

Prevalence of bovine trypanosomosis and its associated risk factors in selected woredas of Gambella Regional State, South West Ethiopia

Jemberu Alemu • Eshetu Gudina

Department of Animal Production and Health, Gambella University College of Agriculture and Natural Resources, Ethiopia.

*Corresponding author. E-mail: jemba_2003@yahoo.com.

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Abstract. Cross-sectional study was conducted from October 2017 to February 2018 to determine the prevalence status of bovine trypanosomosis in Itang special and Gambella woredas, Gambella region of south west Ethiopia and to assess associated risk factors of the disease. Blood samples were collected from 384 randomly selected cattle of the study areas and evaluated through standard parasitological and haematological methods. The overall prevalence of trypanosomosis was 17.2%, (95% confidence interval (CI) 8.79-24.75). The most common trypanosome species identified were *T. congolense* (51.51%) followed by *T. vivax* (39.39%), *T. brucei* (27.72%) and mixed (7.58%) infections, respectively. Disparity in the prevalence of trypanosome infection was recorded in the different woredas, between the two sexes and body condition and the difference was not statistically significant ($p > 0.05$). Univariable logistic regression analysis showed that anaemic (PCV < 24%) had 0.881 times the risk of being trypanosomosis positive compared with non-anaemic animal (> 24) (OR = 5.7, 95% CI 2.77-11.77). Statistically significant difference ($P = 0.001$) was observed with the mean PCV values between aparasitaemic ($24.92 \pm 0.32SE$) and parasitaemic animals (21.94 ± 0.29). In conclusion, this study revealed that trypanosomosis poses a threat to cattle production in the districts. Hence, appropriate disease prevention and control methods should be implemented to improve livestock production and agricultural development in the area.

Keywords: Epidemiology, prevalence, risk factors, trypanosoma, tsetse fly.

INTRODUCTION

Livestock sector plays a significant role for the economy and has a great potential to assist the economic development by providing meat, milk, other food products, cultivation power, transport, security in times of crop failure and farm yard manure (fertility and energy) and also plays a major role in export commodity. The sector contributes 15% of total GDP and over 30% of the agricultural GDP (MoA, 1998).

The livestock production is low consequently impeding the overall agricultural development. One of the most

important constraints for this is trypanosomosis by affecting the health and productivity of livestock in the most fertile and arable land of the country due to the infestation of tsetse fly (Woyessa *et al.*, 2014).

Trypanosomosis is the most important constraint to livestock and mixed crop-livestock farming in tropical Africa. About 3 million livestock die every year due to tsetse fly transmitted trypanosomosis which covers one third of the continent estimated to be 10 million km². In this region at least 46 million cattle are exposed to the

risk of contracting tsetse-borne trypanosomosis, as are millions of sheep, goats, donkeys, camels and horses (Reid *et al.*, 1998). A study estimated the direct annual cost of trypanosomosis to be about 1.34 billion US\$ (Kristjanson *et al.*, 1999). African livestock producers are administering an estimated 35 million curative and prophylactic treatments annually which costs the producers and the government at least 35 million US\$ (Geerts and Holmes, 1998). The direct losses from trypanosomosis in livestock include mortality, morbidity, impaired fertility and the cost of implementing and maintaining tsetse fly and trypanosomosis control operations. Indirect losses stem from farmers responses to the perceived risk of the disease, including the reduction and in some cases, the exclusion of livestock from tsetse-infested grazing lands and reduced crop production due to insufficient animal draught power (ILRAD, 1993).

The host range of trypanosomosis includes domestic and wild animals as well as human beings (Juyal *et al.*, 2005; Parashar *et al.*, 2016; Diallo *et al.*, 2018). The vector includes several species of tsetse flies and other biting flies. Tsetse flies are grouped in the three categories: *Glossina morsitans* group (savanna areas), *Glossina fusca* group (forest areas) and *Glossina palpalis* group (river and lake areas). The most important trypanosome species that affect cattle, sheep and goats are: *Trypanosoma congolense*, *T. vivax* and *T. brucei*. Tsetse transmitted animal trypanosomosis is a serious constraint to livestock production and agricultural development in Ethiopia. A total of 14.8 million cattle, 6.12 million sheep and goats, 1 million camels and 1.23 million are at risk of contracting trypanosomosis (MoA, 1995). According to this report 1 to 2 million doses of trypanocidal drugs are administered at the cost of 0.5 to 1 million US\$ per annum in Ethiopia.

