Epidemiology of *Taenia saginata* taeniosis/cysticercosis: a systematic review of the distribution in southern and eastern Africa

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Abstract

**Background:** The beef tapeworm, *Taenia saginata*, causing cysticercosis in bovines and taeniosis in humans, is thought to have a global distribution. In eastern and southern Africa, cattle production plays a crucial role in the economy, but a clear overview of the prevalence of *T. saginata* in the region is still lacking. This review aims to summarize existing knowledge on *T. saginata* taeniosis and bovine cysticercosis distribution in eastern and southern Africa.

**Methods:** A systematic review was conducted, that gathered published and grey literature, including OIE reports, concerning *T. saginata* taeniosis and bovine cysticercosis in eastern and southern Africa published between January 1st, 1990 and December 31st, 2017.

**Results:** A total of 1232 records were initially retrieved, with 78 full text articles retained for inclusion in the database. Unspecified taeniosis cases were reported for Angola, Ethiopia, Kenya, Madagascar, Malawi, South Africa, Tanzania, Uganda and Zambia, whereas *T. saginata* taeniosis cases were found for Ethiopia, Kenya, South Africa, Tanzania, Zambia and Zimbabwe. The prevalence of taeniosis ranged between 0.2–8.1% based on microscopy, and between 0.12–19.7% based on coproAg-ELISA. In Ethiopia, the percentage of tapeworm self-reporting was high (45.0–64.2%), and a substantial number of anthelmintic treatments were reported to be sold in towns. The presence of bovine cysticercosis was reported in all 27 countries/territories included in the study, except for Rwanda and Somalia, Comoros, Madagascar, Mauritius, Mayotte, Seychelles and Socotra. The prevalence of cysticercosis ranged between 0.02–26.3% based on meat inspection, and between 6.1–34.9% based on Ag-ELISA.

**Conclusions:** Although *T. saginata* has been reported in the majority of countries/territories of the study area, *T. saginata* taeniosis/cysticercosis remains a largely ignored condition, probably due to the absence of symptoms in cattle, the lack of data on its economic impact, and the fact that human taeniosis is considered a minor health problem. However, the occurrence of bovine cysticercosis is a clear sign of inadequate sanitation, insufficient meat inspection, and culinary habits that may favour transmission. Measures to reduce transmission of *T. saginata* are therefore warranted and the infection should be properly monitored.

**Keywords:** *Taenia saginata*, Cestode, Beef tapeworm, Taeniosis, Bovine cysticercosis, Eastern Africa, Southern Africa

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Background
The beef tapeworm, *Taenia saginata*, utilizes bovines as intermediate hosts and humans as final hosts. Although tapeworm infections have been reported since ancient times [1], it was not until 1782 [2] that differentiation of *T. saginata* from the other well-known meat-transmitted human tapeworm, *Taenia solium*, was established. Furthermore, it was not until 1871 that the role of cattle as intermediate hosts for the parasite was established, with “measly” beef being reported as the source of infection in patients [3].

Ingestion of raw or undercooked infected beef is indeed the mode of transmission of this zoonotic parasite to humans, in whom it develops to its adult form, a several metres long segmented worm consisting of a scolex with four suckers, neck and strobila, i.e. a chain of proglottids [4]. In contrast to *T. solium*, the gravid proglottids of *T. saginata*, which contain thousands of embryonated eggs, are mobile and can migrate from the anus independently of, as well as during, defaecation [5]. Eggs are then shed into the environment, and cattle become infected through grazing contaminated pastures, or ingesting contaminated fodder or water. After hatching, and penetration of the intestinal wall, the oncospheres reach the general circulation, distributing them throughout the body where they develop into cysticerci [4]. Common predilection sites for *T. saginata* cysticerci include the heart and masseter muscles [6].

In both intermediate and definitive hosts, *T. saginata* causes few symptoms. In humans, infection is usually characterized by anal pruritus due the active migration of *T. saginata* proglottids and some mild abdominal pain [7]. Nevertheless, the (potential) presence of a tapeworm in the body can cause distress [8], and some people even suffer from a pathological fear of tapeworms, often encouraged by horror stories circulating in popular media or books [9, 10]. Moreover, although rare, complications due to taeniosis, such as appendicitis, have been reported [11]. In cattle, the infection is generally asymptomatic but nevertheless may incur great economic losses for the meat sector due to carcass condemnation or treatment upon detection of cysticerci during meat inspection, as well as related insurance costs [12, 13].

*Taenia saginata* is distributed globally, with the parasite occurring in both developed and developing countries, although less frequently in countries where cultural preferences limit consumption of bovids or where adequate sanitary infrastructure reduces the likelihood of bovids ingesting human faecal matter. Thus, the prevalence of human taeniosis and bovine cysticercosis are considered particularly high in Africa, Latin America and some parts of Asia [4].

In eastern and southern Africa, the cattle population was estimated at a massive 20.6 million in 2016 [14], so the parasite is thought to be of particular relevance here. In the area, bovines are essential for the livelihoods of smallholders, serving as a source of food, draft power and manure, as well as acting as a financial buffer for challenging times. Although there are indications of the widespread presence of the parasite in at least some countries in this region (e.g. Ethiopia: [15–17]), an extensive overview of its distribution in this region, along with epidemiological considerations regarding its presence, is still lacking. Our aim was therefore to gather recent information on the presence of *T. saginata* in eastern and southern Africa.

