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Seroprevalence and Associated Risk Factors of Peste Des Petits Ruminants (PPR) in Sheep and Goats in Four Districts of Bench Maji and Kafa Zones, South West Ethiopia

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Abstract: A cross sectional study with multistage cluster sampling was employed to determine the seroprevalence and associated risk factors of peste des petits ruminants (PPR) in four districts of Bench Maji and Kafa zones from December 2016 to July 2017. A total of 968 serum samples from 96 flocks were collected and tested using Competitive ELISA. An overall apparent seroprevalence of 2.1% (95% CI= 1.2 - 3.0%) at individual animal and 18.8% (95% CI= 10.9 - 26.6%) at flock levels was recorded. A seroprevalence of 3.7% (95% CI= 1.9 - 5.5%) in Bench Maji and 0.7% (0.0 - 1.5%) in Kafa zones was recorded. The highest seroprevalence of 3.9% (95% CI= 1.5 - 6.3%) was recorded in Menit Shasha district followed by 3.4% (95% CI= 0.7 - 6.1%) in North Bench and 2.0% (95% CI= 0.1 - 4.0%) in Chena. Univariable logistic regression analysis was conducted to reduce the non-important hypothesized risk factors with a critical P-value of =0.25. Factors that were put into univariable logistic regression were age, sex, species, agro-ecology, grazing management, housing system, flock size, introduction of newly purchased sheep/goats into a flock and availability of nearby veterinary clinics. One of the potential risk factors significantly different with multivariable logistic regression analysis was flock size (P= 0.012). The odds of large-sized and medium-sized flocks of sheep and goats were 8.7 (OR= 8.730; 95% CI= 1.956 - 38.974%) and 3.7 (OR= 3.717; 95% CI= 0.605 - 22.845%) times more likely to be seropositive than small-sized flocks, respectively. In addition, the odds of introduction of newly purchased sheep/goats into a flock (P = 0.001) to be seropositive was 5.5 times (OR= 5.455; 95% CI= 2.081 - 14.303%) more likely. It was concluded that overcrowding and the practice of introducing newly purchased sheep and goats increased the disease occurrence. It is, therefore recommended that vaccination strategy needs to be practiced in the study areas to prevent the spread of PPR virus.

Key words: Peste Des Petits Ruminants · Seroprevalence · Risk Factors · Sheep · Goats · Bench Maji · Kafa

INTRODUCTION

Peste des petits ruminant (PPR) is an acute, highly contagious and economically important trans-boundary viral disease of goats and sheep, which is listed by the world organization for animal health (OIE) as notifiable disease. The disease is characterized clinically by severe pyrexia, oculo-nasal discharge, necrotizing and erosive stomatitis, enteritis and pneumonia [1, 2].

Peste des petits ruminant is caused by peste des petits ruminants virus (PPRV). The virus is a member of the genus *Morbillivirus* in the family Paramyxoviridae. Virions are pleomorphic in nature, varying between 130-390 nm in diameter. PPRV has a non-segmented, single-strand RNA genome of 15,948 nucleotides that encodes eight proteins including six structural proteins namely the nucleoprotein (N), the phosphoprotein (P), the matrix protein (M), the fusion protein (F), the haemagglutinin protein (H) and the large polymerase protein (L) and two nonstructural proteins V and C; in the order 3´-N-P(C/V)-M-F-H-L-5´ [3]. Four genetic lineages (I-IV) and a number of viral strains have been identified. Lineage IV viruses have become especially prevalent in recent years. The virus is closely related to rinderpest virus, which has been eradicated globally [4].

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PPR was first described in Ivory Coast in 1942 and considered to be confined to West Africa but later it was described throughout Africa south of the Sahara and north of the equator, as well as the Middle East and Asia. This area encompasses much of the developing world that relies heavily on subsistence farming to supply food or goods for trade and small ruminants provide an excellent supply of both. With its associated high morbidity and mortality, PPRV constitutes one of the major obstacles to subsistence farming [5, 6].

Peste des petits ruminants was clinically suspected for the first time in Ethiopia in 1977 in a goat herd in the Afar region, east of the country. Later clinical and serological evidence of its presence has been reported and confirmed in 1991 from an outbreak in a holding near Addis Ababa [7, 8]. Few studies have been conducted to show PPR is circulating in Ethiopia [9-12].

Ethiopia has an estimated number of 28,892,380 sheep and 29,704,958 goat populations [13]. According to the report of Central Statistics Authority of Ethiopia [13], there are 465,734 sheep and 268,713 goats in Kafa zone; and 159,065 sheep and 87,314 goats in Bench Maji zone. This study aimed at investigating seroprevalence and associated risk factors of PPR in these areas.