There are five species of *Glossina* in Ethiopia: *G. pallidipes*, *G. morsitans submorsitans*, *G. fuscipes*, *G. tachinoides* and *G. logipennis*. Several reports made in Ethiopia revealed that tsetse fly occupy over 66,000 km² areas (Ford *et al.*, 1976) based on a 1500 m.a.s.l. breeding limit in the southern and southwestern valleys of the country. Langridge (1976) has reported that some 98,000 km² area 1600 m.a.s.l. breeding limit in the southern and southwestern parts of Ethiopia. However, due to the advancement of tsetse flies into formerly free areas reaching 130,000 to 150,000 km² (Slingenbergh, 1992) based on 1700 m.a.s.l. and recently 220,000 km² areas is estimated to be affected by tsetse flies (NTTICC, 1996) based on 2000 m.a.s.l. breeding limit. These areas follow the Baro, Omo and Abbay valleys of the large rivers in the country. On the other hand these areas possess the most arable land with a high potential for agricultural development due the high annual rain fall (Jemal and Hugh-Jones, 1995). There are five economically important animal trypanosome species in Ethiopia: *T. congolense*, *T. vivax*, *T. brucei* and *T.*

Evansi (Langridge, 1976) and *T. equiperdum* (Dagnachew and Shafo, 1981). The most prevalent trypanosome species in tsetse-infested areas of Ethiopia are *T. congolense* and *T. vivax*. Rowlands *et al.* (1993) reported a prevalence rate of 37% for *T. congolense* in southwest Ethiopia. Abebe and Jobre (1996) reported an infection rate of 58.5% for *T. congolense*, 31.2% for *T. vivax* and 3.5% for *T. brucei* in southwest Ethiopia. In the same report it is also indicated that 8.71% prevalence rate was recorded in the highlands (tsetse free areas) of which 99% is due to *T. vivax* in the south western part of Ethiopia; the Gambella regional state bordering the Baro river, one of the south western tsetse belt areas of Ethiopia, tsetse transmitted trypanosomosis is becoming a serious threat for livestock production and agricultural activity in particular. Earlier works by Langridge (1976) indicated that the tsetse belts extend from the southern part of the Rift valley, around the southern corner of the country and along the western lowlands and escarpment to the Abbay River.

The principle of prevention and control of tsetse-transmitted trypanosomosis depends on minimizing contact between domestic, game animals and tsetse flies. So far the methods used for the control of trypanosomosis in tsetse infested areas include control of tsetse fly numbers, use of curative or prophylactic trypanocidal drugs and use of livestock breeds that tolerate the disease. However, uses of these methods are highly variable. Trypanocidal drugs remain the principal method of animal trypanosomosis control in most African countries including Ethiopia. With increasing liberalization of veterinary drugs the controls on the use of trypanocides are diminishing, hence there is a growing concern that their future effectiveness may be severely curtailed by widespread drug resistance. In general, in areas where trypanocides have been used intensively drug resistance is more common than in areas where they have been used less intensively. The problems of drug resistance have been reported from 13 countries in sub-Saharan Africa. Drug resistant to *T. congolense* have been reported in Ethiopia by different workers (Codjia *et al.*, 1993; Afewerk *et al.*, 2000; Assefa and Abebe, 2001; Tewelde *et al.*, 2004). For the effective way of controlling tsetse transmitted trypanosomosis the knowledge of insect biology and ecology, the status of the disease prevalence and trypanocidal drug efficacy is of paramount importance. According to the report of Gambella region Bureau of Agriculture (2012) animal health problems such as infectious diseases, internal and external parasitic diseases, and protozoal diseases are the main constraints of livestock production and agricultural development in the region. Trypanosomosis is commonly found in the lowland part of the region where the present study area is located and is becoming a serious threat for livestock production and utilization of the fertile and arable land. A survey conducted by ESTC/SRVETEP (2000) indicated that tsetse transmitted

trypanosomiasis is the most important problem for agricultural activity and livestock production in south western part of the country. Therefore, the present study is designed for the objective to determine the prevalence of bovine trypanosomiasis and to assess the risk factors of the disease together with the identification of species of trypanosomiasis in study area.

MATERIALS AND METHODS

Study area

The study was conducted in Itang, and Gambella woredas of Gambella Regional state, Southwest Ethiopia from October 2017 to February 2018.

The Gambella People's Regional State is located south west Ethiopia between the geographical coordinates of 6° 28' 38" to 8° 34' North Latitude and 33° to 35° 11' 11" East Longitude, 766 km far from Addis Ababa which covers an area of about 34,063 km². The Region is bounded to the North, North East and East by Oromya National Regional State, to the South and Southeast by the Southern Nations and Nationalities and People's Regional State and to the Southwest, West and Northwest by the Republic of south Sudan (Behailu *et al.*, 2011).

