Spatiotemporal distribution and economic loss associated with bovine cysticercosis and human taeniasis in Ethiopia

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**Abstract**

A metacestode stage (bovine cysticercosis) and adult stage *Taenia saginata*, accounted for zoonotic and economic losses from organ contamination and treatment cost. The objective of this paper is to assess the spatiotemporal distribution and economic loss from bovine cysticercosis and human taeniasis with treatment approach in different parts of Ethiopia. All available published research articles from Ethiopia on the disease were collected. The data were assessed using the current regional administrative, the locality and chronology of the reports for prevalence and economic loss with treatment trend. Prevalence ranging from 1.9% at Addis Ababa City to as high as of 26.3% Hawasa-SNNPR using postmortem examination. However, one study confirmed 92.7% of 41 isolates as bovine cysticercosis using polymerase chain reaction (PCR) method. Teaniasis was ranged from 7.8% in Modjo-Oromia to as high as 89.4% in Addis Ababa City. Except for 17.9% at Addis Ababa City, 29.0% at Mekele-Tigray and 19.0% at Halaba Kulito–SNNPR teaniasis in Ethiopia were greater than 30% over 2001–2018 years. Questionnaire survey and retrospective data were the major tools used for teaniasis reporting either pharmaceutical and/or traditional (herbs) medicines were used for teaniasis treatments. Niclosamide, mebendazole and praziquantel were pharmaceutical teanaicidal drugs used in Ethiopia until the years of 2009, uses of albendazole begins from 2011 to date (2018 year). *Hagenica abyssinia* “Kosso/Heto” flowers is still widely used in Ethiopia in that it contains Kosso-toxin, closely related to folic acid, are responsible for some cases of hepatic carcinoma and blindness. Only few data (reports) were available on spatiotemporal economic loss associated with bovine cysticercosis and *Taenia saginata* in Ethiopia showing an overall 4,052,278.16 ETB (212,202.76 USD) from five reports. Highest economic loss (88,500.00 USD) was registered at Yirgalem-SNNPR [2005–2009]. Study at Kombolcha-Amhara region during 2016 accounted 1,841,311.00ETB (73,652.44 USD) from *C. bovis* and teaniasis treatment cost. Total cost for the used pharmaceutical drugs accounted 921,112.00ETB over 2005–2016. The maximum drug expenditure was reported during the year 2013. Thus, bovine cysticercosis and *Taenia saginata* cycle interruption via stopping human open defecation with assessing the dynamics of the disease in the country.

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**Keywords:** Bovine cysticercosis, Economic loss, Treatment trend, Taeniasis

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https://doi.org/10.1016/j.parepi.2018.e00078
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1. Introduction

*Taenia saginata* (the adult in human intestine) and its *Cysticercus bovis* (the metacestode larval stage in active muscle of bovine) (*Urquhart et al., 1996; OIE, 2000*) occur throughout the world with variable degree of prevalence (*Harrison and Sewell, 1991*). Poor hygiene and sanitation, poor livestock husbandry practices and inadequate meat inspection and control as well as eating raw or insufficiently cooked meat can be the main risk factors for the spread of the disease (*Cabaret et al., 2002*). There are 77 million taeniasis patients of which 32 million are in Africa, 11 million in Asia and about 3 million in the new world. Highly endemic areas include Central and East African countries Ethiopia, Kenya, Argentina and in the Mediterranean Region (Syria, Lebanon and Yugoslavia) (*Frolova, 1982*). Cattle are infected by ingestion of pasture and drinking water contaminated with *T. saginata* eggs (*Teka, 1997*). The parasites appear to be specific to cattle, while wild animals play no part as intermediate hosts (*Symth, 1984*). Variability in degrees of awareness in human infection varies with age, sex, religion, educational level, presence and usage of sanitary facilities especially toilets (*Megersa et al., 2010*).

