known about the epidemiology of *T. ovis*. The lifecycle of the parasite is well known, involving dogs as the definitive host and sheep or goats as the intermediate host. An effective vaccine does exist, although it is not presently commercially available. In New Zealand an industry-based, non-regulatory programme was created to educate producers about *T. ovis* and necessary control strategies, including the need to treat farm dogs with cestocides regularly. This programme resulted in a substantial decrease in the prevalence of *T. ovis* infections between 1991 and 2012. Historically, *T. ovis* was not a concern for the Canadian sheep industry, but more recently the percentage of lamb condemnations due to *T. ovis* has increased from 1.5% in 2006 to 55% in 2012. It has been suggested that coyotes may be transmitting *T. ovis,* but this has not been confirmed. Recommendation are made for the Canadian sheep industry to adopt a control programme similar to that used in New Zealand in order to reduce the prevalence of *T. ovis* infection.

KEY WORDS: *Taenia ovis, cysticercus, sheep, control*

Introduction

Taenia ovis is a cestode with an intermediate stage that results in lesions in the musculature of sheep and goats, sometimes known as “sheep measles”. The muscle lesion caused by this parasite, called a cysticercus, is responsible for condemnation and trimming of sheep carcasses and can cause significant financial losses to sheep industries. The lifecycle of *T. ovis* is indirect, and is carried out in two different host species. The definitive host is a member of the family Canidae and the intermediate host is a sheep or goat (Ransom 1913). Condemnations due to *T. ovis* tend to be a continual issue in some countries, whilst in others it appears to be an emerging or re-emerging problem (Eichenberger *et al.* 2011; DeWolf *et al.* 2012). Beginning in 2007, Canadian abattoirs started to see a marked increase in sheep carcass condemnations due to infection with *T. ovis*. Although the parasite has been reported in Canada for decades (Soehl 1984), the sudden increase in condemnations has raised concerns and has resulted in investigations into *T. ovis* epidemiology and control. The following review describes programmes that have been developed to control *T. ovis* transmission, and intends to illustrate how similar programmes may be useful in Canada, while highlighting some of the current challenges faced by the Canadian sheep industry regarding control of *T. ovis*.

Lifecycle of *T. ovis*

In its adult stage, *T. ovis* inhabits the small intestine of canids where it can grow to 1.5 metres. It is rare to find more than one adult worm inhabiting the intestine at a given time (Jackson and Arundel 1971). The tapeworm’s scolex attaches to the intestinal mucosa using four suckers and an armed rostellum containing 24–36 hooks (Verster 1969). The length of the rostellar hooks allows differentiation between *T. ovis* and most other *Taenia* spp.; the one exception being *T. krabbei* which is discussed in more detail below.

The eggs of *T. ovis* are released into the environment in the faeces of a definitive host. In a 24-hour period, a dog with a patent *T. ovis* infection can pass between one and three proglottids per adult cestode (Gregory 1976). Each proglottid contains a mean of 78,000 eggs (min 30,000, max 150,000; Arundel 1972). Therefore, theoretically, a single parasite could release up to 250,000 eggs per day. The duration of time that eggs of *T. ovis* remain infective in the environment has been investigated in both field and laboratory studies but remains poorly understood. Because of the variation in experimental techniques used in earlier studies, it is difficult to completely understand the effect environment has on the duration of infectivity. It is likely that eggs of *T. ovis* can remain infective for up to one year on pasture, with desiccation being the primary factor contributing to their demise (Lawson and Gemmell 1983). It has been reported that within 10 days of deposition eggs of *T. ovis*, mean 0.5 μm in diameter, can be found up to 80 meters from their original

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FAO	Food and Agriculture Organisation
NHC	National Hydatids Council
OML	Ovis Management Limited
RFID	Radiofrequency Identification

location (Gemmell and Johnstone 1976). This distribution could be explained by the movement of sheep, which may inadvertently pick up eggs on their fleece or hooves and carry them to other areas (Gemmell 1972). Alternatively, it has been proposed that wind, rainwater, invertebrates, and even birds can act as mechanical vectors and transport eggs (Lawson and Gemmell 1983, 1985). At least two reports have suggested the transport of eggs of *T. ovis* via birds to secluded locations where canids were absent (Crewe and Crewe 1969; Torgerson *et al.* 1995).