Most of Gambella region is flat and its climate is hot and humid. The mean annual temperature of the Region varies from 17.3 to 28.3°C and absolute maximum temperature occurs in mid-March and is about 45°C and the absolute minimum temperature occurs in December and is 10.3°C. The annual rainfall of the Region in the lower altitudes varies from 900 to 1,500 mm; at higher altitudes it ranges from 1,900 to 2,100mm. The annual evapotranspiration in the Gambella reaches about 1,612mm and the maximum value occurs in March and is about 212 mm (Tilahun, 2012).

Based on the 2013/2014 Census conducted by the Central Statistical Agency of Ethiopia (CSA), the Gambella Region has total population estimation of 406,000 (CSA, 2013/2014) and livestock population of Gambella 253,389 cattle, 39,564 sheep and 83,897 goat (CSA, 2010/2011).

Study population

The study population constitutes zebu cattle of various body condition scores, age groups and sexes therefore Local Nuer/Abigar breed cattle were used as study population for the prevalence study.

Study design

A cross sectional study was employed in the two purposively selected woredas of the Gambella region to

determine the prevalence of bovine trypanosomiasis, to identify the prevailing species of trypanosomes and to assess the host related risk factors of the disease.

Sampling method and sample size determination

Simple random sampling technique was followed to select the study animals. The desired sample size was calculated according to Thrusfield (2005) sample size determination formula as follows:

$$n = \frac{1.96^2 \times p_{exp} (1 - p_{exp})}{d^2}$$

Where: n = required sample size

P_{exp} = expected prevalence =50%

d = desired absolute precision =0.05

As a result of having no previous study of the disease prevalence rate in the region 50% expected prevalence was employed, and the sample size was 384.

During sampling age, sex and body condition scores of the animals were recorded. Body condition score for each cattle were estimated according to Nicholson and Butterworth (1986) ranging from score one (emaciated) to score five (obese).

Sample collection and parasitological examination

Packed cell volume (PCV) determination

Blood samples were collected from the marginal ear vein by pricking it with the tip of lancet after properly securing the animal and aseptically preparing area around the ear vein. The samples were collected using two hematocrit capillary tubes to the level of ¾ of the height and sealed with bee wax in one end. For the measurement of PCV using a micro-hematocrit centrifuge (Hawksley and Sons, UK), the capillary tubes were placed in micro hematocrit was allowed to centrifuge at 12,000 rpm for five minutes. The length of the packed red blood cells column is expressed as a percentage of the total volume of blood. Animals with PCV less than 24% were considered to be anemic.

Buffy coat technique

Blood sample was collected from an ear vein using heparinized micro-hematocrit capillary tube and the tube was sealed. A heparinized capillary tube containing blood was centrifuged for 5 min at 12000 rpm. After centrifugation, trypanosomes are usually found in or just above the buffy coat layer. The capillary tube was cut using a diamond tipped pen 1mm below the buffy coat to include the upper most layers of the red blood cells and

Table 1. Univariable logistic regression analysis of different risk factors.

Risk factors	Risk categories	Number examined	Number positive	Prevalence (%) (95% CI)	Odds ratio (95% CI)	P
Site	Gambella	192	36	18.75 (25.69 - 46.60)	Reference	0.305
	Itang	192	30	15.625 (14.43 - 34.22)	0.56 (0.28 - 1.37)	
BCS	Poor	163	40	24.53 (24.19 - 47.45)	Reference	0.13
	Medium	155	18	11.61 (18.52 - 36.80)	0.68 (0.35 - 1.34)	
	Good	66	8	12.12 (13.49 - 36.50)	0.59 (0.27 - 1.31)	
Age	Young	115	16	13.91 (87.53 - 27.61)	Reference	0.5
	Adult	269	50	18.587 (26.79 - 42.08)	2.36 (1.16 - 4.81)	
Sex	Male	197	26	13.19 (24.96 - 42.92)	Reference	0.429
	Female	187	40	21.39 (16.75 - 33.25)	0.65 (0.36 - 1.17)	
PCV	<24%	202	50	24.75 (18.23 - 32.33)	Reference	0.001*
	≥ 24%	182	16	8.79 (6.14 - 17.12)	.882 (.591 - 1.317)	

BCS, Body condition score; CI, Confidence Interval; *, significance.

3mm above to include the plasma. The content of the capillary tube was expressed onto a slide and covered with cover slip. The slide was examined under $\times 40$ objective and $\times 10$ eye piece for movement of parasite (Juyal and Singla, 2005). Trypanosome species were identified according to their morphological descriptions as well as movement in wet film preparations provided by OIE (2008).