Methods
Search strategy
A systematic review of published literature was conducted to collect data on the occurrence, prevalence, and geographical distribution of bovine cysticercosis and human taeniosis in eastern and southern Africa, published between January 1st, 1990 and December 31st, 2017. For the purpose of this study, eastern and southern Africa was defined as the area covered by the following countries/territories: Angola, Botswana, Burundi, Comoros, Djibouti, Eritrea, Ethiopia, Kenya, Lesotho, Madagascar, Malawi, Mauritius, Mayotte (French), Mozambique, Namibia, Réunion (French), Rwanda, Seychelles, Socotra (Yemeni), Somalia (including the autonomous regions Puntland and Somaliland), South Africa, Swaziland, Tanzania (including the semi-autonomous region of Zanzibar), Uganda, Zambia and Zimbabwe. The PRISMA guidelines were followed whilst conducting the review [18] (Additional file 1). The search protocol can be found in Additional file 2.

The international bibliographic databases PubMed (http://www.ncbi.nlm.nih.gov/pubmed) and Web of Science (http://ipsisence.thomsonreuters.com/product/web-of-science/) were searched using the following search phrase: ((cysticerc* OR cisticerc* OR “C. bovis” OR tae-nia* OR tenia* OR saginata OR taeniosis OR teniosis OR taeniasis OR ténia OR taeniid OR cysticercque) AND (Angola OR Botswana OR Burundi OR Comoros OR Djibouti OR Eritrea OR Ethiopia OR Kenya OR Lesotho OR Madagascar OR Malawi OR Mauritius OR Mayotte OR Mozambique OR Namibia OR Réunion OR Rwanda OR Seychelles OR Socotra OR Somalia OR South Africa OR Swaziland OR Tanzania OR Uganda OR Zanzibar OR Zambia OR Zimbabwe OR “East Africa” OR “Horn of Africa” OR “Southern Africa” OR Puntland OR Somaliland)).

Furthermore, a range of databases for grey literature and MSc/PhD thesis documents were searched using keywords from the above search phrase (the full list of databases is presented in Additional file 3). Data on bovine cysticercosis from the different scientific databases were complemented with data from OIE.
databases “Handistatius” (1996–2004) and “WAHIS” (2005) [19, 20]. Finally, reference lists of reviews on the topic were screened and additional relevant records were added to the database.

Selection criteria
Upon compilation of search results from the different databases, duplicate records were removed. Thereafter, titles and abstracts were screened for relevance, applying the following exclusion criteria: (i) studies concerning a parasite other than T. saginata; (ii) studies conducted outside the study area; (iii) studies published outside the study period; (iv) studies reporting results outside the scope of the review question (e.g. review, experiment, intervention trial); and (v) duplicated data. After the screening process, full text articles were evaluated using the same criteria listed above (Additional file 4).

Data extraction and generation
Data from included records were extracted. In reports where the numerator and denominator of the study sample were available, prevalence data were calculated, if not already provided. When not presented in the manuscript, the 95% exact confidence intervals (CI) were calculated, using the “binom.test” function (“stats” package) in R 3.5.1 [21].

Results
Search results
A total of 1228 records were obtained from the database search, and four additional records were added through screening of the reference lists of relevant reviews (Additional file 4). After removal of duplicate records (n = 71), 1161 records were screened based on title and, thereafter, abstract. During title screening, 987 records were excluded, and a further 85 records were removed upon abstract screening; three of these were remaining duplicate records, whereas the other removed records focussed on a different parasite (n = 32) or study area (n = 18), were published outside the study period (n = 1), or had a different scope (e.g. laboratory experiments, review) (n = 31). Thus, 89 full text articles (n = 89) fulfilled the eligibility criteria for evaluation, but three of these were unavailable. During the evaluation of the remaining 86 records, eight were excluded due to having a different scope.

Thus, 78 records were included in the qualitative synthesis (journal articles: 73, online data repositories: 2, MSc thesis: 2, PhD thesis: 1). Apart from the two OIE sources describing the occurrence of bovine cysticercosis throughout the study area, the majority of records presented data from Ethiopia (n = 37). The others included data from Kenya (n = 11), Tanzania (n = 7), South Africa (n = 7), Zambia (n = 4), Zimbabwe (n = 2), Angola (n = 2), Uganda (n = 1), Swaziland (n = 1), Namibia (n = 1), Malawi (n = 1), Madagascar (n = 1) or Botswana (n = 1).

Human taeniosis occurrence
A total of 48 records reported the presence of human taeniosis cases (excluding those with confirmed T. solium taeniosis). Unspecified taeniosis cases were reported from Angola, Ethiopia, Kenya, Madagascar, Malawi, South Africa, Tanzania, Uganda and Zambia, whereas known T. saginata taeniosis cases were reported from Ethiopia, Kenya, South Africa, Tanzania, Zambia and Zimbabwe (Fig. 1). Microscopy results were included in 32 reports, most of which presented data from Ethiopia (18) (Table 1). Taeniosis
Table 1  Reported occurrence of taeniosis in southern and eastern Africa: microscopy studies