Definitive hosts only become infected with the parasite following the ingestion of viable metacestodes from the muscle of infected sheep or goats. Following ingestion, the prepatent period in dogs is between six and nine weeks (Ransom 1913). Evidence from New Zealand suggests a prepatent period shorter than six weeks can occur when aggressive treatment with cestocides is implemented (Heath and Lawrence 1980).

The metacestode stage of *T. ovis* occurs within sheep or goats, the intermediate hosts. Infection occurs when animals inadvertently ingest the eggs of *T. ovis* from an environment contaminated with infective faeces. The larvae burrow through the intestinal mucosa using three pairs of keratinised hooks, and perhaps secretions (Heath 1971; Fairweather and Threadgold 1981; Jabbar *et al.* 2010) and migrate via the bloodstream to muscle. The most common predilection sites include the animal's heart, diaphragm and masseter muscles, but other skeletal muscles are also routinely infected. The cysticerci can appear as clear or white cyst-like structures within the muscle. The cysticerci in the muscle of the intermediate host can be detected visually as early as 10 days post infection (Ransom 1913) but at least 46 days are required before cysticerci become infective to the definitive host (Arundel 1972). This developmental period is required for the larvae to mature and develop necessary structures, namely suckers and rostellar hooks needed to parasitise the definitive host (Sweatman and Henshall 1962). The cysticercus only remains infective for four to eight weeks, after which the larvae within the lesion die (Ransom 1913). Although the lesion is no longer infective, it can remain in the muscle of the host for the remainder of the animal's life. The duration of the infective period in sheep is highly dependent on the immune status of the individual animal. Infected sheep will develop an immune response against subsequent *T. ovis* infection (Rickard and Bell 1971).

It has been suggested that within sheep, immunity to metacestodes occurs at two different stages of infection (Gemmell 1962; Rickard *et al.* 1976). The initial immune response occurs within the intestine upon ingestion of cestode eggs and involves both innate and acquired defences. A second distinct antibody-mediated immune response is induced by the larva once it reaches the predilection site (Gemmell 1962; Blundell *et al.* 1968).

Several studies have also examined transfer of immunity from ewes to their offspring via colostrum. Investigations have shown that both naturally and artificially infected ewes are capable of transferring immunity to their lambs. It is thought that maternal immunity provides protection until 6–9 weeks of age (Rickard and Arundel 1974; Heath *et al.* 1979).

Distinguishing *T. ovis* and *T. krabbei*

Generally *Taenia* spp. can be distinguished as adult tapeworms through differing host species and morphological differences, particularly the number and size of the rostellar hooks. Predilection sites of intermediate stages are also useful criteria for differentiating species. A notable exception is *T. ovis* and *T. krabbei*. The only apparent distinction between these two species is differing intermediate host species. Unlike *T. ovis*, which largely relies on a lifecycle involving dogs and domestic sheep, the lifecycle of *T. krabbei* is sylvatic and normally involves coyotes (*Canis latrans*) or wolves (*Canis lupus*) as the definitive host, and deer or moose (*Alces alces*) as the intermediate host (Olsen and Williams 1959). *T. ovis* has been reported in domestic sheep worldwide, whereas *T. krabbei* appears only in the Northern hemisphere in areas where cervids and wolves are common (Verster 1969). The similarities and overlapping ranges between the two species have resulted in controversy about whether they are, in fact, a single species.

Sweatman and Henshall (1962) provided some evidence, using cross-infection studies, that *T. ovis* and *T. krabbei* are distinct species. In their work 10,000 eggs collected from *T. krabbei* were fed to sheep and goats, none of which developed characteristic lesions in their muscle. Unfortunately, the experiment did not have cervid controls to demonstrate that the eggs were indeed viable. This experiment should be repeated with appropriate controls to validate the results.

