Eastern Journal of Agricultural and Biological Sciences (EJABS)
ISSN: 2753-3247
Website: https://qabasjournals.com/index.php/ejabs

Article Review: A brief knowledge for the larval and adult stages of *Taenia hydatigena* in intermediate and final hosts

Zahraa N.K. Al Aboudi [1], Duaa R.M. Al-Safi [2]

[1] *Department of Biology, College of Education for Pure Sciences, University of Wasit, Wasit, Iraq*
[2] *Department of Physiology and Pharmacology, College of Veterinary Medicine, University of Wasit, Wasit, Iraq*

Corresponding Author: Zahraa N.K. Al Aboudi; E-mail: *zkhalaf@uowasit.edu.iq*

ARTICLE INFO

Received: September 12, 2024
Accepted: November 20, 2024
Volume: *4*
Issue: 3

KEYWORDS

Tapeworms, Cestodes, Cysticercus tenuicollis, Sheep, Goats, Dogs

ABSTRACT

Taenia hydatigena is one of the most important tapeworms which infecting the wild and domestic animals, globally. The lifecycle of the parasite is indirect and involved an intermediate (domestic animals) and final (wild animals) hosts. The parasite is distributed worldwide at a variable prevalence among different hosts and countries. For diagnosis, different traditional methods such as direct examination of fecal samples and floatation were applied but with a low rate of sensitivity and specificity. In last decades, development of coproantigenic and molecular methods had made identification of the parasite and it species more sensitivity and specificity. However, combination of both traditional and advanced tools could provide more valuable data in diagnosis of different parasites. In conclusion, this study provided a brief knowledge about the prevalence of the larval and adult stages in intermediate and final hosts. Based on our investigation, Iraq is an endemic area for the parasite; however, the number of studies and information still limited and low. Therefore, moreover studies using of traditional and advanced diagnostic assays are of great importance and appear to be very necessary throughout all Iraqi areas and among different field animals, to establishment a database for the parasite and to developing an effective control and preventing schemes.

1. Background

Tapeworms belong for the genus of *Taenia* were involved more than 100 species infecting canine, feline, caprine, ovine, bovine, and other livestock (Mulinge et al., 2020). *Taenia hydatigena* is one of the most important tapeworms which infecting the wild and domesticated animals globally (Nguyen et al., 2016). *Taenia* was described in 1758, and *hydatigena* has been used for which about 40 names. *Taenia hydatigena* was reported as species of the genus *Taenia Linnaeus*, 1758 was noteasily identified by morphological means. Then Pallas in 1766 was described as *hydatigena* and Vorster (1969) replaced the generic name *Hydatigena* Lamarck, 1816 (Eom et al., 2020). *Taenia hydatigena* is an international parasite of domestic and wild animals (dogs, wolves, vultures, and coyote) and can infect various free-range animals such as sheep, buffalo, cattle and goats and their liver stages (Jarošová et al., 2022). Popova and Kanchev (2013) evaluated the effects of *Cysticercus tenuicollis* leading to liver damage associated with bacterial growth. *Taenia hydatigena* has been reported as a last resort in the small intestine of carnivorous animals such as dogs, cats, mice, wolves and rats (Abbas et al., 2021).

2. Classification

Kingdom: Animalia
Subkingdom: Eumetazoa
Phylum: Platyhelminthes
Subphylum: Cestodes
Class: Cestoda
Subclass: Eucestoda
Order: Cyclophyllidea

Family: Taeniidae
Genus: Taenia
Species: hydatigena
Scientific name: *Taenia hydatigena* (Lavikainen, 2014)

3. General morphology

Adult *T. hydatigena* could reach to 75-500 cm, and involved a head known as scolex, neck and strobila that composing from flat segments named as proglottid. Adult parasite existed in small intestine of dogs (Mehlhorn and Mehlhorn, 2016; Hama et al., 2018; Mariaux, 2024).
There are two rostellar hooks on the head of adult, and the length of the uterus is 10-14 to 4-7 mm (Figure 1, Table 1). There is only one special hole on each side (Radfar et al., 2005; Hama et al., 2018). Other distinct morphological features used in the morphological classification of worm species, such as the size and shape of rostellum branches: *T. hydatigna* 26-44 has a 170-220 µm ring or a branch with a large ring have 110-160 µm with small joints and attachment barrier (Slais, 2013; Mehlhorn and Mehlhorn, 2016; Abbas et al., 2021).