| Country      | Period               | People tested | People positive | Prevalence (%) (95% CI) | Species identification | Group studied                                           | Reference |
|--------------|----------------------|---------------|-----------------|-------------------------|------------------------|---------------------------------------------------------|-----------|
| Angola       | 9/2012-12/2013       | 344           | 2               | 0.58 (0.07–2.1)         | N                      | Children below 5 with diarrhea                          | [50]      |
| Angola       | 1/2015-5/2015        | 230           | 2               | 0.87 (0.10–3.1)         | N                      | School children in 16 schools                           | [51]      |
| Ethiopia     | 11/1995-4/1996; 6-9/1996 | 1750         | 79              | 4.5 (3.6–5.6)           | Y                      | Sugar-estate residents                                  | [52]      |
| Ethiopia     | 3-4/1999; 2/2002     | 3167          | na              | < 4 (na)                | N                      | Schoolchildren, peasants and teachers                   | [53]      |
| Ethiopia     | 1/2002-2/2002        | 104           | 1               | 0.96 (0.02–5.2)         | Y                      | HIV/AIDS and HIV-seronegative individuals in a teaching hospital | [54]      |
| Ethiopia     | 2007–2012            | 32191         | 322             | 1.0 (0.9–1.1)           | N                      | Rural hospital visitors                                 | [55]      |
| Ethiopia     | 5/2007-6/2007        | 419           | na              | 1.4 (na)                | N                      | na                                                     | [56]      |
| Ethiopia     | 12/2007-2/2008       | 7171          | 23              | 0.32 (0.20–0.48)        | N                      | Visitors of health centers                              | [57]      |
| Ethiopia     | 8/2008-12/2008       | 343           | 14              | 4.1 (2.2–6.8)           | N                      | HIV patients recruited at hospital                      | [58]      |
| Ethiopia     | 11/2008              | 121           | 5               | 4.1 (1.4–9.4)           | N                      | Prison inmates                                          | [59]      |
| Ethiopia     | 11/2008              | 115           | 1               | 0.87 (0.02–4.7)         | N                      | Tobacco farm workers                                    | [59]      |
| Ethiopia     | 4/2009               | 384           | 5               | 1.3 (0.4–3.0)           | N                      | Food handlers                                           | [60]      |
| Ethiopia     | 9/2010-7/2011        | 858           | 18              | 2.1 (1.2–3.3)           | N                      | Highland and lowland dwellers                           | [61]      |
| Ethiopia     | 1/2011-6/2011        | 200           | 1               | 0.5 (0.01–2.8)          | N                      | Food handlers                                           | [62]      |
| Ethiopia     | 2012-11/2012         | 260           | 1               | 0.38 (0.01–2.12)        | N                      | Children recruited in Health Center                     | [63]      |
| Ethiopia     | 2013-5/2013          | 172           | 5               | 2.9 (1.0–6.7)           | N                      | Asymptomatic food handlers                              | [64]      |
| Ethiopia     | 2013-11/2013         | 180           | 2               | 1.1 (0.13–4.0)          | N                      | HAART initiated and naive paediatric HIV patients        | [65]      |
| Ethiopia     | 2015-2/2015          | 503           | 13              | 2.6 (1.4–4.4)           | N                      | School children from 5 schools                         | [66]      |
| Ethiopia     | 1/2016-8/2016        | 213           | 5               | 2.3 (0.8–5.4)           | N                      | Active pulmonary TB patients                            | [67]      |
| Ethiopia     | na                   | 1537          | na              | 8.1 (na)                | Y                      | Participants from 19 communities, includes children and adults | [23]      |
| Ethiopia     | na                   | 491           | 12              | 2.4 (1.3–4.2)           | N                      | Villagers                                               | [68]      |
| Kenya        | 2000–2009            | 31            | 1               | 3.2 (0.08–16.7)         | N                      | Sleeping sickness patients                              | [69]      |
| Kenya        | 2010-7/2012          | 2057          | na              | 0.20 (na)               | N                      | na                                                     | [22]      |
| Kenya        | 2010/2012            | 2113          | na              | 0.30 (0–0.5)            | N                      | Mixed-farming community                                 | [26]      |
| Kenya        | na                   | 285           | na              | 5.3 (na)                | N                      | HIV-positive patients                                   | [70]      |
| Kenya        | na                   | 151           | 0               | 0 (0–2.4)               | N                      | Geophagous pregnant women                               | [24]      |
| Tanzania     | 11/1996-1/1997       | 401           | 3               | 0.75 (0.15–2.2)         | N                      | Patients referred for parasitological examination       | [71]      |
| South Africa | 2009                 | na            | 2               | na                      | N                      | Laboratory results                                      | [72]      |
| South Africa | 2009                 | na            | 4               | na                      | Y                      | Laboratory results                                      | [72]      |
| South Africa | 4/2009-9/2009        | 162           | 3               | 1.9 (0.4–5.3)           | N                      | School children                                         | [73]      |
| South Africa | 2010                 | na            | 11              | na                      | Y                      | Laboratory results                                      | [72]      |
| South Africa | 2010                 | na            | 1               | na                      | N                      | Laboratory results                                      | [72]      |
| South Africa | na                   | 183           | 3               | 1.6 (0.3–4.7)           | N                      | Rural black preschool children                          | [74]      |
| Tanzania     | 2008–2009            | 1057          | 3               | 0.30 (0.06–0.8)         | Y                      | Villagers, after treatment with niclosamide/praziquantel and purgation | [75]      |
| Uganda       | na                   | 5313          | 36              | 0.70 (0.5–0.9)          | N                      | Primary school children                                 | [76]      |
| Zambia       | 6/2007-8/2007        | 403           | na              | 0.90 (na)               | N                      | School children                                         | [77]      |