Thin blood smear

A small drop of blood from a microhaematocrit capillary tube was applied to a clean slide and spread by using another clean slide at an angle of 45° . The smear was dried by moving it in the air and fixed for 2 min in methyl alcohol. The thin smear was flooded with Giemsa stain (1:10 solution) for 30 min. Excess stain was drained and washed by using distilled water. Then it was allowed drying and examined under the microscope ($\times 100$) oil immersion objective lens (Gupta and Singla, 2012).

Data management and analysis

The collected raw data and the results of parasitological and hematological examination was entered into a Microsoft excel spread sheets program and then transferred to SPSS version 20 for analysis. The prevalence of trypanosome infection was calculated as the number of positive animals as examined by Giemsa stain of thin blood film and buffy coat method divided by the total number of animals examined at the particular time. Pearson's chi-square (χ^2) was used to evaluate the

association of different variables with the prevalence of trypanosome infection. P-value less than 0.05 (at 5% level of significance) was considered significant in all analysis.

RESULTS

Parasitological findings

Out of 384 cattle examined with a buffy coat technique, 66 were positive for trypanosomes giving an overall prevalence of 17.2% (95% CI = 8.79 - 24.75). The highest prevalence (24.75%) was observed in anaemic animals. The association of trypanosomes infection with different potential risk factors as analysed by Univariable logistic regression revealed that there were no significant association between trypanosome infection, and the risk factors analysed (body condition and sex of animals). The prevalence was slightly high in female (21.39%) than male cattle (13.19%) and ($P > 0.05$). However, statistically significant association (OR=.882 (.591 - 1.317), $P = 0.001$) was observed between trypanosome infection and PCV (Table 1).

Trypanosoma congolense, *Trypanosoma vivax*, and *Trypanosoma brucei* were the *Trypanosoma* species identified by Giemsa stained thin blood smear examination (Figure 1).

Haematological finding

Among the anaemic animals 24.75% were positive for trypanosomosis while only 8.79% of non-anaemic animals

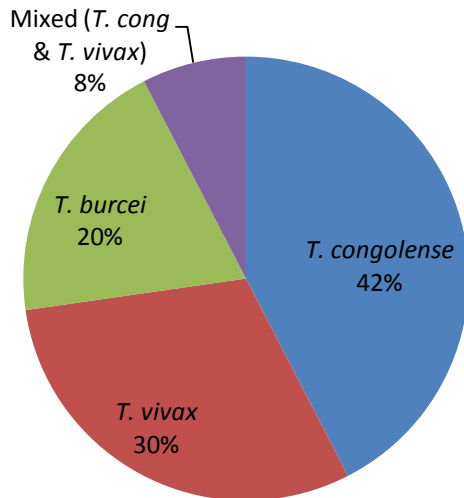


Figure 1. Distribution of the species of trypanosomes among the infected animals.

were positive for trypanosomosis (Table 2). The risk of being anaemic increased by 0.882 when animals were infected with trypanosome (Table 2).

The mean PCV of parasitemic animals were lower than that of the aparasitemic ones (Table 3).

Linear regression analysis of PCV and parasitemic cattle confirmed a unit variation/increase in the buffy coat result caused a reduction of the PCV value by 2.98% (Table 4).

DISCUSSION

The overall prevalence of bovine trypanosomosis in the study area was found to be 17.2%. This result is in close agreement with the finding of Terzu (2004) who reported 27.5 and 23% in Arba Minch, Southern Ethiopia and western Ethiopia, Metekel district, respectively. However, in the present study prevalence is higher than the previous result of Ababayehu *et al.* (2011), Teka *et al.* (2012), Fayisa *et al.* (2015), Ayana *et al.* (2012) and Kumela *et al.* (2016) who reported a prevalence of 2.66, 4.43, 4.86, 2.10 and 4.25% from Western Tigray, Northern Ethiopia, Didesa District, Arbaminch area, Amhara region, Northwest Ethiopian and Ilubabor Zone, Southwestern Ethiopia, respectively. The variation between reports might be due to the difference in management system, season of the study period, the development of drug resistance, and the increase of tsetse challenge due to higher vector density and lack of awareness of the animal owners about the disease in the study area.

In this study, three species of trypanosomes mainly *T. congolense*, *T. brucei* and *T. vivax* were identified. Out of the 66 trypanosomes identified, *T. congolense* accounted for 51.52% while the rest 22.73% and 39.39% were due to *T. brucei* and *T. vivax* respectively. Higher prevalence

of *T. congolense* compared to the prevalence of *T. vivax* and *T. brucei* is in agreement with previous works of Rowlands *et al.* (1993), Muturi (1999), Afework *et al.* (2001) and Tewolde (2004). They reported the prevalence for *T. congolense* as 84, 66, 60.9 and 75% in their study in Ghibe valley, Merab, pawe, and western Ethiopia, respectively.