Based on routine carcass inspection, the infection rate of bovine cysticercosis is often around 30–60% in developing countries (*Minozzo et al., 2002*). The organs and tissues most commonly affected and condemned due to *C. bovis* are the heart, tongue, diaphragm and muscles of the jaw (*Dorny et al., 2000; Maed et al., 1996*). Besides human-animal health risk, high prevalence in Sub-Saharan Africa, causes an important economic loss due to partial or total condemnation of infected carcasses (*Wayne et al., 2002; Tegegne et al., 2018*), refrigeration and downgrading of infected carcasses (*Fan, 1997*) and the cost of drug for human treatment (*Tegegne et al., 2018; Abunna, 2013*). Chemotherapeutic, herbal medication or combinations of both were frequently used in Ethiopia (*Tegegne et al., 2018; Abunna, 2013; Desta, 1995*). Thus, different parts of various plants like *Hagenica abyssinia*-flowers, *Cratsonmacro satchyus*-seed, *Embella schimperi*-seed, or *Cynodon dactylon-all parts* are used. Some of them have certain draw backs and are responsible for hepatic carcinoma and blindness (*Desta, 1995*). Praziquantel is reported effective for human taeniasis but this is proved impractical because of high cost (*Reniecke, 1983*).

Over a period of years, investigation on the prevalence of *Taenia saginata* in human and *C. bovis* in beef with economic significance of the diseases has been done in different parts of Ethiopia (*Feseha, 1995; Tembo, 2001; Dawit, 2004; Nigatu, 2004; Hailu, 2005; Abunna et al., 2007; Bedu et al., 2011; Mesfin and Nuradddis, 2012; Abay and Kumar, 2013; Terefe et al., 2014; Abate, 2014; Tolossa et al., 2015; Hiwot, 2016; Abdulaziz et al., 2016; Cheru and Zeryihun, 2017; Dereje, 2017; Tegegne et al., 2018; Tamirat et al., 2018*) in the forms of fragment. The prevalence and spatial epidemiology of cisticercosis in slaughtered cattle from Brazil were assessed by *Dutra et al. (2012)*.

However, prevalence, spatial epidemiology and associated economic losses from bovine cisticercosis and human taeniasis in Ethiopia were not yet summarized. Therefore, the objective of this paper is to assess the spatiotemporal distribution and economic loss from bovine cisticercosis and human taeniasis with treatment approach in different parts of Ethiopia.

2. Methods used

All available published research articles on bovine cisticercosis in different time periods were assessed. Similarly published/none-published reports on *Taenia saginata* in Ethiopia were assessed. The available data shows reported information on bovine cisticercosis from 1990 to 2018 and on *Taenia saginata* in Ethiopia from 2001 to 2018 years period different parties Ethiopia.

Focusing on spatiotemporal, treatment trend and associated cost, all reports were categorized. Thus, the current nine (9) administrative regions (Afar, Amhara, Benishangul-Gumiz, Ethio-Somali, Gambella, Harari, Oromia, South Nation Nationalities and People Regional Government (SNNPR) and Tigray Regional States) and the two councils (the Addis Ababa City and Dire Dawa town), the locality and chronology of the reports were considered. With regard to time, reports of bovine cisticercosis were categorized by years from 1990 to 2018 and that of *Taenia saginata* from 2001 to 2018.

Considering published/none-published date, *Taenia saginata* treatment trend and the types of drugs used were also assessed. Reported cost of organ and carcasses condemnation as well as treatment were assessed. Again the encoded cost was categorized using spatiotemporal and expressed both by Ethiopian Birr (ETB) and United State of American Dollar (USD).