*aReported as T. saginata, yet unclear from methodology

*bConfirmed by PCR

Abbreviations: CI, confidence interval; na, not available; HAART, highly active antiretroviral therapy
prevalence based on microscopy alone ranged between 0.2–8.1% (villagers in Kenya [22] and Ethiopia [23], respectively), and one study reported the absence of taeniosis (in geophagous pregnant women in Kenya [24]). Four records presented data from coproAg-ELISA studies conducted in Kenya and/or Zambia, with a prevalence ranging between 0.12–19.7% (villagers in Zambia [25] and Kenya [26], respectively) (Table 2), two of which involved confirmed *T. saginata* cases. Overall, common study groups were school-children, patients suffering from other diseases [e.g. HIV infection, sleeping sickness and active pulmonary tuberculosis (TB)], as well as occupational groups (e.g. tobacco farm workers, food handlers). Furthermore, eight studies reported taeniosis prevalence in communities based on self-reporting by questionnaire respondents (prevalence range: 45.5–64.2%) (Table 3), and five records presented data on anthelmintic sales in towns (Table 4), both in Ethiopia. Another two records contained data on household latrine sampling, thus presenting prevalence at the household level (Malawi: 40.4% [27]; South Africa: 18.0% [28]). Finally, one report discussed a case of intestinal obstruction due to impaction of a *T. saginata* tapeworm in Zimbabwe, requiring enterotomy with bolus removal as well as appendectomy [29].

### Bovine cysticercosis

Based on the retrieved data sources (both OIE databases and manuscripts/reports), the presence of bovine cysticercosis was reported in all of the 27 countries/territories studied, except for Comoros, Madagascar, Mauritius, Mayotte and Seychelles. In addition, no information was available for Rwanda, Somalia, Mayotte and Socotra (Fig. 2). Data from the two OIE data sources indicating the occurrence and/or number of cases are presented in Table 5. Apart from the OIE data sources, a total of 39 records were found to document results on bovine cysticercosis in the study region. Meat inspection results were included in 35 records (Table 6), with prevalence estimates ranging between 0.02–26.3%, while two records reported the absence of positive animals (Tanzania: 2011 [30], Zambia: 2001 [31]). Seven records provided serological data, mostly based on Ag-ELISA results (prevalence range: 6.1–53.5%), while one presented Ab-ELISA data (prevalence: 10.0%) [32] and another IHAT results (prevalence: 25.7%) [33] (Table 7). One study estimated the town level costs due to condemnation caused by bovine cysticercosis [Mekelle, abattoir level: 31,952 ETB/6 months (991 EUR, according to July 2018 exchange rates; 1 ETB = 0.0310 EUR) [34]], and another five studies provided data on total economic losses due to condemnation for a wide variety of conditions [17, 30, 35–37]. Overall, the

### Table 2

Reported occurrence of taeniosis in southern and eastern Africa: coproAg-ELISA studies

| Country | Study period | People tested | People positive | Prevalence (%) 95% CI | Species identification | Group studied | Reference |
|---------|--------------|---------------|-----------------|------------------------|------------------------|--------------|-----------|
| Kenya   | 1/2007-4/2007 | 204           | 12              | 5.9 (3.1–10.0)         | *Y*                    | District inhabitants | [78]     |
| Kenya   | 8/2010-7/2012 | 2113          | na              | 19.7 (16.7–22.7)       | N                      | Mixed-farming community | [26]     |
| Kenya   | na            | 691           | na              | 1.9 (na)               | N                      | Slaughterhouse workers | [79]     |
| Zambia  | 2006          | 190           | 5               | 2.6 (0.9–6.0)          | *Y*                    | Pupils primary schools | [78]     |
| Zambia  | 8/2009;10/2010| 817           | 1               | 0.12 (0.003–0.68)      | *Y*                    | Consenting villagers  | [25]     |

*Results based on coproAg-ELISA, specific for *T. saginata*
*Results based on coproAg-ELISA with coproPCR (*T. saginata* specific) confirmation

### Abbreviations

CI, confidence interval; na, not available

### Table 3

Reported occurrence of taeniosis: questionnaire studies in Ethiopia

| Town                     | Study period | People interviewed | People reporting infection | Prevalence (%) 95% CI | Reference |
|--------------------------|--------------|--------------------|----------------------------|------------------------|-----------|
| Awassa                   | 10/2005-4/2006| 120                | 77                         | 64.2 (54.9–72.7)       | [44]      |
| Soddo                    | 11/2007-4/2008| 79                 | 40                         | 50.6 (39.1–62.1)       | [45]      |
| Jimma                    | 11/2008-3/2009| 60                 | 34                         | 56.7 (43.2–69.4)       | [46]      |
| Yirgalem                 | 11/2009-3/2011| 170                | 119                        | 70.0 (62.5–76.8)       | [47]      |
| Sebeta, Tulu Bolo, Weliso| na            | 392                | na                         | 55.1 (na)              | [48]      |
| Harar                    | na            | 300                | 182                        | 60.7 (54.9–66.2)       | [16]      |
| Adarma                   | 11/2013-4/2014| 200                | 91                         | 45.5 (38.5–52.7)       | [15]      |
| Batu                     | 12/2014-4/2015| 100                | 59                         | 59.0 (48.7–68.7)       | [49]      |

*Abbreviations: CI, confidence interval; na, not available*
The majority of records presented data from Ethiopia (21/41), followed by Tanzania (8/41) and Kenya (7/41).