Carcass condemnation due to *T. ovis*

The cystic lesions caused by *T. ovis* in the muscle of infected sheep do not cause infection in humans, but are aesthetically undesirable in meat destined for human consumption. Sheep or lamb carcasses heavily infected with *T. ovis* at slaughter are routinely condemned for human consumption; lightly or moderately infected carcasses may be trimmed and passed. In areas where the prevalence of *T. ovis* infection is high, the resulting financial consequences associated with high numbers of condemned carcasses can have a substantial negative impact on the local sheep industry (Lawson 1994).

In many countries inspection of lamb carcasses at abattoirs is based on guidelines for meat inspection developed by the Food and Agriculture Organization (FAO) of the United Nations. These guidelines recommend that a carcass be condemned due to *T. ovis* infection if it is heavily infected with the parasite, meaning "if lesions are discovered in two of the usual inspection sites including the masseter muscle, tongue, oesophagus, heart, diaphragm or exposed musculature, and in two sites during incision into the shoulder and the rounds" (Anonymous 1994). If a carcass is lightly or moderately infected, the FAO recommendation is to trim the carcass; the cysticerci are removed from the carcass, and the meat is held for 10 days at -10°C before being passed. At this temperature, all viable cysticerci are killed, ensuring the carcass is free of any infective parasites that may have been missed during trimming (Whitten 1971). Heating the carcass to at least 72°C is also effective at killing living parasites (Arundel 1972).

The gold standard for detecting *T. ovis* infection in lamb carcasses is to finely slice the animal's muscle into 3–4 mm slices and search for lesions. Though too laborious for routine meat inspection, this is the only way to ensure all lesions are accounted for. The sensitivity of detecting *T. ovis* at slaughter is dependent on infection burden in the animals (Heath *et al.* 1985), but the true prevalence of *T. ovis* can be five to ten times greater than that reported by routine meat inspection (McNab and Robertson 1972). Therefore, using abattoir data to estimate the true prevalence of this infection in a population will result in significant underestimation.

Currently the only absolute method of confirming *T. ovis* infection in sheep is through microscopically measuring the rostellar hooks of the protoscolex. This is obviously not feasible during meat inspection. Despite this, based on the size and location of *T. ovis* in the intermediate host, it is generally believed that misidentification is unlikely to occur during routine meat inspection. There have been efforts to develop a PCR that allows for rapid identification of helminths from dog and coyote faeces. At this time however, the ability of PCR to differentiate *T. ovis* and *T. krabbei* remains uncertain (Mathis and Deplazes 2006).

Treating *T. ovis* infection

There have been several studies that have investigated the use of high-dose anthelmintics to kill metacestode infections in sheep, and the results of these inquiries vary (Gemmell and Johnstone 1983; Sikasunge *et al.* 2008; Gavidia *et al.* 2010). Most importantly, treatments did nothing to remove cysticerci from tissues, meaning treated carcasses would still be condemned or trimmed. Currently, there is no practical option for the treatment of *T. ovis* in the intermediate host, but further investigation is warranted.

The use of licensed cestocides is effective at treating adult *T. ovis* infections in dogs (Andrews *et al.* 1983).

Vaccine development

Early work revealed that *T. ovis* oncospheres provide a rich source of immunogens (Rickard *et al.* 1977; Rickard and Williams 1982; Rothel *et al.* 1996). Subsequently, mRNA for several proteins found on the surface of *T. ovis* oncospheres were isolated and developed for various recombinant vaccines. In a clinical trial involving these vaccines, necropsies on lambs challenged with *T. ovis* revealed that immunisation with the 45 W protein in saponin reduced cysticerci by 94% in vaccinated lambs compared to controls following a challenge infection (Johnson *et al.* 1989). A field trial examined both naturally and artificially challenged lambs following two 45 W vaccinations administered subcutaneously in the dorsal neck region at six and 12 weeks of age. Following necropsy and thin-tissue slicing to count lesions, the vaccine reduced cysticerci counts by 98% compared to controls under field conditions (Lawrence *et al.* 1996).

