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Epidemiological investigation of bovine trypanosomosis in Bedele district, Buno Bedele zone, Oromia regional state, Ethiopia

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ABSTRACT

A cross-sectional study was conducted in December 2018 in four purposively selected villages of Bedele district, Oromia Regional State, Southwest Ethiopia. The study aimed to determine the prevalence of bovine trypanosomosis and associated risk factors of trypanosome infections in cattle. A total of 384 blood samples were collected from systematically selected cattle and examined using buffy coat and thin blood smear examination methods. The overall prevalence of bovine trypanosomosis was 8.3%. *Trypanosoma congolense* (68.8%) and *T. vivax* (31.2%) were the prevailing trypanosome species identified in the area. A statistically significant difference ($P < 0.05$) was observed in the prevalence of bovine trypanosomosis between body condition scores of cattle. The prevalence of bovine trypanosomosis was slightly higher in female (9%) as opposed to male (7.3%) cattle, but the difference was not statistically significant ($P > 0.05$). Similarly, no statistically significant difference ($P > 0.05$) was observed between age categories of cattle. The mean PCV value of trypanosome infected cattle (21.4 ± 3.6) was significantly ($P < 0.05$) lower than that of non-infected (25.6 ± 4.6). The current study indicated that, despite vector control measures implemented for several years, bovine trypanosomosis persists and continues to be a core problem to cattle health and production in the Bedele district. Therefore, more attention should be given to control the disease and its vectors based on temporal and spatial distribution. Also, the use of molecular techniques should be encouraged in view of their greater sensitivity when compared to the buffy coat method.

1. Introduction

Ethiopia is a country with substantial livestock resources, being the first in Africa and 10th globally (Tilahun and Schmidt, 2012; CSA, 2013). According to the data obtained from (CSA, 2017), the livestock population of Ethiopia was estimated to be 59.50 million cattle, 30.70 million sheep, 30.02 million goats, 11.01 million equines, 1.21 million camels, and 56.53 million chickens. In Ethiopia, the livestock sector plays a significant role in the economic development and contributes to 15–17% of total GDP and 35–49% of agriculture GDP (CSA, 2017). However, this huge livestock potential is hampered by widespread livestock diseases and poor veterinary services in the country. From livestock diseases, bovine trypanosomosis is one of the most important diseases and continues to cause a significant negative impact on animal health and food production (Leta et al., 2016).

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African animal trypanosomosis is a disease caused by blood and tissue dwelling protozoan parasites of genus *Trypanosoma* and transmitted cyclically by tsetse flies (WHO, 2012), and mechanically by several biting flies (Kone et al., 2011). Trypanosomosis has distributed in an extensive area of the tsetse infested regions in 38 sub-Saharan African countries (Steverding, 2008). Approximately 30% of cattle populations in Africa are exposed to bovine trypanosomosis (WHO, 2006). Bovine trypanosomosis is mainly characterized by intermittent fever, progressive anemia, and loss of body condition of susceptible hosts, and if untreated, it leads to animal mortalities (Bourn et al., 2001). Food and Agriculture Organization has estimated that the problem of African animal trypanosomosis costs Africa about 4.5 billion USD per year (Kabayo, 2002).

In Ethiopia, animal trypanosomosis is widely distributed in five of the nine Ethiopian regional states between longitude 33^0 and 38°E and latitude 5^0 and 12^0 N and endemic in an estimated area of 220,000 km^2 fertile lands (Getachew, 2005). Currently, five species of tsetse flies: -*Glossina pallidipes*, *G.m. sub-morsitans*, *G. f. fuscipes*, *G. tachinoides,* and *G. longipennis* (NTTICC, 2004), and also five trypanosome species:-*T. congolense, T. vivax,* and *T. b. brucei* in cattle, sheep and goats, *T. evansi* in camels and *T. equiperdium* in horses are recorded in Ethiopia (FAO, 2010). However, in terms of economic loss in cattle, the most trypanosomes are *T. congolense, T. vivax,* and *T. b. brucei (*Leta et al., *2016;* Degneh et al., *2019)*.

Despite various efforts to control animal trypanosomosis in Ethiopia, bovine trypanosomosis remains one of the most important diseases, that limit livestock productivity and agricultural development in the most arable and fertile land of the western and southwestern parts of the country (Duguma et al., 2015; Degneh et al., 2017). In Ethiopia, about 14 million cattle and a comparable number of small ruminants are at risk of contracting trypanosomosis (CSA, 2017). According to (Fikru et al., 2012), the prevalence of bovine trypanosomosis in tsetse-infested areas of Ethiopia ranges from 11.85–37%. The direct and indirect agricultural and livestock production annual loss due to trypanosomosis in Ethiopia is estimated at around 200 million USD (FAO, 2010; Taye et al., 2012).