**Taeniosis and bovine cysticercosis occurrence**

The co-occurrence of both bovine cysticercosis and taeniosis during the study period was reported in Angola, Ethiopia, Malawi, South Africa, Tanzania, Uganda, Zambia and Zimbabwe, but this was not the case for the other countries/territories studied. The occurrence of bovine cysticercosis or taeniosis was reported for all the countries/territories studied, except for Somalia, Rwanda and the Comoros, Mauritius, Mayotte, Seychelles, Mayotte and Socotra islands.

**Discussion**

The present study aimed at describing the epidemiology of *T. saginata* taeniosis/cysticercosis in eastern and southern Africa (1990–2017). Based on our findings, both human taeniosis and bovine cysticercosis were widespread in the 27 countries/territories studied, except for Somalia, Rwanda and six island states/territories, indicating that *T. saginata* is present in most countries of the study area. However, lack of diagnosis and reporting, particularly in rural areas, mean that the data accrued are likely to underestimate occurrence. The absence of data for some countries does not exclude the possibility that this parasite is present there as well. For example, given that of the three countries bordering Rwanda that are included in this review (Burundi, Tanzania and Uganda) all report the presence of this parasite, it seems unlikely that Rwanda is free from *T. saginata*. On the other hand, one potential hypothesis for the lack of reported *T. saginata* in Rwanda is the remarkably higher rate of access to improved sanitation services, at 60.8% in comparison to neighbouring Burundi at 35.5% [38]. The Rwandan civil war, during 1990–1994, culminating in the genocide of 1994, may have impacted reporting during that period, but does not explain the more recent lack of reporting. For Somalia, the ongoing civil war might explain the lack of reported data for the country, whereas for the six island states and territories, governmental or scientific interest in reporting cases may be lacking.

Cases of taeniosis were reported for Angola, Ethiopia, Kenya, Madagascar, Malawi, South Africa, Tanzania,

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**Table 4** Reported town level taeniicidal sales in Ethiopia

| Town  | Year | Number | Value (ETB) | Value (EUR)** | Reference |
|-------|------|--------|-------------|---------------|-----------|
| Awassa | 2002 | 1,582,254 | 1,880,330 | 58,290 | [44] |
| Awassa | 2003 | 1,221,004 | 1,746,585 | 54,144 | [44] |
| Awassa | 2004 | 946,330 | 1,803,300 | 55,902 | [44] |
| Awassa | 2005 | 889,759 | 1,788,776 | 55,452 | [44] |
| Soddo  | 2004 | 74,747  | 192,979  | 5982   | [45] |
| Soddo  | 2005 | 77,705  | 203,675  | 6342   | [45] |
| Soddo  | 2006 | 79,230  | 210,133  | 6314   | [45] |
| Soddo  | 2007 | 105,090 | 279,660  | 8669   | [45] |
| Jimma  | 2007 | 51,462  | na        | na     | [46] |
| Jimma  | 2008 | 52,134  | na        | na     | [46] |
| Yirgalem | 2005 | 95,712  | na        | na     | [47] |
| Yirgalem | 2006 | 93,059  | na        | na     | [47] |
| Yirgalem | 2007 | 95,093  | na        | na     | [47] |
| Yirgalem | 2008 | 95,121  | na        | na     | [47] |
| Yirgalem | 2009 | 93,028  | na        | na     | [47] |
| Batu   | 2013 | 42,557  | 148,100   | 4591   | [49] |
| Batu   | 2014 | 29,049  | 97,492    | 3022   | [49] |

**Notes**

- **Based on July 2018 exchange rates (1 ETB = 0.0310 EUR)
- Abbreviation: na, not available

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**Legend**

- Green: Reported to be absent
- Blue: Reported to be present
- Grey: Not part of study area
- Light blue: No information available

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**Fig. 2** Bovine cysticercosis in southern and eastern Africa
Uganda, Zambia and Zimbabwe, yet the majority of reports on human taeniosis cases did not, unfortunately, provide species determination. Thus, cases of *T. saginata* taeniosis were not differentiated from infections caused by other *Taenia* spp. The pork tapeworm, *T. solium*, for instance, is presumed to also be widely distributed throughout eastern and southern Africa [39] and therefore we cannot conclude that all reported, unspecified taeniosis cases are due to *T. saginata*. *Taenia solium* is known to be the causative agent of the severe condition neurocysticercosis, associated with epilepsy, severe headaches, cognitive deficits [40] and a major cause of deaths among the food-borne diseases [41]. The presence of a single *T. solium* tapeworm carrier poses a major risk for his/her surroundings, as humans acquire neurocysticercosis through the ingestion of *T. solium* eggs transmitted through poor hygiene practices resulting in faecal-oral transmission [42]. Although tapeworm infections usually have an asymptomatic course [7] apart from some sporadic complications (e.g. intestinal obstruction in the Zimbabwean patient [29]), it is thus paramount to register cases as well as to differentiate case species, to allow precise prevalence estimates, and to guide appropriate control measures. Species determination, however, is hampered by the fact that *Taenia* spp. eggs cannot be differentiated upon coprological examination. Expelled proglottids of *T. solium* and *T. saginata* can be distinguished on the basis of the number of uterine branches, but such material is not always available. Moreover, more advanced diagnostic tools (e.g. copro-PCR) to differentiate species are often lacking in resource poor settings [43], and even in developed countries are not often performed due to lack of awareness about neurocysticercosis [12].