MATERIALS AND METHODS

The study was conducted from December 2016 to July 2017 in selected districts of Kafa and Bench Maji zones, Southern Nations Nationalities and Peoples Region (SNNPR). Chena and Bita districts from Kafa zone and Menit Shasha and Semen Bench districts from Bench Maji zone were selected to conduct this study.

Study Animals: There are 465,734 sheep and 268,713 goats in Kafa zone and 159,065 sheep and 87,314 goats in Bench Maji zone [13] that constitute the target population. The study population was sheep and goats that are found in 4 selected study districts; and the study units were unvaccinated sheep and goats that are more than six months included in the sample. Sheep and goats which are adapted to the study areas are classified under Bonga breed [14, 15].

Study Design and Sampling Strategy: A cross sectional study design with multistage cluster sampling was employed in this study with hierarchical stages (Zone, District, PA and Village) to reach to the sampling units. Clustering was made on PAs into different villages and a village was considered as one flock of sheep/goats (single-level clusters) that share common grazing areas and watering points. Two zones were selected purposively based on sheep and goat population and different agro-ecological aspects while four districts were selected randomly. Twenty PAs and a total of ninety six flocks were selected conveniently based on road access from which ten sheep/goats were sampled randomly from willing owners.

Sample Size Determination: The sample size was determined using the formula described by Thrusfield [16] considering a conservative prevalence of 50% and an absolute precision of 5% with 95% confidence interval (CI). The formula is given by:

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

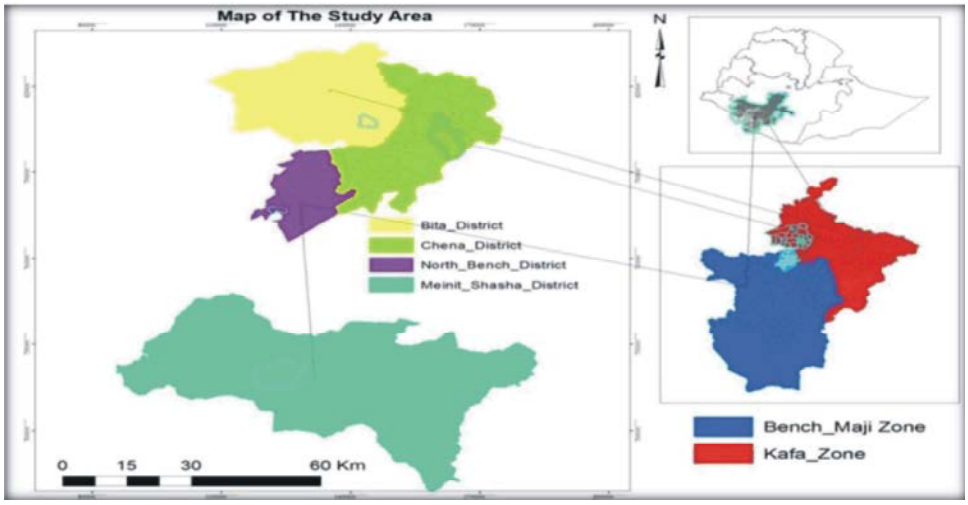

Fig. 1: Map of the study area

where:
n = Sample size; d = Desired Absolute Precision = P_{exp}= Expected Prevalence

Substituting each value gives n = 384. Since two separate populations (sheep and goats) were considered, the sample size was doubled (i.e. 768). It was recalculated to get a closer accuracy with that of simple random sampling by considering the design effect (cluster effect). The design effect was calculated by using the intra-cluster correlation coefficient (rho= ρ) which is a measure of correlation of observations in a cluster.

Design effect = 1+ ρ (m - 1);

where "m" is number of individuals sampled per cluster and a flock of sheep/goats in one village was considered as a cluster and approximately 10 animals were sampled from each selected cluster. Rho of 0.029 was used which was obtained from the national survey of PPR in 1999 in Ethiopia [9].

Design effect = 1 + 0.029 (10-1) = 1.261

The new sample size (n') was calculated by multiplying n(=768) by the design effect [19]. i.e. n'= n x Design effect. Therefore, n' = 768x1.261= 968

Sampling with probabilities proportional to number of small ruminants in each district was used to determine the number of small ruminants to be included in the study in each district and PA [17]. Similarly, the number of villages and PAs was proportionally allocated per each district.