Two other unrelated immunogenic recombinant proteins have since been isolated and found to be effective in eliciting protective immunity against *T. ovis* infection in lambs. These proteins, called To16 and To18, were the subject of clinical trials and provided a 92% and 99% reduction in the number of cysticerci, respectively, in vaccinated lambs compared to controls (Harrison *et al.* 1996).

Despite the successful development of a vaccine against *T. ovis*, both in terms of efficacy and large-scale manufacturing (Dempster *et al.* 1996), the product has never been available for commercial use anywhere in the world (Lightowlers 2006). The primary motivation behind *T. ovis* vaccine development was the financial losses associated with high numbers of condemnations, and the impact the infection was having on lamb export, particularly in Australia. By the time the vaccine had been developed, shown to be effective, and made ready for licensing, it was decided that the financial returns associated with the vaccine would be insufficient to warrant further marketing (Rickard *et al.* 1995; Lightowlers 2006).

T. ovis control programmes

T. ovis is generally considered a sporadic infection that has been reported in every inhabited continent of the world (Ransom 1913; Drabble 1934; McCleery and Wiggins 1960; Cardoso and Oliveira 1994; Al-Qureishy 2008). However, official records of *T. ovis* condemnations are rarely kept, and the prevalence of infection in most countries is not known. It is clear, however, that *T. ovis* is not equally distributed around the world, and that certain countries have been more aggressive in their response to the parasite compared to others. It is also known that because of the low sensitivity of detecting the parasite in sheep at slaughter, the infection is likely greatly underreported in all countries in which it has been found.

The sheep industries in Australia and New Zealand have endured considerable adversity from *T. ovis* infection. In New Zealand, throughout the first half of the twentieth century, *T. ovis* infection was rare (Lawson 1994) and almost exclusively a parasite of dogs working at abattoirs. There was, however, a high prevalence of *Echinococcus granulosus* in farm dogs, which became a substantive issue for both human and sheep health throughout New Zealand (Gemmell 1958; Lawson 1994). In 1959, the first formal control programme against *E. granulosus*, known as the Hydatids Act, was initiated in New Zealand. The Hydatids Act resulted in the formation of a regulatory body known as the National Hydatids Council (NHC) that had a mandate to develop and implement new policy in an attempt to control the infection (Lawson 1994). The NHC initiated an educational campaign focusing on control measures that were specifically directed at sheep producers. This educational campaign also consisted of mandatory treatment of farm dogs using arecoline hydrobromide, a purgative and moderately effective cestocide. A central point in the NHC's educational campaign against *E. granulosus* was to discontinue the feeding of sheep offal to farm dogs. To compensate for no longer feeding offal, the carcasses of cull ewes became the staple diet for the majority of farm dogs, resulting in increased exposure to *T. ovis*. Consequently, during the 1960s, the prevalence of *T. ovis* infection in slaughtered ewes rose substantially (McNab and Robertson 1972). The moderate efficacy of arecoline hydrobromide as a cestocide combined with the high fecundity of *T. ovis* contributed to the increased incidence (Gemmell *et al.* 1987). In 1970, New Zealand added *T. ovis* to the Hydatids Act, making it illegal to feed dogs sheep meat that had not been frozen or cooked, and also requiring producers to treat farm dogs with cestocides every six weeks (Lawson 1994). Following the introduction of mandatory treatment, the number of *T. ovis* condemnations declined.

Concurrently in Australia, warnings about escalating numbers of sheep carcass condemnations due to cestode infections were issued to producers. During 1970, the United States and Canada completely banned all imports of Australian mutton. The occurrence of *T. ovis* infection played a role in the ban, but caseous lymphadenitis was also partly responsible. Immediate changes were implemented at Australian abattoirs to better allow the detection of *T. ovis* prior to export. The improvements immediately increased the quality of Australian meat being exported, and the bans on Australian mutton were lifted (Arundel 1972).