In certain countries in the study area, specific culinary habits put the consumers at great risk of contracting *T. saginata* taeniosis. For instance, in Ethiopia, “kitfo” is a very popular beef dish, in which the meat is usually consumed raw or lightly cooked, while “tibs” is another dish often containing undercooked beef.

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### Table 5 OIE data on occurrence of bovine cysticercosis in the southern and eastern Africa (1996–2005) [19, 20]

| Country        | 1996 | 1997 | 1998 | 1999 | 2000 | 2001 | 2002 | 2003 | 2004 | 2005 |
|---------------|------|------|------|------|------|------|------|------|------|------|
| Angola        | 6    | 11   | na   | na   | na   | na   | na   | na   | 4    | +    |
| Botswana      | na   | 53   | 4356 | 12,863 | 14,000 | 10,181 | 15,363 | na   | +    |
| Burundi       | na   | na   | na   | na   | na   | +    | na   | na   | na   | na   |
| Comoros       | na   | na   | na   | na   | na   | na   | na   | na   | na   | na   |
| Djibouti      | na   | na   | na   | na   | na   | na   | +    | +    | +    | +    |
| Eritrea       | +    | +    | +    | 2    | +    | +    | na   | +    | 370  | -    |
| Ethiopia      | +    | na   | na   | na   | na   | +    | +    | +    | +    | +    |
| Kenya         | +    | +    | +    | +    | +    | +    | +    | +    | 3999 | na   |
| Lesotho       | 56   | 38   | 139  | na   | na   | na   | 68   | na   | na   | -    |
| Madagascar    | na   | na   | na   | na   | na   | na   | -    | na   | na   | -    |
| Malawi        | +    | +    | +    | +    | +    | +    | +    | +    | 6    | +    |
| Mauritius     | na   | na   | na   | na   | na   | -    | -    | -    | -    | na   |
| Mozambique    | +    | +    | +    | na   | na   | na   | na   | na   | na   | na   |
| Namibia       | +    | 3833 | 3118 | +    | 2852 | 2226 | 2399 | 54   | 1616 | +    |
| Réunion       | +    | na   | na   | -    | -    | -    | -    | -    | na   | -    |
| Rwanda        | na   | na   | na   | na   | na   | na   | na   | na   | na   | na   |
| Seychelles    | -    | -    | -    | na   | -    | na   | -    | na   | -    | na   |
| Somalia       | na   | na   | na   | na   | na   | na   | na   | na   | na   | na   |
| South Africa  | +    | +    | +    | +    | +    | +    | +    | +    | +    | +    |
| Swaziland     | 969  | +    | +    | +    | 1419 | 530  | 245  | 1909 | 561  | +    |
| Tanzania      | +    | +    | +    | na   | na   | na   | +    | 6    | na   | +    |
| Uganda        | +    | 24   | 152  | +    | +    | +    | na   | na   | +    |
| Zambia        | na   | na   | na   | na   | +    | na   | 2    | 248  | na   | na   |
| Zimbabwe      | 244  | 1744 | 2062 | 1988 | 160  | 1447 | +    | na   | na   | na   |

**Abbreviations:** na, not available; +, occurrence of the disease; -, absence of the disease
Table 6  Reported occurrence of bovine cysticercosis in southern and eastern Africa: meat inspection studies