The reason for the high ratio of *T. congolense* than *T. vivax* could be due to the high number of serodemes of *T. congolense* as compared to *T. vivax* and the development of better immune response to *T. vivax* by infected animals (D'leteren *et al.*, 1998; Leak, 1999). However, Cherenet *et al.* (2006) reported that *T. vivax* was responsible for 90.9% of the cattle trypanosome infections in their study in tsetse-free zones of the Amahara region, Northwest Ethiopia while *T. congolense* and *T. vivax* contributed almost equally to the trypanosome infections in tsetse infested area. This is due to fact that *T. vivax* can also be transmitted by mechanical vectors other than tsetse.

Univariable logistic regression analysis of different risk factors (site of the study area, sex, body condition) considered during the study did not show any significant association with occurrence of trypanosomosis. On the other hand, the risk of being anaemic increased by 0.882 times (Table 2) when cattle are infected by trypanosomosis ($P=0.001$). Moreover, linear regression analysis of PCV and parasitemic cattle confirmed a unit variation/increase in the buffy coat result caused an increment of the PCV value by 88.2%, ($P=0.001$). Among anaemic cattle 24.75% were diseased with trypanosomosis the current finding was comparable with the previous results by Afework *et al.* (2001) at Pawe, North West Ethiopia and Muturi (1999) at Merab Abaya, South Ethiopia.

In the current study the prevalence of trypanosome infection did not differ among the study areas and this might be due to similar agro-ecology and vectors abundance in both study areas. On the other hand, the slight difference among the study areas might be attributed to uncontrolled animal movements coupled with favourable environment for the vectors and availability of their preferred hosts, which is not necessarily domestic livestock (Radostits *et al.*, 2000) as the area is endowed with different wild animals.

Sex was not a significant predictor of trypanosome infection in cattle from both districts. This finding coincides with the earlier report by Teka *et al.* (2012) and Tamiru *et al.* (2014) who observed no significant difference in susceptibility between sex groups. The possible explanation for this might be both males and females can be affected equally and uniformly in high tsetse challenge areas.

The infection rate of trypanosomosis is slightly higher in poor body condition compared to medium and good body condition cattle's. In contrast, 75.46% of apparatusaemic cattle were with poor body condition and this indicates that other factors such as diseases, nutritional factors as well as management system may have contributed for

Table 2. Univariable logistic regression analysis of anemic and non-anemic cattle's.

Categories	Number examined	Number positive	Proportion (%) (95% CI)	Mean PCV ± SE	OR (95% CI)	P
Anaemic (<24)	202	50	24.75 (18.23 - 32.33)	21.1± 0.21	.882 (.591 - 1.317)	0.001
Non anaemic (≥24)	182	16	8.79 (6.14 - 17.12)	25.8 ± 0.38		
Total	384	66	17.2% (16.862 - 26.04)	21.9 ± 0.49		

SE, Standard Error; OR, Odd ratio, PCV, Packed cell volume; CI, Confidence Interval.

Table 3. The mean PCV value of parasitemic and aparasitaemic animals.

Infection status	No. examined	Mean PCV (%)	95% CI	SE	T-test (p)
Parasitemic	66	21.94	21.36 - 22.52	0.29	5.68 (0.001)
Apparasitaemic	318	24.92	24.29 - 25.55	0.32	
Total/average	384	24.04	23.54 - 24.55	0.26	

Table 4. Linear regression analysis of PCV and buffy coat result.

PCV	Coefficient	SE	P	95% CI
Buffy coat result	-2.98	0.53	0.001	-4.02 - (1.95)
Constant	24.92	0.29	0.001	24.36 - 25.48

*Packed Cell Volume; SE, Standard Error; CI, Confidence Interval.

the poor body condition of cattle (Smith, 2009). The relatively lower rate of trypanosomosis infection in the medium and good body condition animals might be related to that well-nourished animals have good level of immunity and are in a better position to resist infection, moreover there is a very rare possibility of re-establishment of infection in animals with good body condition.

In this research work, age was found to be a risk factor; higher infection rates were observed in adult animals. This is logically associated to the fact that young animals are also naturally protected to some extent by maternal antibodies (Fimmen *et al.*, 1992). In addition, adult animals travel and cross-different vegetation types for grazing, watering, as well as for draught and harvesting crops to tsetse high challenged areas. Moreover, previous reports also showed that higher prevalence in adult animals as compared to young animals which is believed to be due to high preference of tsetse for adult animals and less exposure of young animals to tsetse challenge as they are usually kept at homestead (Torr *et al.*, 2001; Cherenet *et al.*, 2006).