The prevalence of bovine trypanosomosis has been extensively studied in Ethiopia in cattle (Duguma et al., 2015; Degneh et al., 2017; Dayo et al., 2010), small ruminants (Mekonnen et al., 2014; Kumela et al., 2016), and in camels (Hagos et al., 2009; Tadesse et al., 2012). However, there is a paucity of data on the prevalence of bovine trypanosomosis and associated risk factors in Bedele district, Buno Bedele zone, Oromia Regional State, Ethiopia, except complaints arising from farmers on the increased death rate of their cattle (BBZAHLDO, 2018). Thus, the current study sought to determine the prevalence of bovine trypanosomosis, and assess the host-associated risk factors in the study area.

2. Materials and methods

2.1. Study area

The study was conducted in Bedele district, Buno Bedele zone, Oromia Regional State, southwest Ethiopia. Bedele district is located

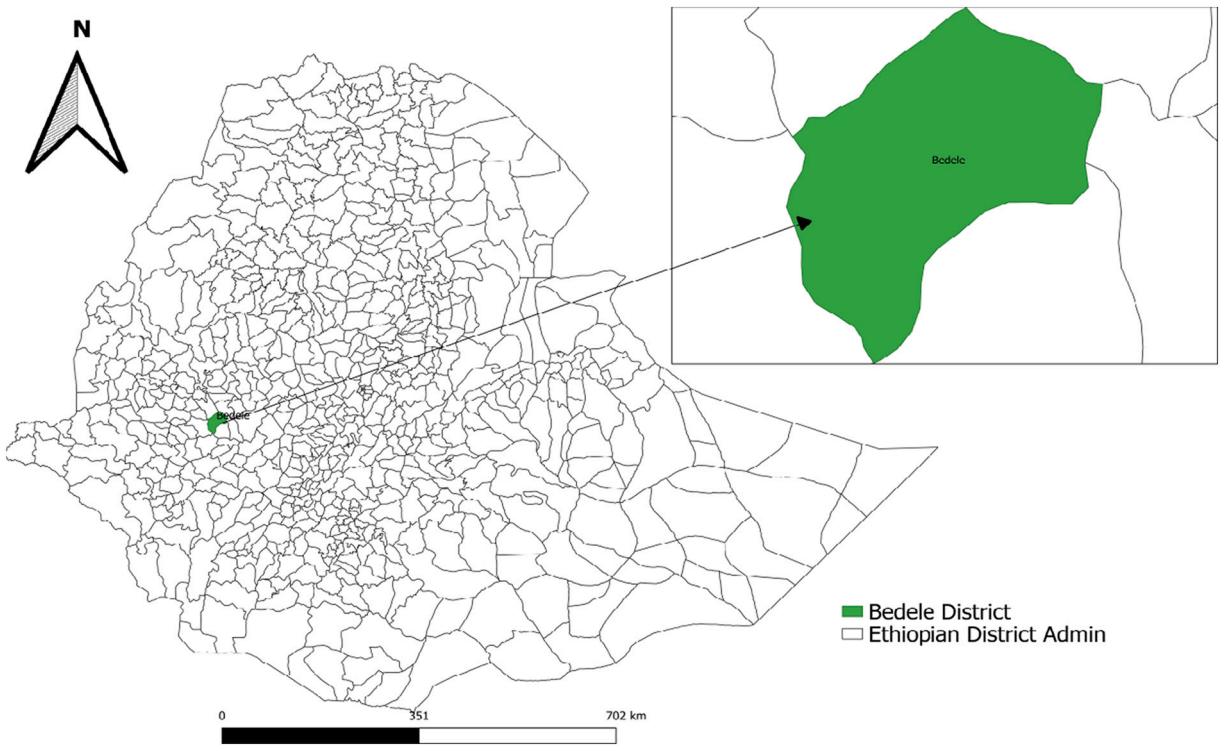

Fig. 1. Map of Bedele district, Bno Bedele, Zone, Oromia Regional State, Southwest Ethiopia.

at 480 km to the southwest of the capital city, Addis Ababa (Fig. 1). Agro-ecologically, the district is divided into midland (75%), lowland (20%), and highland (5%). The area lies within an altitude of 1300–2200 m above sea level and has a mean annual rain-fall of 1200–1800 mm (BBZAHLDO, 2018). According to (CSA, 2017), the total human population in the district was estimated at 123,804. Farmers are mixed livestock-crop producers. The major cattle breeds found in the area are the local zebu cattle breed. Livestock is mainly fed on naturally persistent pastures and crop residues. According to the data obtained from (BBZAHLDO, 2018), the livestock population of the district has been estimated to be 130,200 cattle, 22,000 sheep, 27, 000 goats, 9400 equines and 79,900 chickens.

2.2. Study design

A cross-sectional study design was used to estimate the prevalence of bovine trypanosomosis during the early dry season in December 2018. In the present study, four purposively selected villages were used for the sake of accessibility to transport and based on disease information from the Bedele District Animal Health and Livestock Development Office. A systematic random sampling technique was used to sample every other individual animal caught at communal grazing points of each village.