| Country    | Period       | Animals tested | Animals positive | Prevalence (%) (95% CI) | Reference |
|------------|--------------|----------------|------------------|--------------------------|-----------|
| Botswana   | 1995         | na             | na               | na (9.1–12.6)            | [80]      |
| Ethiopia   | 9/2004-8/2005| 11,227         | 842              | 7.5 (7.0–8.0)            | [81]      |
| Ethiopia   | 9/2005-2/2007| 4456           | 824              | 18.5 (17.4–19.7)         | [82]      |
| Ethiopia   | 10/2005-4/2006| 400          | 105              | 26.3 (22.0–30.9)         | [83]      |
| Ethiopia   | 12/2006-7/2007| 3711         | 308              | 8.3 (7.4–9.2)            | [34]      |
| Ethiopia   | 10/2007-3/2008| 512           | 15               | 2.9 (1.6–4.8)            | [84]      |
| Ethiopia   | 11/2007-4/2008| 415           | 47               | 11.3 (8.4–14.8)          | [45]      |
| Ethiopia   | 12/2007-2/2008| 1023          | 74               | 7.2 (5.7–9.0)            | [57]      |
| Ethiopia   | 11/2008-3/2009| 500           | 22               | 4.4 (2.8–6.6)            | [46]      |
| Ethiopia   | 10/2009-9/2010| 898           | 177              | 19.7 (17.2–22.5)         | [16]      |
| Ethiopia   | 11/2009-3/2011| 400           | 48               | 12.0 (9.0–15.6)          | [47]      |
| Ethiopia   | 2010         | 12,708         | 669              | 5.3 (4.9–5.7)            | [37]      |
| Ethiopia   | 9/2010-9/2012| 3055           | 126 organs       | na                       | [35]      |
| Ethiopia   | 2011         | 34,674         | 3259             | 9.4 (9.1–9.7)            | [37]      |
| Ethiopia   | 2012         | 10,363         | 803              | 7.7 (7.2–8.3)            | [37]      |
| Ethiopia   | 10/2012-4/2013| 745           | 21 organs        | na                       | [35]      |
| Ethiopia   | 2013         | 5172           | 247              | 4.8 (4.2–5.4)            | [37]      |
| Ethiopia   | 11/2013-4/2014| 384           | 10               | 2.6 (1.3–4.7)            | [15]      |
| Ethiopia   | 11/2013-5/2014| 3675          | 40 organs        | na                       | [36]      |
| Ethiopia   | 05/2014-6/2014| 439           | 23               | 5.2 (3.3–7.8)            | [85]      |
| Ethiopia   | 12/2014-4/2015| 384           | 10               | 2.6 (1.3–4.7)            | [49]      |
| Ethiopia   | na           | 522            | 39               | 7.4 (5.4–10.1)           | [33]      |
| Ethiopia   | na           | 1022           | 64               | 6.3 (4.9–7.9)            | [17]      |
| Ethiopia   | na           | 1216           | na               | 4.6 (na)                 | [48]      |
| Kenya      | 1974         | 77,810         | 6784             | 8.8 (8.5–8.9)            | [86]      |
| Kenya      | 1975–1978    | na             | 6784             | < 6.0 (na)               | [86]      |
| Kenya      | 1979–1983    | na             | na               | < 4.0 (na)               | [86]      |
| Kenya      | 1984         | na             | na               | 1.8 (na)                 | [86]      |
| Kenya      | 1985–1990    | na             | na               | < 2.0 (na)               | [86]      |
| Kenya      | 1991         | 315,801        | 3457             | 1.1 (1.06–1.13)          | [86]      |
| Kenya      | 9/2006-1/2007| 188            | 6                | 3.2 (1.2–6.8)            | [87]      |
| Kenya      | na           | 511            | 39               | 7.6 (5.5–10.3)           | [88]      |
| Kenya      | na           | 1184           | 189              | 16.0 (13.9–18.2)         | [32]      |
| Namibia    | 2000         | 12,204         | 973              | 8.0 (7.5–8.5)            | [89]      |
| Namibia    | 2001         | 7888           | 713              | 9.0 (8.4–9.7)            | [89]      |
| Namibia    | 2002         | 10,561         | 798              | 7.6 (7.1–8.1)            | [89]      |
| Namibia    | 2003         | 4411           | 347              | 7.9 (7.1–8.7)            | [89]      |
| Namibia    | 2004         | 5309           | 401              | 7.6 (6.9–8.3)            | [89]      |
| Namibia    | 2006         | 7085           | 435              | 6.1 (5.6–6.7)            | [89]      |
| Namibia    | 2006         | 71,388         | 243              | 0.34 (0.30–0.39)         | [89]      |
| South Africa | 2009–2011   | 1,022,556      | 24,443           | 2.39 (2.36–2.42)         | [90]      |
| South Africa | 2010     | 356,006        | 2169             | 0.61 (0.58–0.64)         | [91]      |
| South Africa | 2011     | 349,458        | 2389             | 0.68 (0.66–0.71)         | [91]      |
refers to the habit of eating cubes of raw beef, finished off with local spices. Unsurprisingly, a high proportion of the Ethiopian population reports having had a tape-worm, and sales of taeniciidal drugs in Ethiopia are high [15, 16, 44–49].

Access to adequate clean water and sanitation services (WASH) is notoriously poor across the whole of sub-Saharan Africa, including the region of interest to this paper. There are large between and within-country disparities, but overall sub-Saharan Africa lags far behind the goals set out by the international community in both the millennium development and the sustainable development goals with only 25.7% (23.1–28.6%) of the population having access to improved sanitation [38]. This lack of WASH capacity is strongly reflected by the presence of parasites such as *T. saginata* which requires ingestion of eggs passed in faecal material for the propagation of its life-cycle.

In eastern and southern Africa the cattle population is large, and bovine products, including meat, are an

### Table 6 Reported occurrence of bovine cysticercosis in southern and eastern Africa: meat inspection studies (Continued)