The mean PCV of parasitaemic cattle were significantly lower than that of the aparasitemic ones ($P = 0.001$) (Table 3) similar finding were reported by Afework *et al.* (2001), Muturi (1999) and Ayana *et al.* (2012). Packed cell volume has been demonstrated to be a good indicator of trypanosomal infection (Marcotty *et al.*, 2008). The aparasitemic cattle with $PCV < 24\%$ in the current

study might be either due to the low sensitivity of buffy coat techniques in chronic cases of trypanosomosis or could be due to other factors like poor nutrition and other diseases particularly parasitic diseases which cause anaemia (Afework *et al.*, 2001; Picozzi *et al.*, 2008). Moreover, the present study also revealed that 8.79% of the cattle have a PCV value in the normal range/non anaemic ($PCV \geq 24\%$) are react positively to trypanosomosis infection and this might have occurred due to recent infection with trypanosomosis. This result agree with the previous result of Garoma (2009) who conclude that cattle's having PCV value of normal range were shown to be infected with trypanosome parasite.

CONCLUSION AND RECOMMENDATIONS

In this cross-sectional study of trypanosomosis in cattle, an overall prevalence of 17.2% was observed and the high prevalence confirmed that there is continuous threat of trypanosomosis in the study area. The major species of trypanosomes identified were *T. congolense* followed by *T. vivax* and *Brucei*. According to the host risk factors, the prevalence of bovine trypanosomosis was higher in adult than in young cattle. Significantly lower mean PCV value of parasitemic animals than that of aparasitaemic animals indicates that infection with trypanosomosis negatively affects PCV profile of animals, however, PCV alone could not be used as diagnostic tool because non

anaemic/normal animals (8.79%) may also become positive for trypanosomosis infection. Therefore, the following recommendations are forwarded:

- Proper strategies have to be designed and implemented to minimize its effect of trypanosomosis on livestock production in the studied area.
- Trypanosomosis and tsetse control methods should be expanded to reach all infested areas besides participatory extension packages to create public awareness.
- Further epidemiological investigation is also a necessity to synchronize control efforts at national level.