2.3. Study animals and sample size determination

Study animals were local zebu cattle above one year of age kept under small holder extensive management system. The sample size was calculated using the formula given by (Thrusfield and Christley, 2018), with an expected prevalence of 50%, at 95% confidence interval and 5% desired absolute precision. Accordingly, 384 animals were sampled during the study period. Each animal was classified by body condition, sex and age, the latter based on two categories: as young (1–3 years) and adult (>3 years) according to (Pace and Wakeman, 2003). The body condition scores of animals were estimated as per the recommendations by (Nicholson and Butterworth, 1986), and classified as good, medium and poor based on the appearance of ribs and dorsal spines.

2.4. Blood sampling and examination

Blood samples were collected in heparinized capillary tubes, which were sealed on one side with cristaseal. The capillary tubes were centrifuged for 5 min at 12,000 rpm. After centrifugation, the packed cell volume (PCV) was measured and recorded (Samdi et al., 2010). In this study, a PCV measurement of 25% and above was considered normal (Douglas and Wardrop, 2010). Then, the buffy coat and the uppermost layer of red blood cells of each sample were extruded onto a microscope slide and examined for trypanosomes (Murray et al., 1977). For trypanosome species identification, thin blood smears were made from positive blood samples, stained with Giemsa, and examined by light microscopy. The trypanosome species were distinguished using their size, position of the kinetoplast, degree of the development of undulating membranes, and presence or absence of free flagellum according to (OIE, 2009) (Fig. 2).

2.5. Data analysis

All the data collected were entered into a Microsoft Excel spreadsheet program and then transferred into SPSS version 20.0 to perform statistical analyses. The prevalence of bovine trypanosomosis was calculated as the number of infected individuals divided by the number of animals sampled and multiplied by 100. Prevalence based on sex, age, and body condition was compared using chi-square. The Student's *t*-test was utilized to compare the difference in mean PCVs between infected and non-infected cattle. All statistics were considered significant at $P < 0.05$.

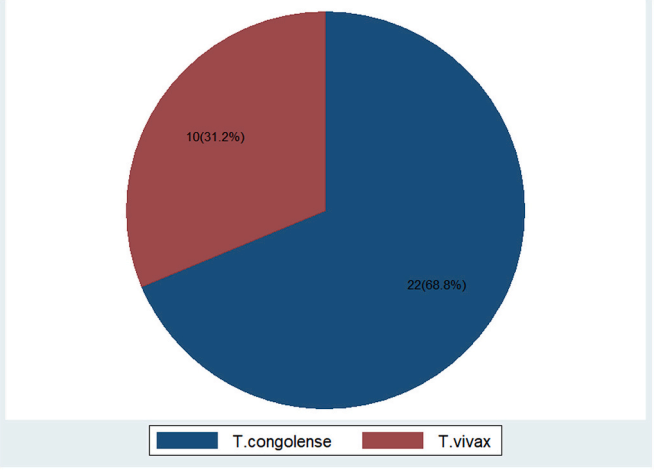

Fig. 2. The distribution of trypanosome species among the infected animals, Buno Bedele district, Oromia regional state, Southwest Ethiopia.

3. Results

Out of 384 cattle examined, 32 were infected by trypanosomes with an overall prevalence of 8.3% (95% CI: 5.9–11.6%). The prevalence of trypanosome infections was varied significantly between different villages ($P < 0.05$). The highest prevalence was observed at Haro Tatessa 17.7% (95% CI: 11.25–26.74), followed by Chafe Jalala 9.4% (95% CI: 4.92–17.12), Ambalta 4.2% (95% CI: 1.55–10.65) and the lowest at Kollo Siri village 2.1% (95% CI: 0.51–8.03). Two pathogenic trypanosome species: *T. congolense* and *T. vivax* were identified in the study animals with the prevalence of 5.7% (95% CI, 3.8–8.56) and 2.6% (95% CI, 1.4–4.78), respectively ($P > 0.05$). *Trypanosma congolense* (68.8%) and *T. vivax* (31.2%) were the most prevalent trypanosome species identified.

The association of the disease between body conditions scores, sex, and age of cattle were assessed. A significantly higher prevalence of bovine trypanosomosis (12.8%) was observed in animals with a poor body condition than those with medium (8%) and good (3.1%) body condition scores ($P < 0.05$). The prevalence of bovine trypanosomosis was higher in females (9%) than in males (7.3%), but the observed difference was not statistically significant ($P > 0.05$). Similarly, no statistically significant difference ($P > 0.05$) was observed among age groups of cattle. However, the prevalence was slightly higher in older (8.9%) than in younger (6.7%) cattle, respectively (Table 1). In this study, 280 older (172 females and 108 males) and 104 younger (62 females and 42 males) cattle were examined. The prevalence of bovine trypanosomosis was 9.3%, 8.3%, 8.04% and 4.8% in female and male older and younger cattle, respectively ($P > 0.05$).