| Country       | Period       | Animals tested | Animals positive | Prevalence (%) (95% CI) | Reference |
|---------------|--------------|----------------|------------------|-------------------------|-----------|
| South Africa  | 2012         | 348,309        | 1980             | 0.57 (0.54–0.59)        | [91]      |
| South Africa  | 2013         | 361,232        | 3382             | 0.94 (0.91–0.97)        | [91]      |
| Tanzania      | 1987–1989    | 42,434         | na               | 16.4 (na)               | [92]      |
| Tanzania      | 1/2002-4/2004| 12,444         | 185              | 1.5 (1.3–1.7)           | [93]      |
| Tanzania      | 2005         | na             | 19               | 0.06 (na)               | [94]      |
| Tanzania      | 2006         | na             | 24               | 0.06 (na)               | [94]      |
| Tanzania      | 2007         | na             | 16               | 0.04 (na)               | [94]      |
| Tanzania      | 2010         | 27,444         | 20 organs        | na                      | [30]      |
| Tanzania      | 2/2010-1/2011| 30,713         | 18 organs        | na                      | [95]      |
| Tanzania      | 2011         | 30,671         | 0 organs         | na                      | [30]      |
| Tanzania      | 2012         | 27,865         | 6 organs         | na                      | [30]      |
| Tanzania      | 12/2013      | 2438           | 1 and 0.1% organs| na                      | [30]      |
| Tanzania      | na           | na             | 21               | na                      | [96]      |
| Zambia        | 2000         | 4629           | 1                | 0.02 (0.0005–0.12)      | [31]      |
| Zambia        | 2001         | 9422           | 0                | 0 (0–0.04)              | [31]      |
| Zambia        | 2002         | 10,147         | 2                | 0.02 (0.002–0.07)       | [31]      |
| Zambia        | 2003         | 11,519         | 2                | 0.02 (0.002–0.06)       | [31]      |
| Zimbabwe      | 1/2006-12/2007| 86,080         | 1364             | 1.6 (1.5–1.7)           | [97]      |

**Abbreviations:** CI, confidence interval; na, not available

### Table 7 Reported occurrence of bovine cysticercosis in southern and eastern Africa: serological studies

| Country       | Period       | Diagnostic tool | Animals tested | Animals positive | Prevalence (%) (95% CI) | Reference |
|---------------|--------------|-----------------|----------------|------------------|-------------------------|-----------|
| Ethiopia      | na           | IHAT            | 743            | 190              | 25.6 (22.4–28.9)        | [33]      |
| Kenya         | 9/2006-1/2007| Ag-ELISA        | 188            | 44               | 23.4 (17.8–30.1)        | [87]      |
| Kenya         | 10/2006-11/2006| Ag-ELISA     | 792            | 143              | 18.1 (15.4–20.9)        | [87]      |
| Kenya         | 8/2010-7/2012| Ag-ELISA        | 983            | na               | 53.5 (48.7–58.3)        | [26]      |
| Kenya         | na           | Ag-ELISA        | 511            | 117              | 22.9 (19.3–26.8)        | [88]      |
| Kenya         | na           | Ag-ELISA        | 1184           | 413              | 34.9 (32.2–37.7)        | [32]      |
| Kenya         | na           | Ab-ELISA        | 1184           | 118              | 10.0 (8.3–11.8)         | [32]      |
| South Africa  | na           | Ag-ELISA        | 1315           | 300              | 22.8 (20.6–25.2)        | [98]      |
| South Africa  | na           | Ag-ELISA        | 1159           | 174              | 15.0 (13.0–17.2)        | [98]      |
| Swaziland     | na           | Ag-ELISA        | 600            | na               | 28.0 (na)               | [99]      |
| Zambia        | 12/1999-9/2000| Ag-ELISA      | 628            | 38               | 6.1 (4.3–8.2)           | [100]     |

**Abbreviations:** CI, confidence interval; na, not available; IHAT, indirect hemagglutination test
important protein source for humans, as well as a source of
draft power and form of investment. Beef cattle are
typically kept in an extensive manner; animals are basic-
ally free-ranging. The presence of human *T. saginata*
carriers shedding eggs into the environment puts these
cattle at risk of bovine cysticercosis, and this presumably
occurs widely in the study area. In developed countries,
the condition is known to cause economic losses due to
freezing or condemnation of the carcass as well as re-
lated insurance costs (e.g. Belgium: 3,408,455 EUR/year
[13]). Studies investigating the magnitude of this eco-
mic loss in the study area are, however, limited, with
data available from only one abattoir in Ethiopia [34].
Furthermore, reporting of bovine cysticercosis to OIE
appeared to be inconsistent, with large variations in
number of cases reported even within the same country,
and gaps in the annual reporting (e.g. no data available
after 2005).

**Conclusions**

*Taenia saginata* taeniosis/cysticercosis is a widespread,
yet largely ignored, condition in southern and eastern
Africa. This is probably due to the lack of symptoms in
cattle, the lack of good data on its economic impact, and
because human taeniosis is considered a minor health
problem. Nevertheless, the presence of bovine cysticerc-
osis is a clear sign of inadequate sanitation, insufficient
meat inspection, and culinary habits that may favour
transmission. Measures to reduce transmission of *T.
saginata* are therefore warranted, and the infection
should be properly monitored, in both humans and cat-
tle. It should also be noted that as cattle are an impor-
tant source of human protein and livelihoods in the area,
ensuring optimal health and productivity of cattle is of
indirect importance to human health and welfare as well
as any direct impact. Species identification in tapeworm
carriers is paramount to gain detailed insights in the dis-
tribution of the different *Taenia* spp. in the area, as well
to avoid the development of the severe condition neuro-
cysticercosis within communities due to ingestion of
eggs shed by a *T. solium* tapeworm carrier. We conclude
that in order to ensure both the safety of beef consumed
in the southern and eastern Africa, and to improve the
underlying sanitary conditions perpetuating the parasitic
life-cycle, concerted, co-ordinated efforts must be made by
integrating public, animal and environmental health in a One Health approach.

**Additional files**

- Additional file 1: PRISMA checklist. (DOC 63 kb)
- Additional file 2: Search protocol of systematic review. (DOCX 18 kb)
- Additional file 3: Databases used in systematic review. (DOCX 16 kb)
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