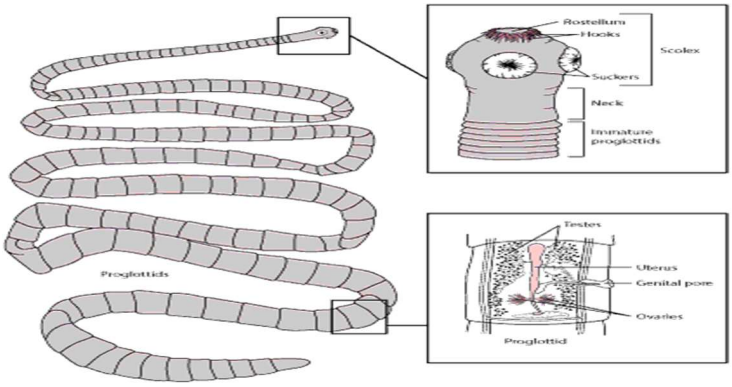

Figure 1. Diagram of Tania's adult tapeworm (Peregrine, 2014).

Table 1. Rostellar hook characteristics of *C. tenuicollis* cyst from sheep and goats.

Rostellar characteristics		Sheep origin	Goat origin
Arrangement of hooks		Large and small hooks alternating in 2 rows	Large and small hooks alternating in 2 rows
Large hooks	No. of hooks	15.33 ± 1.33	14.66 ± 0.5
	Blade length (µm)	94.8 ± 7.4	95.7 ± 5.48
	Handle length (µm)	104.3 ± 7.19	103.55 ± 8.76
	Guard length (µm)	35.65 ± 5.07	37.9 ± 7.48
	Total length (µm)	199.1 ± 10.93	198.7 ± 10.49
Small hooks	No. of hooks	15.44 ± 1.42	14.77 ± 0.66
	Blade length (µm)	73.55 ± 5.12	74.65 ± 6.64
	Handle length (µm)	61.3 ± 9*	67.45 ± 9.75*
	Guard length (µm)	31.75 ± 4.2*	34.1 ± 5.70*
	Total length (µm)	134.85 ± 11.63*	141.8 ± 8.33*

3. Eggs

Taenia hydatigena eggs are morphologically indistinguishable from other tapeworms of the *Taeniids* family; the eggs are, round or oval and about 30µm in diameter (Figure 2), (Saari et al., 2018; Adolph and Peregrine, 2021). Importantly, eggs are released

only after part of the gravity zone has collapsed (Cork and Lejeune, 2019). *Taenia hydatigna* can lay over 100, 000 eggs daily, most of which hatch in small immature intestines (Jayousi, 2014).

Figure 2. Taenia eggs (Saari et al., 2018).

4. *Cysticercus tenuicollis*

Cysticercus tenuicollis is the larval stage of the adult *Taenia hydatigna* which represent the highly importance among sheep and goats (Mirzaei and Rezaei, 2015). The parasite is found in the mucous membrane, mesentery, brain, visceral surface of the liver (called cystic hepatitis), subcutaneous tissue, bones, eyes, as well as the lungs and heart (Figure 3). It is pathogenic and is 6-8 cm wide (Love and Hutchinson, 2003; Eberhard, 2008; Saari et al., 2018).

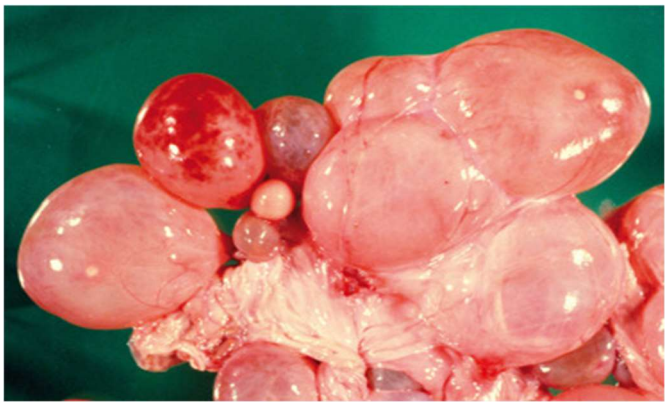

Figure 3. Cysticercus tenuicollis larval stage of *T. hydatigena* (Saari et al., 2018).

After eating an egg, the sac in the egg under the influence of gastric fluid and bile ducts breaks down blast cells and eventually activates the sac. The sac enters the intestinal epithelium using secretions and secreted enzymes. Thus, glandular closure acts as a stem cell rental agent that helps branches pass through muscle. It takes about 30-120 minutes for the mucous membrane to enter the small intestine, and after passing through the epithelium, some balloons enter the subepithelial capillaries and are carried through the venous portal system to the liver, where they become cystic (Mohammed, 2019).
Cysticercus tenuicollis has been shown to be fatal in sheep due to severe liver disease (Corda et al., 2020). Its cystic structure filled with excess fluid, especially in the myocardium of the abdominal organs. In middle-aged people, the infection is usually mild and small with mild severity, including the needle heads of future worms in other cysts (Ghaffar, 2011; Corda et al., 2020).