In this study, out of the total examined cattle, 43.7% were anemic with a PCV value of less than 25%. The overall mean PCV value of examined cattle was 25.2 ± 4.7. Using a PCV value of 25% as a cut off, 78.1% of the infected and 21.9% of the non infected animals were found to be anemic. The mean PCV value of infected cattle (21.4 ± 3.6.) was significantly ($P < 0.05$) lower than that of non-infected (25.6 ± 4.6) (Table 2).

4. Discussion

The present parasitological study confirmed that, bovine trypanosomosis is widespread, and a major obstacle to cattle production in western Oromia (Duguma et al., 2015; Degneh et al., 2017; Kassaye, 2015). The overall prevalence of bovine trypanosomosis in the study was 8.3%. This prevalence is well following the studies of (Duguma et al., 2015; Mekuria and Gadisa, 2011; Degneh et al., 2018), in northwest and western Ethiopia, who reported an overall prevalence of 9.6%, 10.1%, and 11.16%, respectively. The similarity in prevalence with the current result may be due to similar agro-ecological conditions and management systems practiced in these areas. However, significantly higher prevalence values were also reported in Ethiopia (Mulaw et al., 2011; Kassaye, 2015), which may be because of differences in husbandry practices, the season of sampling, parasite and fly control operations, and deforestation for crop cultivation (Majekodunmi et al., 2013). The highest prevalence observed in Haro Tatessa (17.7%), followed by Chafe Jalala (9.4%), Ambalta (4.2%) and the lowest prevalence was observed in Kollo Sirii village (2.1%) ($P > 0.05$). Such variations in prevalence may arise because of differences in agro-ecology, vector infection rate, the practice of trypanocidal drug usage, which may impact epidemiological situations of the disease (Majekodunmi et al., 2013; Geiger et al., 2015).

Two important pathogenic trypanosome species of cattle, *T. congolense* and *T. vivax* were identified at the prevalence of 6.3% and 2.6%, respectively, which agree with the observations made by other groups in different tsetse-infested areas in Ethiopia (Duguma et al., 2015; Mekuria and Gadisa, 2011). The highest prevalence due to *T. congolense* in this study may suggest an increased presence of the biological vectors for *T. congolense* and reduced occurrence of other biting flies, which have been implicated in mechanical transmission of *T. vivax* (Desquesnes et al., 2009). It could be because of better immune response to *T. vivax* by the infected animals (Abenga et al., 2002). According to (Stephen, 1986), *T. congolense* is mainly confirmed in the blood, while *T. vivax* and *T. brucei* also invade the tissues. The higher proportion of *T. congolense* in this study (68.8%) was similar to the previous results (Duguma et al., 2015; Degneh et al., 2017; Mekuria and Gadisa, 2011), in southwest (76%), Western (62%) and northwest Ethiopia (77.6%), respectively. Moreover, in several studies conducted in sub-Saharan Africa, *T. congolense* is the most prevalent trypanosome species in cattle (Ameen et al., 2008; Simo et al., 2015).

Several studies (Degneh et al., 2017; Mekuria and Gadisa, 2011; Bitew et al., 2011) have shown the effect of bovine trypanosomosis

Table 1
Prevalence of bovine trypanosomosis in relation with different host related risk factors, Bedele District, Buno Bedele Zone, Oromia Regional State, Southwest Ethiopia.

Risk Factors	No. of examined animals	Prevalence (%)	χ^2	*P*-value
Body Condition Scores				
Poor	125	12.8		
Medium	162	8		
Good	97	3.1	6.772	0.034
Sex				
Male	150	7.3		
Female	234	9	0.3222	0.570266
Age				
≤3 years	105	6.7		
>3 years	279	9	0.0965	0.756043

Table 2
Overall Mean PCV of infected and non-infected cattle, Bedele district, Buno Bedele Zone, Oromia Regional State, Southwest Ethiopia.

Status of animals	No. examined	Trypanosome positive	Prevalence (%)	Mean PCV	Std. Dev.	95% CI	*P*-value
Anemic	168	25	14.9	21.4	3.6	20.1–22.7	0.00
Non anemic	216	7	3.2	25.6	4.6	25.1–26.1	
Overall	384	32	8.3	25.3	4.7	24.8–25.7	

on the body condition of cattle in Ethiopia. In this study, a statistically significant difference ($P < 0.05$) was observed in the prevalence of bovine trypanosomosis in different body condition scores of cattle. The majority of the infected animals manifested clinically poor body condition, as trypanosomosis is characterized by progressive weight loss (Radostitis et al., 2007). In contrast, 87.2% of poor body conditioned animals were not infected by trypanosomes. The absence of trypanosome infection in the poor body condition animals might be attributed to malnourishment, frequently treatment of animals treated with trypanocidal drugs (Zewdu et al., 2013), and low sensitivity of the buffy coat method used (Marcotty et al., 2008a) or helminthes parasites (OIE, 2009).