Sample Collection Procedures: About 5ml of blood was collected directly from jugular vein of sheep and goats by venipuncture using plain vacutainer tubes and sterile needles. Then, an identification code was given to each sample and labeled appropriately. The blood samples were allowed to stand in slant position overnight at room temperature to allow serum separation. Clear straw-colored serum was decanted into 2ml cryovials and labeled accordingly and kept in refrigerator until arrival to Mizan Regional Veterinary Laboratory Center and stored at deep freezer (-20°C). Serum samples were shipped to National Animal Health Diagnostic and Investigation Center (NAHDIC) laboratory by keeping the cold chain and analyzed there using competitive enzyme linked immuno-sorbent assay (C-ELISA) (collectively produced by ID.vet innovative diagnostics, France)according to the instructions of the manufacturer.

Competitive ELISA

Test Principle: The PPR competitive ELISA kit (collectively produced by ID.vet innovative diagnostics, France) was used for the test. The test is based on the competition between the anti-H protein of PPR virus monoclonal antibodies (MAb) and specific immunoglobulin in serum samples for binding the PPR antigen. The presence of antibodies to PPR virus in the serum samples blocks reactivity of the monoclonal antibodies which causes reduction in the expected color following the addition of enzyme labeled anti-mouse conjugate and chromogen solution.

Test Procedure: All reagents were allowed to come to room temperature (21°C ±5°C) before use. All reagents were homogenized by vortex/inversion. 25µl dilution buffer 13 was added to each well. 25µl of positive control (PC) was added to A1 and B1. 25µl of negative control (NC) was added to wells C1 and D1. 25µl of each sample to be tested was added to the remaining wells. The prepared plate was incubated for 45min ±4min at 37°C±3°C. Each well was washed 3 times with approximately 300µl of the wash solution by avoiding drying of wells between each washing. Conjugate 1x was prepared by diluting the conjugate 10x to 1/10 in dilution buffer 4. Then 100µl of conjugate 1x was added to each well. The prepared plate was incubated for 30min±3min at 21°C± 5°C. Each well was washed 3 times with approximately 300µl of the wash solution by avoiding drying of wells between each washing. 100µl of substrate solution was added to each well. The prepared plate was incubated for 15min±2min at 21°C±5°C in the dark. 100µl of stop solution was added to each well in order to stop the reaction. The optical density (OD) was read and recorded at 450 nm

For each sample, the competition percentage of sample (S) per negative control (N) (S/N %): $\frac{S}{N}\% = \frac{OD_{Sample}}{OD_{Negativecontrol}}$ was calculated. Then, ≤50% was considered as Positive, 50% < S/N <60% as Doubtful and S/N ≥%60% Negative.

Data Collection: Animal health and production professionals working in the study areas and district agricultural offices provided relevant information. Sampling frame of study villages was found from administrative unit of each selected peasant association (PA). Data on housing system, whether animal owners recently introduced newly purchased animals into a flock during the last 6 months and flock size was collected.

The number of sheep and goats farmers own was categorized as small size (<10 sheep/goats), medium size (10-20 sheep/goats) and large size (>20 sheep/goats). Additionally, data on other factors such as species, age, sex, availability of nearby veterinary clinics in the PA, altitude and grazing management system was collected during sample collection. Age of sheep and goats was recorded using dentition, physical observation and asking the owners. The age was then categorized as young (6-12 months), adult (12-36 months) and old (>36 months). According to agro-altitudinal and agro-climatology classification of Ethiopia, lowland falls between 500 and 1,500, midland falls between 1,500 and 2,300 and highland falls between 2,300 and 3,200 meter above sea level [18].

Data Management and Analysis: Data were entered into MS excel spread sheet 2016 program, coded and transferred to Statistical Package for Social Sciences (SPSS) version 20 (SPSS Inc., Chicago, Illinois, USA). Overall apparent seroprevalence was calculated by dividing the number of seropositive samples to the total number of animals sampled [16]. The formula is given by:

$$\text{Apparent prevalence} = \frac{\text{Seropositive samples}}{\text{Total number of animals sampled}} \text{x100}$$

Per each risk factor, proportion of seropositivity was calculated. Confidence interval for proportions was calculated using Epi-Info online software (version 3.5.1., CDC). The apparent prevalence (Ap) was adjusted for the sensitivity (Se) and specificity (Sp) of C-ELISA (94.5% and 99.4%, respectively) [18] to get the true prevalence by the formula:

$$\text{True Prevalence} = \frac{AP + Sp - 1}{Se + Sp - 1} \text{x100}$$

To calculate the flock level prevalence, a village was considered as a flock:

$$\text{Flock Level Prevalence} = \frac{\text{Number of positive flocks with at least one infected animal}}{\text{Total number of flocks sampled}} \text{x100}$$

Univariable logistic regression analysis for the proportions was carried out to reduce the non-important hypothesized risk factors with P =0.25. Multi-collinearity of risk factors was checked. This was further tested by multivariable logistic regression analysis for final conclusion with a probability predictive limit of less than 5% (P <0.05). Odds ratio (OR) was used to associate the statistical strength of PPR seropositivity with different potential risk factors. The interaction effect of significant risk factors in the multivariable logistic regression analysis was also assessed. Model fitness was assessed using Hosmer-Lemeshow goodness of test (P value >0.05).