5. Life cycle

The lifecycle of the adult parasite *T. hydatigena* is indirect needing to definitive and intermediate hosts for completing it, adult worm lives in small intestine of wild animals (dogs, wolves, jackals, and foxes). The gravid segment separated, and eggs excreted to contaminate environments (Figure 4).

Figure 4. Lifecycle of *T. hydatigena* (Saari et al., 2019).

After ingestion by intermediate hosts (domestic animal), eggs hatched to embryo that penetrated intestinal wall and entered blood circulation until they reached peritoneal cavity to result in the adult stage of parasite, *Cysticercus tenuicollis* (Smith et al., 1999; Cork and Lejeune, 2019). Metacestode (*C. tenuicollis*) is a variable sized-cyst that filled with transparent fluid. This cyst is responsible of morbidities and mortalities in intermediate hosts (Ladds, 2009; Bayu et al., 2013; Mwanja, 2019). It causes hemorrhage and serve as predisposing factor for traumatic hepatitis and peritonitis in acute cases, while in chronic cases, it's economically important in slaughtered animals as it damages the carcasses (Wondimu et al., 2011; Logose, 2013).

6. Epidemiology

The parasite is distributed worldwide at a variable prevalence ranged between 0.1 to 32% among different hosts and countries (Ohiolei, et al., 2019). The prevalence of cystic disease varies from country to country and from country to country (Braae et al., 2015; Scala et al., 2015; Nguyen et al., 2016). It may reach 63.9% in Africa, 55.5% in Asia, 39% in South America, and 14.6% in Europe (Oryan et al., 2012; Scala et al., 2015; Gulelat et al., 2022).
All studies reported are slaughtered animals because the infection rate of goats is higher than that of sheep because most sheep have a number of people who live with insects at an early age and a defense system that protects against infection. Sultan et al. (2010) have confirmed the increase using surgery in goat moving forward. A small number of studies were conducted in four regions in Saudi Arabian and Iraq, and *T. hydatigena* was performed on animals with small horns.

Table 2. Worldwide prevalence of *T. hydatigena* and *C. tenuicollis*.

Country	Prevalence (%)		Reference
	Sheep	Goat	
Addis Ababa	37.2	44	Bejiga (2016)
Benin	58.2	53.3	Attindehou and Salifou (2012)
Brazil	17.4	39	Morais et al. (2017)
China/Mongolia	1.3-12.5	-	Zhang et al. (2018)
Colombia	39.13	-	Caicedo Martínez et al. (2016)
Ethiopia	32.7	-	Adem and Alemneh (2016)
Ethiopia	79	53	Sissay et al. (2008)
Ethiopia	40	46.6	Samuel and Zewde (2010)
Ethiopia	7.81	15.8	Bayu et al. (2013)
Ethiopia	22.8	26.4	Mekuria et al. (2013)
Germany	16.7	-	Hasslinger et al. (1993)
Ghana	22.66	22.34	Addy et al. (2021)

India	37.03	27.29	Pathak et al. (1982)
India	-	23.01	Ganaie et al. (2018)
India	2.36	1.62	Rao et al. (2003)
India	-	21.01	Nath et al. (2010)
Iran	12.87	18.04	Radfar et al. (2005)
Iran	12.08	37.03	Dalimi et al. (2006)
Iran	-	37.03	Eslami et al. (2010)
Iran	28.04	18.04	Oryan et al. (2012)
Iran	17.52	55.05	Oryan et al. (2015)
Iran	4.08	4.33	Khanjari et al. (2015)
Iran	4	4.9	Mirzaei and Rezaei (2015)
Italia	14.6	-	Scala et al. (2015)
Nigeria	21.4	34.2	Dada (1980)
Nigeria	30.2	-	Fakae (1990)
Nigeria	13.03	-	Saulawa et al. (2011)
North India	2.23	4.83	Singh et al. (2015)
Pakistan	4.67	4.07	Alvi et al. (2020)
Tanzania	63.8	34.7	Ernest et al. (2009)
Tanzania	2	3	Mellau et al. (2010)
Tanzania	51.9	45.7	Baraae et al. (2015)
Tanzania	42.2	61.1	Miran et al. (2017)