3. Spatiotemporal distribution of bovine cisticercosis in Ethiopia

Bovine cisticercosis is reported in various countries including Ethiopia, as a major parasite disease responsible for organ condemnation, and public health risk. Prevalence was reported in Ethiopia and showed variable with region, localities and years...
Table 1
Spatiotemporal distribution of bovine cysticercosis in some regions of Ethiopia [1990–2018].

| Region/council | Location | Study method | Number of samples | Prevalence in % | Reference Year |
|----------------|----------|--------------|-------------------|-----------------|---------------|
| Oromia         | Nekemt   | PME          | 740               | 21.7            | Issa, 1990    |
| Oromia         | Bishoftu | PME          | 396               | 13.8            | Getachew, 1990|
| Amhara         | Bahir Dar| PME          | 486               | 19.4            | Mulugueta, 1997|
| Addis Ababa    | A.A.C.   | PME Serology | 732               | 7.5             | Nigatu, 2004  |
| Oromia         | Mojo     | PME          | 768               | 17.6            | Hailu, 2005   |
| SNNPR          | Hawassa  | PME          | 400               | 26.3            | Abunna et al., 2007|
| Oromia         | Jimma    | PME          | 500               | 4.4             | Megeras et al., 2010|
| Addis Ababa    | A.A.C.   | PME          | 44,000            | 1.9             | Deresse et al., 2012|
| Oromia         | Mojo     | PME          | 17,000            | 8.5             | Deresse et al., 2012|
| SNNPR          | W.S.T.** | PME          | 380               | 2.6             | Dawit et al., 2012|
| SNNPR          | Virgalem | PME          | 400               | 12.0            | Abunna, 2013  |
| Tigray         | Mekelle  | PME          | 1023              | 7.2             | Abay and Kumar, 2013|
| Tigray         | Shire    | PME          | 439               | 5.2             | Belay and Mekelle, 2014|
| Harari         | Harar    | PME          | 898               | 19.7            | Terefe et al., 2014|
| Oromia         | Bishoftu | PME          | 430               | 5.6             | Emurum, 2014  |
| Ethiopia       | Different | PCR          | 41                | 92.7            | Hallemariam et al., 2014|
| Oromia         | Adama    | PME          | 384               | 2.6             | Tolossa et al., 2015|
| Amhara         | Gondar   | PME          | 768               | 3.0             | Motbenyon and Terefe, 2015|
| Amahara        | Gonder   | PME          | 400               | 2.25            | Kine et al., 2016|
| Amhara         | Gonder   | PME          | 450               | 2.0             | Adem and Alemneh, 2016|
| Oromia         | Bishoftu | PME          | 700               | 5.4             | Hiwot, 2016  |
| Tigray         | Mekelle  | PME          | 1800              | 22.2            | Getachew et al., 2017|
| Oromia         | Nekemt   | PME          | 600               | 15.5            | Dereg, 2017   |
| Oromia         | West Arsi| PME          | 768               | 4.94            | Kebede, 2017  |
| Ethio-Somali   | Jjiga    | PME          | 400               | 2.25            | Biruk, 2017   |
| Amahara        | Gonder   | PME          | 400               | 5.5             | Churu and Zeryuhun, 2017|
| Amhara         | Bahir Dar| PME          | 480               | 4.2             | Tamirat et al., 2018|
| Amhara         | Kombolcha| PME          | 234               | 8.97            | Tegegne et al., 2018|

Note: ¶Year = year of report; *A.A.C. = Addis Ababa City; **W.S.T = Wollayita Soddo Town.

Table 2
Spatiotemporal distribution of human taeniasis in some regions of Ethiopia [2001–2018].