In the current study, sex was not found a significant risk factor ($P > 0.05$), though the prevalence revealed a slightly higher in female cattle (9%) than in males (7.3%). Similar findings were reported in Ethiopia (Dayo et al., 2010; Teka et al., 2012), and in Nigeria (Quadeer et al., 2008; Samdi et al., 2011). A possible explanation for the relatively higher prevalence observed in females may to the stress associated with hormonal imbalances during pregnancy and lactation, which usually increases females' susceptibility to infections (Torr et al., 2006). On the other hand, (Magona et al., 2008) reported a significantly higher prevalence of trypanosomosis in male than female cattle, suggesting that male animals travel more long distances to tsetse abundant areas for draught purposes.

Although, no statistically significant difference ($P > 0.05$) was observed between age categories, the prevalence of bovine trypanosomosis was higher in older (8.9%) than in younger (6.7%) animals, which could be explained in terms of grazing behavior that exposes adult animals for the tsetse and biting flies than younger cattle (Alemayehu et al., 2012). Similar observations were made by (Degneh et al., 2017; Terefe et al., 2015) in Ethiopia, where they reported the effect of age on the prevalence of trypanosome infections. In current study, the number of older females (172) examined were more than older males (108), which might be skew the result to females. Older cattle have large body sizes, produce more carbon dioxide trails, and hence more likely to attract tsetse flies (Simukoko et al., 2007). According to (Torr et al., 2006), tsetse flies are attracted significantly more by the odor of older animals and animals that showed less defensive behavior. Moreover, *T. congolense* is a chronic disease that increases with the age of animals and its infection is usually higher in adult animals than in young animals (McDermott et al., 2003).

There were significant differences ($P < 0.05$) in the PCV values of both infected and non infected cattle, as observed by (OIE, 2009; Stein et al., 2011) in Ethiopia and (Samdi et al., 2010; Quadeer et al., 2008) in Africa. Using a PCV value of 25% as a cut off, 78.1% of the infected and 41.5% of non- infected animals were found to be anemic. According to (Marcotty et al., 2008b; Mbewe et al., 2015), infection with trypanosomes resulted in a significant decline in the PCV values of cattle. Different confounding factors, such as poor nutrition and other anemia causing diseases could also contribute to the general low PCV (Radostitis et al., 2007; Simukoko et al., 2011). The 41.5% of non infected cattle with PCV $\leq$25% in this study could be because of low sensitivity of the buffy coat method used (Marcotty et al., 2008b). On the other hand, 21.9% of cattle that were trypanosome positive, but not anemic can be explained as new infections that had not progressed to chronicity (Luckins, 2010).

5. Conclusions

The current study indicated that, despite vector control measures implemented for several years, bovine trypanosomosis persists and continues to be a core problem to cattle health and production in Bedele district. *Trypanosoma congolense* and *T. vivax* are the predominant trypanosome species identified in the area. Significant variation in prevalence was observed between body condition scores of cattle. This finding is of paramount importance in planning the control of bovine trypanosomosis in the area. Therefore; more attention should be given to control both the disease and its vectors in the study district. Vector trapping should be undertaken to look at the prevalence of infection in potential vectors. In addition, use of molecular techniques should be encouraged given the poor sensitivity of the buffy coat method used.

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Authors' contributions

ED drafted the proposal and the manuscript, collected, analyzed and interpreted the data. TK facilitated and supervised the data collection and edited the manuscript. NK and ZA supported the analyses and interpretation of the results and edited the manuscript. All authors reviewed and approved the final manuscript.

Ethics approval and consent to participate

Ethical values were considered, starting from the approval of the proposal. Participants' involvement in the study was on a voluntary basis; the purpose of study was explained to the owners of the animals. Humane handling of animals was followed and the sampling sites were thoroughly disinfected before and after sampling.

Declaration of Competing Interest

The authors declare that there is no conflict of interest regarding the publication of this paper.

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References

Abenga, J.N., Ewenzor, F.N.C., Lawani, F.A., Ezebuiro, C., Sule, J., David, K.M., 2002. Prevalence of try-panosomiasis in trade cattle at slaughter in Kaduna State, Nigeria. J. Parasitol. 23, 107–110.

Alemayehu, B., Basaznew, B., Tewodros, F., Mersha, C., 2012. Bovine trypanosomosis; a threat to cattle production in Chena district, South-west Ethiopia. J. Anim. Sci. 2, 287–291.

Ameen, S.A., Joshua, R.A., Adedeji, O.S., Raheem, A.K., Akingbade, A.A., Leigh, O.O., 2008. Preliminary studies on prevalence of Ruminant trypanosomosis in Ogbomoso area of Oyo State, Nigeria. Middle-East J. Sci. Res. 3 (4), 214–218.