Table 3. Prevalence of *T. hydatigena* and *C. tenuicollis* in Arabic countries

Country	Prevalence (%)		Reference
	Sheep	Goats	
Algeria	24.21	43.9	Ouchene-Khelifi and Ouchene (2017
Algeria	7.8	22.3	Mokhtaria et al. (2018)
Egypt	14.29	-	Abu-Elwafa and Al-Araby (2008)
Egypt	45.7	51.9	Braae et al. (2015)
Egypt	16	19	Omar et al. (2016)
Egypt	18	-	Aboulaila et al. (2020)
Jordan	9.2	6·2	Dajani and Khalaf (1981)
Oman	9.3	-	Johnson et al. (1989)
Palestine	2.15	-	Adwan et al. (2018)
Saudi Arabia	0.45	23.4	Bakhraibah and Alsulami (2018)
Saudi Arabia	1.25	-	EL-Metenawy (1999)
Tunisia	2.8	8.9	Khaled et al. (2020)

Table 3. Prevalence of *T. hydatigena* and *C. tenuicollis* in Iraq

Country	Prevalence (%)		Reference
	Sheep	Goat	
Al-Diwania	7.4	-	Al-Mayali (2005)
Al-Diwania	11.73	2.85	Al-Hamzawi and Al-Mayali (2020)
Baghdad	14.22	-	Azawi and Al-Biatee (2019)
Baghdad	21	35	Al-Sudani and Al-Amery (2022)
Basra	77	-	Al-Saqur and Al-Jourani (1987
Basrah	40.55	26.25	Essa and Al-Azizz (2011)
Duhok	0.7	-	Ghaffar (2008)
Duhok	22.6	-	Mohammed and Kadir (2019)
Erbil	-	9.4	Molan and Saeed (1988)
Karbala	34.53	37.08	Haddawee et al. (2018)
Sulaimani	2.63	2.59	Hama et al. (2018)

7. Epidemiology of intermediate host

In Iraq, Leiper (1957) was the first recorded *C. tenuicollis* infection in the peritoneal cavity of sheep. Mathur et al. (1974) recorded an infection in the peritoneal cavity of sheep in the north of Iraq by *C. tenuicollis*. Al-Saqur and Al-Gorani (1987) observed that the rate of infection in Basra was 1% in sheep. Also, Essa and AL-Azizz (2011) in Basra determine the rate 40%, 55%, 26, and 25% respectively. While Al-Mayali (2005) reviewed that slaughtered sheep at Al-Diwania abattoir in 1999 the rate of (7.4%) were infected with cysticercosis although Hama et al. (2018) in Sulaimani abattoir at 2.63% and 2.58% in sheep and goat, respectively. Mohammed and Kadir (2019) showed that *C. tenuicollis* infection of sheep was carried out 22, 6% in sheep only in the Duhok abattoir. Ghaffar (2008) reviewed that examined sheep in the Duhok abattoir in 2009. Al-Azawi and Al-Biatee (2019) referred to the prevalence of larval stage of *T. hydatigena*in Baghdad was 14.22%. Also, Al-Sudani and Al-Amery (2022) revealed total occurrence of ovine and caprine parasite was 21% and 35%, respectively.

8. Epidemiology of *T. hydatigena* in stray dogs

Al-Alousi et al. (1980) was first reported *T. hydatigena* in Mosul stray dog. Abul-Eis (1983) recorded 52.63% of cases of *T. hydatigena* in Baghdad dogs. Al-Tae et al. (1988) reported that dogs in Mosul have an infection rate of 39%. Al-Aziz (2005) reported 7.62% of *T. hydatigen* in stray dogs of Basra province. Cabrera et al. (1996) reported 13.9% of dogs infected with *T. hydatiena* in parts of Uruguay. Emamapour et al. (2015) reported that 43% of the poor in northeastern Iran have female and adult infectious diseases, but Trasviña-Muñoz et al. (2020) reported through testing of 2000 dogs in a city in Mexico that *T. hydatiena* levels ranged 2.6-3.0%. In Italy,
Morandi et al. (2020) found that 43.7% of dogs carry the common species *T. hydatiena*. According to a study conducted from 1997 to 2015, *T. hydatigena* is a highly isolated parasite in dogs, accounting for 30% of 1,539 dogs. Generally, *T. hydatigena* is the most common worm species found in the home and in nature around the world (Jarošová et al., 2022). Trasviña-Muñoz et al. (2020) found that the rates of *T. hydatiena* infection between male and female dogs were 2.6% and 3.0%, respectively for the spread of infection in adults worldwide.