| Region/council | Locations of study | Study method | No. of sample | Prevalence in % | Reference Year |
|----------------|--------------------|--------------|---------------|-----------------|---------------|
| Addis Ababa    | A.A.C.             | Questionnaire| –             | 89.4            | Tembo, 2001   |
| SNNPR          | W.S.T.             | Questionnaire| –             | 62.5            | Dawit, 2004   |
| SNNPR          | Hawassa            | Questionnaire| 120           | 64.2            | Abunna et al., 2007|
| Oromia         | Jimma              | Questionnaire| 60            | 56.7            | Megeras et al., 2010|
| Oromia         | Ziway              | Questionnaire| 120           | 56.7            | Bedu et al., 2011|
| Oromia         | Mojo               | Stool exam.  | 90            | 7.8             | Deresse et al., 2012|
| Addis Ababa    | A.A.C.             | Stool exam.  | 134           | 17.9            | Deresse et al., 2012|
| SNNPR          | Hawassa            | Questionnaire| 192           | 44.0            | Mesfin and Nurraydis, 2012|
| Tigray         | Mekelle            | Questionnaire| 7171          | 29.0            | Abay and Kumar, 2013|
| SNNPR          | Virgalem           | Questionnaire| 170           | 70.0            | Abunna, 2013   |
| Harari         | Harar              | Questionnaire| 300           | 60.7            | Terefe et al., 2014|
| Oromia         | West Shoa          | Questionnaire| 110           | 63.6            | Abate, 2014    |
| Oromia         | Bishoftu           | Questionnaire| 100           | 64.0            | Emurum et al., 2014|
| Oromia         | Adama              | Questionnaire| 200           | 45.5            | Tolossa et al., 2015|
| SNNPR          | Halaba Kulito      | Questionnaire| 100           | 19.0            | Abdulaziz et al., 2016|
| Oromia         | Bishoftu           | Questionnaire| 200           | 69.5            | Hiwot, 2016    |
| Addis Ababa    | Gonder             | Questionnaire| 130           | 33.1            | Churu and Zeryuhun, 2017|
| Oromia         | Asella             | Questionnaire| 125           | 71.2            | Elmko et al., 2017|
| Amhara         | Gondar             | Questionnaire| 400           | 33.07           | Churu and Zeryuhun, 2017|
| Oromia         | Nekemt             | Questionnaire| 80            | 60.0            | Dereg, 2017    |
| Amhara         | Kombolcha          | Questionnaire| 110           | 31.82           | Tegegne et al., 2018|
| Amhara         | Bahir Dar          | Questionnaire| 69            | 30.4            | Tamirat et al., 2018|

Note: ¶Year = year of report; *A.A.C. = Addis Ababa City; **W.S.T = Wollayita Soddo Town; - = studied number of sample were not accessed; Stool Exam. = stool examination.
Existence of higher population density, raw meat consumption, low awareness, poor hygiene and sanitary infrastructures may facilitate transmission of the disease between animals and human beings in the rural area (Frolova, 1982; Feseha, 1995; Teka, 1997). However, variability in degrees of awareness in human infection varies with age, sex, religion, educational level, presence and usage of sanitary facilities especially toilets (Megersa et al., 2010). Using the organ and tissues suggested by Dorny et al. (2000) and Maed et al. (1996), the organs and tissues most commonly affected and condemned due to C. bovis were the heart, tongue, diaphragm and muscles of the jaw (Issa, 1990; Feseha, 1995; Tembo, 2001; Dawit, 2004; Nigatu, 2004; Hailu, 2005; Abunna et al., 2007; Bedu et al., 2011; Mesfin and Nuraddis, 2012; Abay and Kumar, 2013; Terefe et al., 2014; Abate, 2014; Tolossa et al., 2015; Hiwot, 2016; Abdulaziz et al., 2016; Cheru and Zeryihun, 2017; Dereje, 2017; Tegegne et al., 2018; Tamirat et al., 2018).

Except for Nigatu (2004) whose used detailed postmortem (PME) with Serology and Hailemariam et al. (2014) whose used PCR, almost all investigations in Ethiopia were based on detailed PME.

4. Spatiotemporal distribution of Taenia saginata in Ethiopia

Globally, there were 77 million human carriers of taeniasis of which 40% live in Africa (WHO, 2013). In developed countries even if the disease has very low prevalence, the problem with the removal and treatment facilities in their sewage system plays a great role in the distribution of eggs that can survive longer in sewages (Gracey and Collins, 1992). Due to the habit of eating raw or undercooked beef dishes, habit of defecating in the open grazing fields, human taeniasis is common in Ethiopia (Tolossa et al., 2015; Megersa et al., 2010; Deresse et al., 2012; Teka, 1997). It is highly associated with poor sanitary condition in general and inappropriate human excreta disposal in particular.