BBZAHLDO, 2018. Buno Bedele Zone Animal Health and Live stalk development Office. Annual Report, Bedele, 2018.

Bitew, M., Yeshitila, A., Asmamaw, A., Tadele, T., 2011. Prevalence of bovine trypanosomosis in selected areas of Jabi Tehenan district, West Gojam of Amhara region Northwestern Ethiopia. Afr. J. Agric. Res. 6, 140–144.

Bourn, D.M., Reid, R.S., Rogers, D.J., Shnow, W.F., Wint, G.R.W., 2001. Environmental Change and the Autonomous Control of Tsetse and Trypanosomosis in Sub-Saharan Africa: Case Histories from Ethiopia (Gambia, Kenya, Nigeria and Zimbabwe, Environmental Research Group Oxford Limited, Oxford, UK).

CSA, 2013. Agricultural Sample Survey. Report on livestock and livestock characteristics, Addis Ababa, Ethiopia, Vol. 2, p. 4.

CSA, 2017. Agricultural Sample Survey, Volume II: Report on Livestock and Livestock Characteristics (Private Peasant Holdings). Statistical Bulletin 585. Central Statistical Agency (CSA), Federal Democratic Republic of Ethiopia, Addis Ababa, Ethiopia.

Dayo, G.K., Bengaly, Z., Messad, S., Bucheton, B., Sidibe, I., Cene, B., 2010. Prevalence and incidence of bovine trypanosomosis in agro-pastoral area of Southwestern Burkina Faso. Res. Vet. Sci. 88, 470–477.

Degneh, E., Shibeshi, W., Terefe, G., Aseres, K., Ashenafi, H., 2017. Bovine trypanosomosis: changes in parasitemia and packed cell volume in dry and wet seasons at Gidami District, Oromia regional state, Ethiopia. Acta Vet. Scand. 59, 59. https://doi.org/10.1186/s13028-017-0327-7.

Degneh, E., Ashenafi, H., Terefe, G., Kassa, T., Kebede, N., Shibeshi, W., Asres, K., 2018. A cross-sectional study of bovine Trypanosomosis in Sayo District, Oromia Regional State, Western Ethiopia. Int. J. Nutr. Food. Sci. 7 (2), 56–64.

Degneh, E., Hagos, A., Getachew, T., Tesfu, K., Nigatu, K., Workineh, S., Kaleab, A., 2019. Trypanocidal drug resistance: a threat to animal health and production in Gidami District of Kellem Wollega zone, Oromia regional state, Western Ethiopia. Prev. Vet. Med. 168, 103–107.

Desquesnes, M., Biteau-Coroller, F., Bouyer, J., Dia, M.L., Foil, L.D., 2009. Development of a mathematical model for mechanical transmission of trypanosomes and other pathogens of cattle transmitted by tabanids. Int. J. Parasitol. 39, 333–346.

Douglas, J.W., Wardrop, K.J., 2010. Schalm's Veterinary Hematology, 6th ed. Blackwell, Oxford.

Duguma, R., Tasew, S., Olani, A., Damena, D., Alemu, D., Mulatu, T., 2015. Spatial distribution of Glossina and Trypanosoma species in South-Western Ethiopia. Parasit. Vectors 9, 430.

FAO, 2010. Field Guide for Diagnosis, Treatment and Prevalence of African Animal Trypanosomiasis 2nd Ed. FAO, Rome, pp. 27–34.

Fikru, R., Goddeeris, B.M., Delespaux, V., Moti, Y., Tadesse, A., Bekana, M., Claes, F., De, D.R., 2012. Buscher P. Widespread occurrence of Trypanosoma vivax in bovines of tsetse- as well as non-tsetse-infested regions of Ethiopia: a reason for concern? Vet. Parasitol. 190 (3), 55–61.

Geiger, A., Ponton, F., Simo, G., 2015. Adult blood-feeding tsetse flies, trypanosomes, microbiota and the fluctuating environment in Sub-Saharan Africa. ISMEJ. 9, 1496–1507.

Getachew, A., 2005. Review article: Trypanosomosis in Ethiopia. Ethio. J. Biol. Soc. 4, 75–121.

Hagos, A., Yilkal, A., Esayass, T., Alemu, T., Fikru, R., Feseha, G., Goddeeris, B.M., Claes, F., 2009. Parasitological and serological survey on trypanosomis (surra) in camels in dry and wet areas of Bale Zone, Oromyia Region, Ethiopia. Revue. Méd. Vét. 160 (12), 569–573.

Kabayo, J.P., 2002. Aiming to eliminate tsetse from Africa. Trends Parasitol. 18, 473–475.

Kassaye, B.K., 2015. Prevalence of bovine Trypanosomosis and apparent density of tsetse flies in Sayonole District Western Oromia, Ethiopia. J. Vet. Sci. Technol. 6, 254. https://doi.org/10.4172/2157-7579.1000254.