REFERENCES

- Abebayehu T, Esthete H, Berhanu M, Rahmeto A, Solomon M (2011)**. Mechanically transmitted bovine trypanosomosis in Tselemy Woreda, Western Tigray, and Northern Ethiopia. *J. Agric.* 6(1):10-13.
- Abebe G, Jobre Y (1996)**. Trypanosomosis: A threat to cattle production in Ethiopia. *Revesta. Med. Vet.* 147:897-902.
- Afewerk Y, Clausen PH, Abebe G, Tilahun G, Mehlitz D (2000)**. Multiple-drug resistant *Trypanosoma congolense* population in village cattle of Metekel district, northwest Ethiopia. *Acta Trop.* 76:231-238.
- Afewerk Y, Clausen PH, Abebe G, Dieter M (2001)**. Appearance of multiple drug resistant trypanosome populations in village cattle of Metkel District. North West Ethiopia. Livestock community and environment. Proceedings of the 10th Conference of the Association of Institute for Tropical Veterinary Medicine. Copenhagen, Denmark, pp. 1-11.
- Assefa E, Abebe G (2001)**. Drug resistant *Trypanosoma congolense* in naturally infected donkeys in North Omo Zone, Southern Ethiopia. *Vet. Parasitol.* 99:261-271.
- Ayana M, Tesfaheywet Z, Getnet F (2012)**. A cross-sectional study on the prevalence of bovine trypanosomosis in Amhara region, Northwest Ethiopia. *Livestock Res. Rural Dev.* 24:148. Retrieved October 12, 2016.
- Behailu H, Tsedal M, Jemal A, Katckos G, Weshik R, Asere G, Haile T, Banjo A, Wasihun Z, Umode U (2011)**. Action Plan of Adaptation to Climatic Change: Gambella national regional states woredas. pp. 1-62.
- Central statistical agency, CSA (2010/2011)**. Federal democratic republic of Ethiopia central statistical agency agricultural sample survey, volume II report on livestock and livestock characteristics (private peasant holdings).
- Central statistical agency, CSA (2013/2014)**. Population and Housing Census of Ethiopia. Addis Ababa, Ethiopia.
- Cherenet T, Sani RA, Speybroeck N, Panandam JM, Nadzr S, Van den Bossche P (2006)**. A comparative longitudinal study of bovine trypanosomosis in tsetse-free and tsetse-infested zones of the Amhara Region, northwest Ethiopia. *Vet. Parasitol.* 140:251-258.
- Codjia V, Mulatu W, Majiwa PAO, d'leteren GDM, Peregrine AS (1993)**. Epidemiology of bovine trypanosomosis in the Ghibe valley, southwest Ethiopia. Occurrence of population of *Trypanosoma congolense* resistant to diminazine, isometamidium and homidium. *Acta Trop.* 53:151-163.
- D'leteren G, Authie E, Winsock N, Murry M (1998)**. Exploitation of resistance to trypanosomosis. Breeding for Disease Resistance in Farm Animals. 2nd edition of CABI publishing. Wallingford, England. pp. 195-216.
- Dagnachew Z, Shafo K (1981)**. An investigation of dourine in Arsi administrative region. *Ethiopian. Vet. Bull.* 4:3-9.
- Diallo T, Singla LD, Sumbria D, Kaur P, Bal MS (2018)**. Conventional and molecular diagnosis of haemo-protozoan infections in Cattle and equids from Republic of Guinea and India. *Indian J. Anim. Res.* 52(8):1206-1211.
- ESTC /SRVETEP (2000)**. Pilot survey on tsetse and trypanosomosis in Dembecha wereda. Amhara region, northwest Ethiopia.
- Fayisa G, Mandefro A, Hailu B, Chala G and Alemayehu G (2015)**. Epidemiological status and vector identification of bovine trypanosomosis in Didesa District of Oromia Regional State, Ethiopia. *Int. J. Food Sci. Nutr.* 4(3):373-380.
- Fimmen HO, Mehlitz D, Horchiner F, Korb E (1992)**. Colostral antibodies and *Trypanosoma congolense* infection in calves. Trypanotolerance research application. *GTZ, Germany* 116:173-187.
- Ford J, Makin MJ, Grimble RJ (1976)**. Trypanosomosis Control Program for Ethiopia. Ministry of Overseas Development of Great Britain. pp. 1-30.
- Garoma D (2009)**. The prevalence of bovine trypanosomosis in Gari settlement area of East Wollega Zone. DVM Thesis Jimma University, FVM, Jimma, Ethiopia.
- Geerts S, Holmes PH (1998)**. Drug management and parasite resistance in bovine trypanosomosis in Africa. PAAT Technical and Scientific Series, no.1, vii+31p. FAO, Rome (Italy): ISBN 92-5-104185-7.
- Gupta SK, Singla LD (2012)**. Diagnostic trends in parasitic diseases of animals. In: *Veterinary Diagnostics: Current Trends*. Gupta RP, Garg SR, Nehra V and Lather D (Eds), Satish Serial Publishing House, Delhi, pp. 81-112.
- International Laboratory for Research on Animal Diseases Reports, ILRAD (1993)**. Estimating the costs of animal trypanosomosis in Africa. ILRI, Nairobi, Kenya.
- Jemal A, Hugh-Johns ME (1995)**. Association of tsetse control with health and productivity in the Didessa valley, western Ethiopia. *Prev. Med.* 22:29-40.
- Juyal PD, Singla LD (2005)**. Towards newer approaches for diagnosis and control measures of suura (due to *Trypanosoma evansi*) in livestock. In: *Compendium of Winter School on Novel Approaches for Diagnosis and Control of Parasitic Diseases of Domestic and Wild Animals held from 07-27 October, 2005 at PAU, Ludhiana*, pp. 294-305.
- Juyal PD, Singla LD and Kaur P (2005)**. Management of surra due to *Trypanosoma evansi* in India: an overview. In: *Infectious Diseases of Domestic Animals and Zoonosis in India*, Tandon V and Dhawan BN (Eds), *Proceedings of the National Academy of Sciences India Section B: Biol. Sci.* 75(Special issue):109-120.
- Kristjanson PM, Swallow BM, Rowlands GJ, Kruska RL (1999)**. Measuring the cost of African animal trypanosomosis, the potential benefits of control and returns to research. *Agric. Syst.* 59:79-98.
- Kumela L, Delesa D, Senbeta T, Mohamed K, Mulisa M (2016)**. Prevalence of bovine trypanosomosis and vector distributions in Chewaka Settlement area of Ilubabor Zone, Southwestern Ethiopia. *Adv. Biol. Res.* 10 (2): 71-76.
- Langridge WP (1976)**. Tsetse and Trypanosomosis Survey of Ethiopia. Ministry of Overseas Department UK. pp. 1-40.
- Leak SGA (1999)**. Tsetse biology and ecology: The role in the epidemiology and control of Trypanosomosis. CAB international. Wallingford (UK), pp. 152-210.
- Marcotty T, Simukoko H, Berkvens D, Verduyck J, Praet N, Van Den Bossche P (2008)**. Evaluating the use of packed cell volume as an indicator of trypanosomal infections in cattle in eastern Zambia. *Prevent. Vet. Med.* 87:288-300.
- Muturi KS (1999)**. Epidemiology of bovine trypanosomosis in selected sites of the Southern rift valley of Ethiopia. MSc thesis, Addis Ababa University with Freie University, Berlin.
- Nicholson MJ, Butterworth MH (1986)**. A guide to condition scoring of zebu cattle. ICCA, Addis Ababa, Ethiopia.
- NTTIC (1996)**. Annual Report. Ministry of Agriculture, National Tsetse and Trypanosomosis Investigation and Control Center (NTTICC). Bedelle, Illubabor, Ethiopia. p. 29.
- Office International des Epizooties, OIE (2008)**. Trypanosomiasis (tsetse-transmitted): Terrestrial Manual. Office Internationale des Epizooties (OIE), Paris, France, pp. 22-75.
- Parashar R, Singla LD, Kaur P (2016)**. Is a typical human trypanosomosis an emerging threat to human society? : A debatable one health issue to public health experts and parasitologists. *Int. J. Vet. Sci. Res.* 2(1):036-041.
- Picozzi K, Tilly A, Fe'vere EM, Coleman P, Magona JW, Odiit M, Eisler MC, Welbum S (2002)**. The diagnosis of trypanosome infections: applications of novel technology for reducing disease risk.