Published work on Taenia saginata in Ethiopia was collected and summarized based on the current administrative regions, districts, study methodology and chronological order of the reports (Table 2). Except from the Afar, Benishangul-Gumiz, Gambella and Ethio-Somali Regional States as well as the Dire Dawa town, bovine cysticercosis was reported from all other areas at different degrees of prevalence. This could be due to parallel investigation of both the bovine cysticercosis and Taenia saginata. Taeniasis was ranged from 7.8% in Modjo-Oromia (Deresse et al., 2012) to as high as 89.4% in Addis Ababa City (Tembo, 2001). Except for 17.9% (Deresse et al., 2012) at Addis Ababa City, 29.0% (Abay and Kumar, 2013) at Mekele-Tigray and 19.0% (Abdulaziz et al., 2016) at Halaba Kulito –SNNPR, taeniasis in Ethiopia was greater than 30% over 2001–2018 years. Except for Deresse et al. (2012) who’s used stool examination, almost all of the reports were using Questioner survey and retrospective data reports.

5. Human taeniasis treatment trend in Ethiopia

Still taeniasis in Ethiopia is under-reported, missing many infections owing to the tradition of self-treatment using modern or traditional plant medicines. Tegegne et al. (2018) reported out of the 35 taeniasis patients 19 (54.3%) used pharmaceutical, while 28.6% uses the traditional (herbs) medicine and the remaining 17.2% uses both. Of pharmaceutical, a single dose of praziquantel (10 mg/kg body weight) is effective. Other drugs, albendazole or mebendazole can also be given but they are considered not fully

Table 3
Major taeniacidal herbs used in Ethiopia. Source: Desta, 1995.

| Scientific name               | Local name | Parts used | Traditional formulation/dosage forms                           |
|------------------------------|------------|------------|----------------------------------------------------------------|
| Hagenica abyssinia           | Kosso      | Flowers    | Aqueous/hydroalcoholic extract                                 |
| Cratatum macropodum satchyus | Bisanna    | Seed       | Paste in honey                                                  |
| Embelia schimperi            | Enkoko     | Fruits     | Aqueous/hydroalcoholic extract                                 |
| Cucurbita pepo               | Dubafire   | Seed       | Fried and salted                                                |
| Thysmmus serrulatus          | Togigne    | Seed       | Paste in honey                                                  |
| Cynodon dactylon             | Serdo      | All parts  | Paste in honey                                                  |
| Myrsine africana             | Kechemo    | Flower     | Aqueous                                                         |
| Cynodon dactylon             | Mettere    | Flower     | Aqueous                                                         |

Table 4
Economic loss associated with taeniasis/cysticercosis in Ethiopia [2005–2016].

| Region/councils | location | Year(s)       | Total cost* | Remarks | Reference       |
|----------------|----------|---------------|-------------|---------|-----------------|
| SNNPR          | Yirgalem | [2005–2008]   | 1,416,093.00| 88,500.00| TcDC Abunna, 2013|
| Oromia         | Jimma    | [2007–2008]   | 222,706.00  | 22,270.60| TcDC Megersa et al., 2010|
| Oromia         | Adama    | [2011–2013]   | 378,609.66  | 18,379.11| TcDc Tolossa et al., 2015|
| Amahara        | Gonder   | [2013–2014]   | 193,558.50  | 9400.61  | ¶ TcDC + OC Cheru and Zeryihun, 2017|
| Amahara        | Kombolcha| [2016]        | 1,841,311.00| 73,652.44| Tegegne et al., 2018|
| Total          |          |               | 4,052,278.16| 212,202.76|                 |

Note: *ETB to USD exchange currency varies with year; ¶calculated from Tolossa et al., 2015; TcDC = taeniacidal drugs cost; OC = organ condemnation.
The maximum drug expenditure was during the year 2013 (Tolossa et al., 2015; Cheru and Zeryihun, 2017) and vermox (Megersa et al., 2010) in Ethiopia have been reported. Among several traditional drugs (Table 3), Hagenica abyssinia "Kosso/Heto" flowers is still widely used in Ethiopia. Hagenica abyssinia contains Kosso-toxin, closely related to folic acid, are responsible for some cases of hepatic carcinoma and blindness (Desta, 1995).