Kone, N., N'Goran, E.K., Sidibe, I., Kombassere, A.W., Bouyer, J., 2011. Spatio-temporal distribution of tsetse and other biting flies in Mouhoum River basin, Burkina Faso. Med. Vet. Entomol. 25, 156–168.

Kumela, L., Adem, A., Delesa, D., 2016. Prevalence of small ruminant Trypanosomosis in Dangur District, Metekel zone, Benishangul Gumuz region, North Western Ethiopia. J. Vet. Sci. Technol. 7, 334. https://doi.org/10.4172/2157-7579.1000334.

Leta, S., Alemayehu, G., Seyoum, Z., Bezie, M., 2016. Prevalence of bovine trypanosomosis in Ethiopia: a meta-analysis. Parasit. Vectors 9 (139), 2–9.

Luckins, A.G., 2010. Methods for Diagnosis of Trypanosomiasis in Livestock. FAO corporate document repository. http://www.fao.org.

Magona, J.W., Walubengo, J., Odimin, J.T., 2008. Acute haemorrhagic syndrome of bovine trypanosomosis in Uganda. Acta Trop. 107, 186–191.

Majekodunmi, A.O., Fajinmi, A., Dongkum, C., Picozzi, K., Thrusfield, M.V., Welburn, S.C., 2013. A longitudinal survey of African animal trypanosomiasis in domestic cattle on the Jos Plateau, Nigeria: prevalence, distribution and risk factors. Parasit. Vectors 6, 239. https://doi.org/10.1186/1756-3305-6-239.

Marcotty, T., Simukoko, H., Berkvens, D., Vercruysse, J., Praet, N., Van den Bossche, P., 2008a. Evaluating the use of packed cell volume as an indicator of trypanosomal infections in cattle in Eastern Zambia. Prev. Vet. Med. 87, 288–300.

Marcotty, T., Simukoko, H., Berkvens, D., Vercruysse, J., Praet, N., Van Den Bossche, P., 2008b. Evaluating the use of packed cell volume as indicator of trypanosomal infections in cattle in eastern Zambia. Prevent. Vet. Med. 87, 288–300.

Mbewe, N.J., Sitali, L., Namangala, B., Michelo, C., 2015. Adherence to the Food and Agricultural Organization guidelines on trypanocide usage among cattlefarmers in Itezhi tezhi, Central Zambia. Vet. Parasitol. 209, 43–49.

McDermott, J., Woitag, T., Sidibe, I., Bauer, B., Diarra, B., Ouedraogo, D., Kamuanga, M., Peregrine, A., Eisler, M., Zessin, K.H., Mehlitz, D., Clausen, P.H., 2003. Field studies of drug resistant cattle trypanosomesin Kenedougou Province, Burkina Faso. Acta Trop. 86, 93–103.