In New Zealand, the efforts to control *E. granulosus* and *T. ovis* were separated in 1990 as it was thought that producers could maintain control of *T. ovis* without government support (Lawson 1994). However, in 1991, the prevalence of carcasses infected with *T. ovis* at New Zealand abattoirs tripled to nearly 4.0% (Simpson 2009). In fear of losing their sheep exports, a new industry-based, non-regulatory programme called Ovis Management Limited (OML) was created by the Meat Industry Association of New Zealand, and continues to exist to this day. The purpose of this programme is to educate producers about *T. ovis* and the necessary control strategies, including the need to treat farm dogs with cestocides regularly, preferably every four weeks. Since the formation of OML, the prevalence of *T. ovis* infections detected in sheep in New Zealand has declined to 0.5% in 2011–2012 (Anonymous 2012).

Status of *T. ovis* in Canada

There is little published information on *T. ovis* infection in Canada, where it is neither a reportable, immediately notifiable or annually notifiable disease. As a result, there are few federal or provincial records available concerning rates of infection. The earliest documented instance of *T. ovis* infection in Canada was in 1981 when five geographically distinct farms in Nova Scotia were found to have lambs infected at slaughter. The source of infection was eventually determined to be a farm from which all of the infected farms had recently purchased herding dogs. The source farm routinely offered mutton to their dogs while training them and it was later determined that the farm also had sheep infected with *T. ovis* (Soehl 1984). Since these cases, infections have continued to appear sporadically in sheep at abattoirs across the country. However, because of the continuous transport of sheep across Canada, the origin of infected animals has been difficult to ascertain. There are documented *T. ovis* infections sporadically occurring in sheep carcasses in the United States since as early as 1912 (Ransom 1913; Jensen *et al*. 1975). Given the proximity between Canada and the United States, along with the frequent importation of live sheep into Canada, there was likely *T. ovis* in Canada prior to the 1980s that went unrecorded.

Prior to 2007, *T. ovis* was not a concern for the Canadian sheep industry, despite being present at low numbers. The following data were derived from abattoir condemnation records maintained by the Ontario Ministry of Agriculture, Food and Rural Affairs (Veterinary Science and Policy Unit, Elora, Ontario) and Agriculture and Agri-food Canada (Red Meat and Poultry Sections, Ottawa, Ontario). In 2006 at Canadian federally inspected abattoirs there were 464 lambs condemned for all reasons, of which seven (1.5%) were condemned due to *T. ovis* infection. In 2007, the same abattoirs condemned 796 lambs in total, and *T. ovis* was responsible for 346 (43.5%) of those. The number of lambs being slaughtered did not differ substantially between years. At that time, the spike in condemnations represented the largest number of lamb condemnations due to *T. ovis* ever reported in Canada in one year. The number of *T. ovis* condemnations at federally inspected abattoirs remained elevated from 2007 through to 2010 (DeWolf *et al.* 2012). Since then, the number of lambs being condemned at federally inspected abattoirs has continued to rise steadily. In 2011, 244/507,086 (0.05%) lamb carcasses were condemned at federally inspected abattoirs due to *T. ovis*, which represents an increase from 94/523,380 (0.02%) in 2010 and 8/548,258 (0.001%) in 2006. Condemnations due to *T. ovis* in 2011 represented 244/579 (42%) of total sheep condemnations at federally inspected abattoirs. A similar trend was seen from 1 January to 31 October 2012, when 332/384,503 (0.09%) lamb carcasses were condemned at federally inspected abattoirs due to *T. ovis*, representing 55% of condemnations for all reasons.