6. Spatiotemporal economic loss from bovine cysticercosis and human taeniasis in Ethiopia

Economic losses from bovine cysticercosis are determined by disease prevalence, grade of animal infected, potential market price of cattle and treatment cost for detainee carcasses. Cysticercosis in domestic animals is a significant food safety problem and causes economic loss in food production. This will be particularly important where export industries are involved, since most importing countries have stringent regulation designed to prevent the importation of infected meat (Harrison and Sewell, 1991). The cost implication can be broken down into those involved in treating human taeniasis and cattle carcasses (costs of freezing, boiling) or condemned, as well as the costs involved in the inspection procedures amount to millions of dollars (Mann, 1984).

Only few data (reports) were available on spatiotemporal economic loss associated with bovine cysticercosis and Taenia saginata in Ethiopia (Table 4) showing an overall 4,052,278.16 ETB (212,202.76 USD) from five reports (Abunna, 2013; Megersa et al., 2010; Tolossa et al., 2015; Cheru and Zeryihun, 2017; Tegegne et al., 2018). An annual losses due to treatment in USA was USD 100,000 (Roberts, 1985), in South Africa USD 428 million (Abdusslam, 1975). In Kenya and Botswana bovine cysticercosis resulted in annual losses of USD 4 million and USD 2 million respectively (Grindle, 1978).

Although niclosamide, mebendazole and praziquantel were pharmaceutical taeniacidal drugs used in Ethiopia until the years 2009, uses of albendazole were began from 2011 to date (2018 year). The total treatment cost for these drugs accounted 73,652.44 USD (Tegegne et al., 2018) which could be due to economic loss from cost only. However, in another study at Kombolcha-Amhara region during 2016 was the highest and accounted 1,841,311.00ETB of 2009, uses of albendazole were began from 2011 to date (2018 year). The total treatment cost for these drugs accounted 73,652.44 USD (Tegegne et al., 2018) which could be due to economic loss from cost only. However, in another study at Kombolcha-Amhara region during 2016 was the highest and accounted 1,841,311.00ETB and 1,570,000.00ETB respectively (Abay, G., Kumar, A., 2013). Cysticercosis in cattle and its public health implications in Mekelle City and surrounding areas, Ethiopia. Ethiop. Vet. J. 17 (1), 31 – 38. C. bovis and teaniasis treatment cost.

Although niclosamide, mebendazole and praziquantel were pharmaceutical taeniacidal drugs used in Ethiopia until the years of 2009, uses of albendazole were began from 2011 to date (2018 year). The total treatment cost for these drugs accounted 921,112.00ETB over 2005–2016 in Ethiopia (Table 5). The maximum drug expenditure was during the year 2013 (Tolossa et al., 2015; Cheru and Zeryihun, 2017).

7. Conclusion and recommendations

Bovine cysticercosis and its adult (Taenia saginata) are public health and economically significant cestode parasite prevalent in reported regions of Ethiopia. But low area coverage investigations were observed. Mostly postmortem meat inspection in cases bovine cysticercosis and questioner survey in cases Taenia saginata was implanted as tools of investigation which need other methods like serology and molecular techniques. Although the uses of herbal mediation were reported in Ethiopia, pharmacognosy and dosage formulation of those plants extract could reduce toxicity, replace chemotherapy, prevent associated drug resistance and uses of new drug for Taenia saginata treatment. Taenia saginata cycle interruption via stopping human open defecation could prevent such challenges.

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