Mekonnen, B., Regasa, F., Kahsay, A.G., 2014. Epidemiology of trypanosomosis in goats at Abelti, Bede and Ghibe valley South-West Ethiopia. Int. J. Trop. Med. 9, 10–14.
Mekuria, S., Gadisa, F., 2011. Survey on bovine trypanosomosis and its vector in Metekel and Awi zones of Northwest Ethiopia. Acta Trop. 117, 146–151.
Mulaw, S., Addis, M., Fromisa, A., 2011. Study on the prevalence of major trypanosome affecting bovine in tsetse infested Asosa District of Benshagul- Gumuz Regional State, western Ethiopia. Global. Vet. 7, 330–336.
Murray, M., Murray, P.K., McIntyre, W.I., 1977. An improved technique for the diagnosis of African trypanosomiasis. Trans. R. Soc. Trop. Med. Hyg. 71, 325–326.
Nicholson, M.J., Butterworth, M.H.A., 1986. A Guide to Condition Scoring of Zebus Cattle. ILCA, Addis Ababa Ethiopia, pp. 212–235.
NTTICC, 2004. Annual Report on Tsetse and Trypanosomosis Survey (Bedelle, Ethiopia).
OIE, 2009. Manual of Standards for Diagnostic Tests and Vaccines for Terrestrial Animals, 6th ed., pp. 813–820 (Paris).
Pace, J.E., Wakeman, D.L., 2003. Determining the Age of Cattle by their Teeth. University of Florida, IFAS Service. http://edis.ifas.ufl.edu.
Quadeer, M.A., Danbirni, S., Usman, M., Akogun, O.B., Gundiri, M.A., Bobbo, A.G., 2008. Prevalence of bovine trypanosomosis in Bassa local government area, Plateau State, Nigeria. Nigeria J. Parasitol. 29, 136–139.
Radostitis, O.M., Gay, C.C., Hinchcliff, K.W., Constable, P.D., 2007. Veterinary Medicine: A Text Book of Diseases of Cattle, Horses, Sheep, Pigs and Goats, 10th ed. Saunders-Elsevier, pp. 1536–1596.
Samdi, M.S., Abenga, J.N., Attahir, A., Haruna, M.K., Wayo, B.M., Fajinmi, A.O., Sumayin, H.M., Usman, A.O., Hussaina, J.Z., Muhammad, H., Yarnap, J.E., Ovbagbedia, R.P., Abdullahi, R.A., 2010. Impact of Trypanosomosis on food security in Nigeria: a review, Nigerian Institutefor Trypanosomiasis Research. Int. J. Anim. Vet. Adv. 2 (2), 47–50.
Samdi, S.M., Fajinmi, A.O., Kalejaye, J.O., Wayo, B., Haruna, M.K., Yarnap, J.E., Mshelia, W.P., Usman, A.U., Haruna, S.M., Jijtar, A., Ogunwole, R., Ogbagbedia, R.P., 2011. Prevalence of trypanosomosis in cattle slaughter at Kaduna Central abattoir. Asian Australas. J. Anim. Sci. 5 (2), 162–165.
Simo, G., Fongho, P., Farikou, O., Ndjeuto-Tchouli, P., Tchouomene-Labou, J., Njiokou, F., Asonganyi, T., 2015. Trypanosome infection rates in tsetse flies in the Bsilentˆ sleeping sickness focus of Bafia in the Centre region in Cameroon. Parasit. Vectors 8 (1), 528. https://doi.org/10.1186/s13071-015-1156-z.
Simukoko, H., Marcotty, T., Phiri, I., Geysen, D., Vercruysse, P., van den Bossche, P., 2007. The comparative role of cattle, goats and pigs in the epidemiology of livestock trypanosomiasis on the plateau of eastern Zambia. Vet. Parasitol. 147, 231–238.
Simukoko, H., Marcotty, T., Vercruysse, J., Van den Bossche, P., 2011. Bovine trypanosomiasis risk in an endemic area on the eastern plateau of Zambia. Res. Vet. Sci. 90, 51–54.
Stein, J., Ayalew, W., Rege, E., Mulatu, W., Lemecha, H., Tadesse, Y., 2011. Trypanosomosis and phenotypic features of four indigenous cattle breeds in an Ethiopian field study. Vet. Parasitol. 178, 40–47.
Stephen, L.E., 1986. Trypanosomiasis, a Veterinary Perspective. Perg-amon Press, Oxford, UK.
Steverding, D., 2008. The history of African trypanosomosis. Parasit. Vectors 1, 3.
Tadesse, A., Omar, A., Aragaw, K., Mekbib, B., Sheferaw, D., 2012. A study on camel Trypanosomosis in Jijiga Zone, Eastern Ethiopia. J. Vet. Adv. 2 (5), 216–219.
Taye, M., Belihu, K., Bekana, M., Sheferaw, D., 2012. Assessment of impacts of tsetse and trypanosomosis control measures on cattle herds' composition and performance in southern region, Ethiopia. Trop. Anim. Health Prod. 44, 1759–1763.
Teka, W., Terefe, D., Wondimu, A., 2012. Prevalence study of bovine trypanosomosis and tsetse density in selected villages of Arbaminch, Ethiopia. J. Vet. Med. Anim. Health 4 (3), 36–41.
Terefe, E., Haile, A., Mulatu, W., Dessie, T., Mwai, O., 2015. Phenotypic characteristics and trypanosome prevalence of Mursi cattle breed in the Bodi and Mursi districts of south Omo zone, Southwest Ethiopia. Trop. Anim. Health Prod. 47, 485–493.
Thrusfield, M., Christley, R., 2018. Veterinary Epidemiology, 4rd ed. Blackwell science Ltd, London, pp. 275–294.
Tilahun, H., Schmidt, E., 2012. Spatial analysis of livestock production patterns in Ethiopia, development strategy and governance division, international food policy research institute-Ethiopia strategy support program II, Ethiopia. J. Agric. Crop Res. 6 (5), 97–104.
Torr, S.J., Mwangwiro, T.N.C., Hall, D.R., 2006. The effects of host physiology on the attraction of tsetse (Dipteral: Glossinidae) and Stomoxys (Dipteral: Muscidae) to cattle. Bull. Entomol. Res. 96 (1), 71–84.
WHO, 2006. Human African Trypanosomiasis: epidemiological update. Week Epidemiolog Record 8, 69–80.
WHO, 2012. Fact sheets no 259 tryapanosomiasis, human African 2012. Available at: http://www.who.int/mediacentre/factsheets/fs259/en/.
Zewdu, S., Getachew, T., Hagos, A., 2013. Farmers' perception of impacts of bovine trypanosomosis and tsetse fly in selected districts in Baro-Akobo and Gojeb river basins, Southwestern Ethiopia. BMC Vet. Res. 9, 214.