9. Diagnosis

9.1. Diagnosis of larval stage in dog

Once the tapeworm is automatically released from the feces of a living dog, a fecal test can make a diagnosis (Raether and Hänel, 2003). *Taenia* eggs are analyzed by fecal excrement, but this diagnostic method is less sensitive to *Taeniata* because it is not isolated under an optical microscope. The morphology of the eggs is not diagnostic, and the animal species can be identified using PCR and observations of laboratory detection test (Alvarez Rojas et al., 2018; Deplazes et al., 2019).

9.2. Microscopic examination of fecal sample

9.2.1. Direct method

Fecal samples of the dogs were examined under 10 and 40 power. The direct fecal method is easily conducted and while the proglottids were quite moist, their morphology could assist to recognize the parasite at the level of genus (Henderson-Frost and Gilman, 2018; Mulinge et al., 2020). The proglottid could be Injected with Indian ink were help in distinguishing some species by recognizing the structural details (Garcia et al., 2011; Henderson-Frost and Gilman, 2018).

9.2.2. Concentration techniques (*Flotation method*)

The flotation technique is most generally utilized in veterinary medicine for the assessment of defecation; it depends on contrasts in explicit gravity of parasite eggs (Al-Gharban, 2016; Summitt, 2022). Flotation arrangements incorporate zinc sulfate, NaCl, and Sheather's solution (Gupta et al., 2023; Gharban et al., 2024). The flotation method gain slight material than sedimentation for a lighter number of eggs, it is simple and modest to use (Ajaj et al., 2021).

9.3. Diagnosis of adult stage in dog

9.3.1. Arecoline purgation

Purgation with arecoline intensifies which causes cleaning of entire intestinal substance when it's given to canine lead to loss of motion of the worm troubles then it very well may be recuperation and gathered for perceived (Zou and Ye, 2014). The grown-

up parasites, or their proglottids, can be found in the conclusive host's excrement in the wake of cleansing with is coline compounds that could use for surveys in dog populations of tapeworm infections (Gallagher, 2014).
That survey could be completed by purging the dogs within 1-4 hours when was used arecoline hydrobromide (1.5-3 mg/kg orally after 12 hours of starvation) (Bajalan, 2006). As a result of its side effects, there were no longer recommended, and tapeworms can be recuperated after anthelmintic treatment (Henderson-Frost and Gilman, 2018).

9.3.2. Necropsy of the small intestine
It is the advantage strategy for canines, foxes, and other definitive hosts and the worms can be gathered to recognize (Lightowlers, 2012). Necropsied dogs were tied at both ends of the small intestine and were removed as soon as possible after death (Singh and Arya, 2015).

9.3.3. Coproantigen detection of parasite antigens in feces
Coproantigen diagnosis by enzyme-linked immunosorbent assay (ELISA) for finding cestodes, including *Taenia* species of sandwich-ELISA was advanced for the reveal of soluble *Taenia hydatigena* antigens in dogs feces samples (Feng, 2013; Gottstein, 2018).
Because cross-reactions with other species were possible the uses of serology were not normally recommended because the useing of this technique is not sensitive enough for diagnosis (Kanchev and Mehnaz, 2023).

9.4. Molecular diagnosis

The DNA-mediated diagnostic method is a sufficient or an alternative to examining meat, but the combination of both traditional and molecular techniques makes the diagnosis is better for the importance and nature of the differences within the *T. hydatigena* types (Seipati, 2016 Stephen et al., 2022). *Taenia hydatigena* species cannot be diagnosed by measuring the length of the thorns only. Therefore, molecular methods must be studied to find out (Slais, 2013). Differences within *C. tenuicollis*, as larvae were identified by morphological structures and COX-1 through what was revealed in the molecular decomposition of similarities between *C. tenuicollis* isolated from wild mammals infected with *T. hydatigena* parasite in wolves (Cengiz et al., 2019). Partial studies are used to find out the biological, epidemiological, and endogenous changes of *Taeniidae* of *T. hydatigena* and they demonstrate the genetic variation between species, their epidemiological importance, and the evolutionary relationships between distant taxa (Dixon et al., 2021).

10. Conclusion

This study provided a brief knowledge about the prevalence of the larval stage (*T. hydatigena*) and adult (*C. tenuicollis*) stages among the intermediate (sheep and goat) and final (dog) hosts. Based on our investigation, Iraq is an endemic area for the parasite; however, the number of studies and information still limited and low. Therefore, moreover studies using of traditional and advanced diagnostic assays are of great importance and appear to be very necessary throughout all Iraqi areas and among different field animals, to establishment a database for the parasite and to developing an effective control and preventing schemes.

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