In 2012, 45.5% of lambs slaughtered in Canada were slaughtered in Ontario, despite Ontario farms only producing 30.8% of lambs. Lambs are shipped into Ontario for slaughter because the demand for lamb meat is greatest there. The majority of lambs do not go direct to slaughter upon leaving their farm of origin, and will frequently spend time at a second farm or feedlot until market weight is achieved. This process means that lambs from different origins are continually being mixed and transported between farms across Canada. Between 2003 and 2008 at Ontario provincially inspected abattoirs, the percentage of all sheep carcass condemnations caused by *T. ovis* infection increased from 0/377 (0%) to nearly 303/626 (48.4%) (DeWolf *et al.* 2012). The number of animals being slaughtered during that time period did not change substantially. Since 2008, condemnations caused by *T. ovis* at Ontario provincially inspected abattoirs slowly declined, reaching 78/538 (14.5%) in 2011 and 41/373 (10.9%) in 2012 (to 31 October), but are still considered high based on historic data.

The reason for the increase in *T. ovis* condemnations over the past seven years remains unclear, but probably stems for the transport of large numbers of sheep between farms, causing many naive animals to become exposed in a short time period. Condemnations due to *T. ovis* are a concern for the Canadian sheep industry because as the parasite's prevalence increases, there will be large monetary losses for a relatively small livestock sector.

Wildlife and *T. ovis* infection in Canada

The potential for coyotes and wolves to act as definitive hosts for *T. ovis* is an atypical scenario in Canada that is not seen in many areas of the world where *T. ovis* has caused problems. The only known report of *T. ovis* in wildlife is from Europe (Moks *et al.* 2006) and was based on post-mortem examination of 26 wolves. Taeniids were identified based on morphology in this study, and it is possible that the species was *T. krabbei* misidentified as *T. ovis*. The parasite *T. krabbei* has been well documented in coyote and wolf populations in North America (Holmes and Podesta 1968; Craig and Craig 2005; Bryan *et al.* 2012), but the inability to differentiate between *T. krabbei* and *T. ovis* using morphological criteria means that it cannot be assumed a diagnosis of *T. krabbei* infection is always correct. It is possible that some *T. krabbei* infections identified in coyotes and wolves were actually *T. ovis*, acquired through consumption of domestic sheep.

Of the wild canids in Canada, the coyote has had the greatest impact on sheep production through predation. Although current numbers are lacking, the frequency of predation on sheep farms is high, suggesting that coyotes are almost certainly being exposed to *T. ovis*. The scavenging of improperly disposed sheep carcasses by coyotes is a frequent occurrence on Canadian farms that may also result in *T. ovis* exposure. Although it seems that coyote exposure to *T. ovis* is probable, the risk of transmitting the parasite from coyotes to sheep remains unclear. It is not known how frequently coyotes defecate on pasture while preying on sheep. For a coyote, the pasture may be considered a high-risk environment, producing stress that effectively eliminates the urge to defecate (DeWolf *et al.* 2012). There has been speculation that coyotes use round bales to scout hunting locations, and that defecation could occur on or near them, but this has not been confirmed. If coyotes are not defecating on sheep feed then the risk of them transmitting *T. ovis* to sheep may be minimal and probably limited to secondary transfer of taenid eggs by birds, insects or wind. Further research is needed in this area to determine the impact coyotes have on *T. ovis* transmission in Canada.

Recommendations for *T. ovis* control

Given that *T. ovis* is becoming increasingly prevalent in Canadian sheep, it is necessary for the sheep industry to act quickly to minimise the parasite's impact. Fortunately, research and control programmes from New Zealand have provided valuable information on successfully controlling *T. ovis*. Efforts to control *T. ovis* infection in Canada would be greatly assisted by a national programme, similar to OML in New Zealand. A unified organisation would create producer awareness through education, and act as a liaison between producers and government to facilitate change at a national level. Just as the control programme does in New Zealand, a similar group in Canada would provide consistency across the country, ensuring long-term sustainable control of *T. ovis*. Unfortunately, the dichotomy between provinces, and provincial and federal meat inspection, makes the initiation of such a programme difficult. The onus is on Canada to modify New Zealand's *T. ovis* control programme to fit the intricacies of sheep production in Canada. Based on what is known about *T. ovis*, the following are suggestions that may help with its control in Canada.