- Afr. J. Biotechnol. 1:39-45.
- Radostits OM, Blood DC, Hinchcliff KW (2000).** Veterinary Medicine, A textbook of the disease of cattle, sheep, goat, pigs and horses, 9th ed. Saunders W.B. Company Ltd, London, pp. 1531-1548.
- Reid RS, Kruska RL, Wilson CJ, Perry BD (1998).** The impact of controlling tsetse fly on land-use and the environment. In: Lyman, J., Carter, S. and Reid. R.S. (Eds). Spatial and Temporal Dynamics of African Farming Systems.
- Rowlands GS, Mulatu W, Authie E, Leak SG, Peregrine A (1995).** Epidemiology of bovine trypanosomosis in the Ghibe valley, South West Ethiopia. *Acta Trop.* 53:135-150.
- Rowlands GJ, Mulatu W, Authie E, Leak SGA, Peregrine AS (1993).** Epidemiology of bovine trypanosomosis in the Ghibe valley, southwest Ethiopia. *Acta Trop.* 53:135-150.
- Slingenbergh J (1992).** Tsetse Control and Agricultural Development in Ethiopia. *Wld. Anim. Rev. (FAO)* 70-71:30-36.
- Smith BP (2009).** Trypanosomosis. In: Large Animal Internal Medicine. 4th ed, pp. 1160.
- Tamiru F, Mideksa B, Roy RK, Terfa W (2014).** Post control survey on prevalence of bovine trypanosomosis and vector distribution in Ameya District, South West Shewa, Ethiopia, *Glob. J. Med. Res.* 14(3):41-48.
- 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.
- Terzu D (2004).** Seasonal dynamics of tsetse and trypanosomosis in selected sites of Southern Nation, Nationalities and peoples Regional State, Ethiopia. Msc. thesis, Addis Ababa University, Faculty of Veterinary Medicine, Debre Zeit, Ethiopia, pp. 1-180.
- Tewelde T, Abebe G, Eisler MC, McDermott J, Greiner M, Afework Y, Kyule M, Munstermann S, Zessin KH, Clausen PH (2004).** Application of field methods to assess isometamidium resistance of trypanosomes in cattle in western Ethiopia. *Acta Trop.* 90:163.
- Tewelde N, Abebe G, Eisler M, Dermott MC, Griener J, Afework M, Kyule M, Munstermann S, Zessin KH, Clausen PH (2004).** Application of field methods to assess Isometamidium resistance of trypanosome in cattle in Western Ethiopia. *Acta Trop.* 90:163-170.
- Tilahune 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.
- Torr SJ, Wilson PJ, Schofield S, Mangwiro TN, Akber S, White BN (2001).** Application of DNA markers to identify the individual-specific host of tsetse feeding on cattle. *Med. Vet. Entomol.* 15:78-86.
- Woyessa M, Beshiri A, Yohannes M, Degneh E, Lelisa K (2014).** Bovine Trypanosomosis and Tsetse Fly Survey in Bure District, Western Ethiopia. *Acta Parasitol. Glob.* 5(2):91-97.