It is important to gain a more complete understanding of the prevalence of *T. ovis* on farms. Prevalence in Canada is currently being determined based on condemnation numbers, that may seriously underestimate the true prevalence of infection. Farms that have low infection burdens or stronger flock immunity will have sheep with fewer cysticerci, causing infected carcasses to be missed or trimmed at meat inspection, and not condemned. These lightly infected animals are not represented in the condemnation statistics. Alternative options for identification of infected animals are not practical at the national level. Serology and PCR in farm dogs and coyotes have been suggested, but the specificity of current tests makes it impossible to distinguish *T. ovis* and *T. krabbei*. A better prevalence estimate could be obtained through the identification of trimmed carcasses. There are currently no data collected on the rate of carcass trimming due to *T. ovis* infection at Canadian abattoirs. Although still not perfect, combined data on trimmed and condemned carcasses would provide a more accurate prevalence and distribution estimate for *T. ovis*, compared to condemnation data alone.

Historically, sheep were only required to be tagged at their farm of origin. The opportunity often exists for sheep to become infected with *T. ovis* at secondary locations, provided they remain there for at least two 2 weeks prior to slaughter. By using a complete traceability system, which requires sheep to be identified at each location prior to slaughter, potential sources of infection across the country would be easier to isolate. The initial steps towards a traceability system have been initiated by the Canadian Food Inspection Agency by soon requiring all sheep to be tagged with radiofrequency identification (RFID) tags. The implementation of RFID tags makes it easier for farms and feedlots to identify incoming animals, allowing for better records and greater traceability.

With RFID tagging, a national *T. ovis* trace-back system could be developed that would allow farms with condemned sheep to be contacted and informed of the condemnation. Trace-back of carcasses is thought to be a crucial component for successful, long-term control of the parasite. As shown with the control programme in New Zealand, an essential component of controlling *T. ovis* is producer education. In Canada, because *T. ovis* has historically been considered rare, the infection remains unknown to a large percentage of producers. Although articles on *T. ovis* and its control have been written for sheep producers over the last decade, changes to farm and flock management have been slow to occur, possibly because producers did not realise that their flocks was at risk. By informing producers of carcass condemnations, *T. ovis* awareness would increase and producers could be educated on prevention.

Regarding control of *T. ovis* at the farm-level, generally what has been recommended in New Zealand is applicable in Canada. It has been found that on Canadian farms, the main risk factors for *T. ovis* are farm dogs feeding on dead stock, and failing to dispose of carcasses on farm (DeWolf *et al.* 2012). Therefore it is recommended that dead stock be disposed of quickly and in a manner that prevents scavenging by farm dogs, free-roaming dogs, or coyotes. If there is a chance that farm dogs may have access to carcasses, or if sheep meat is used intentionally as a food item, all dogs should be treated at least every five weeks with a cestocide.

There is not yet evidence confirming the role of coyotes or wolves in *T. ovis* transmission, but, due to their abundance and frequent contact with sheep, the possibility of parasite transmission through these definitive hosts should not be ignored. Efforts should be made to reduce their occurrence on farms, especially in areas where sheep feed.

Conclusion

Most of the literature on *T. ovis* is based on research carried out in Australia and New Zealand, where the parasite has historically created substantial problems for sheep producers. In areas where the parasite is found, *T. ovis* can have dire financial effects on lamb and mutton sales, and effective control strategies are required. As illustrated by the New Zealand control programme, educating producers about *T. ovis* transmission, and promoting control strategies, can greatly reduce the number of carcasses being condemned. Based on this success, it seems prudent for any country experiencing elevated numbers of carcass condemnations to consider adopting a similar approach.

Although it has been reported in Canada for decades, *T. ovis* infection has only recently become a concern for the Canadian sheep industry. The increase in sheep carcass condemnations due to

T. ovis infection has prompted the Canadian sheep industry to take action in an effort to limit further parasite transmission. Canada would be wise to follow in New Zealand's footsteps and initiate the formation of an organisation like OML to be at the forefront of *T. ovis* control. It is essential that Canada continues to monitor the prevalence of *T. ovis* and take the necessary steps to educate producers and promote effective methods of control.

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