RESULTS

Overall Seroprevalence of PPR in Bench Maji and Kafa Zones: A total of 968 serum samples (487 sheep and 481 goats) were collected and tested by C-ELISA. An overall apparent seroprevalence of 2.1% (95% CI= 1.2-3.0%) was recorded.

Seroprevalence of PPR at the Level of District and Peasant Associations (PAs): At the level of district, the highest seroprevalence was recorded in Menit Shasha district followed by North Bench and Chena districts.

Flock Level Prevalence of PPR in Sheep and Goats in the Study Villages: An overall flock level seroprevalence was 18.8% (95% CI= 10.9 - 26.6%) assuming that antibody was detected at least from one flock (in this study antibody was detected from 18 flocks out of 96).

Species-wise Seroprevalence of PPR using C-ELISA in the Study Areas: A total of 487 sheep and 481 goats were sampled and an apparent prevalence of 1.8% and 2.3% was recorded, respectively. A seroprevalence of 4.5% (95% CI= 1.5 - 7.6%) in sheep and 3.2% (95% CI= 1.0 - 5.3%) in goats was recorded in Bench Maji zone. In Kafa zone, a seroprevalence of 0.3% (95% CI= 0 - 1.8%) in sheep and 1.3% (95% CI= 0.3 - 3.8%) in goats was recorded.

Risk Factors for Ppr Seropositivity in Sheep and Goats Univariable Logistic Regression Analysis for the Occurrence of PPR: Univariable logistic regression was used to reduce the non-important hypothesized potential risk factors. To help this exclusion of risk factors from the model, a critical p-value of ≥0.25 was used i.e. those factors having p-value of ≥0.25 were excluded from forward multivariable logistic regression analysis. Factors excluded from the model using univariable logistic regression analysis were species, sex, housing system and availability of nearby veterinary clinics in the PA. Overall, age, flock size, grazing management, introduction

Table 1: Overall seroprevalence of PPR in sheep and goats in Bench Maji and Kafa zones

Zone	Number of tested samples	Positive samples	Apparent prevalence in % (C.I. 95)	True Prevalence in %
Bench Maji	429	16	3.7 (1.9 - 5.5)	3.3
Kafa	539	4	0.7 (0.0 - 1.5)	0.1
Overall	968	20	2.1 (1.2 - 3.0)	1.6

Table 2: Seroprevalence of PPR of sheep and goats in study districts and PAs

District (Wereda)	PA (Kebele)	Tested samples	Positive samples	Apparent prevalence in % (95% CI)	True prevalence in %
Menit Shasha	-	254	10	3.9 (1.5 - 6.3)	3.5
	Bass	64	2	3.1 (0.4- 10.8)	
	Jemu	64	5	7.8 (1.2 - 14.4)	
	Boat	64	2	3.1(0.4- 10.8)	
	Tuyi	62	1	1.6 (0- 8.4)	
North Bench	-	175	6	3.4 (0.7 - 6.1)	3.0
	Genja	35	1	2.9 (0 - 14.9)	
	Tsat	35	2	5.7 (0.7- 19.2)	
	Bir	35	1	2.9 (0 - 14.9)	
	Dizu	35	2	5.7 (0.7- 19.2)	
	Gacheb	35	0	-	
Chena	-	197	4	2.0 (0.1 - 4.0)	1.5
	Agaro	28	2	7.1 (0.9 - 23.5)	
	Bobabela	28	1	3.6 (0.1 - 18.3)	
	Kutashoray	29	1	3.4 (0.1- 17.8)	
Bita	-	342	0	0	0

Table 3: Flock prevalence of PPR in the study areas

Zone	District	Number of flocks sampled	Positive flocks	Flock Level Prevalence in % (95% CI)
Bench Maji	Menit Shasha	24	9	37.5 (18.1 - 56.9)
	North Bench	15	5	33.3 (9.5 - 57.2)
	Zone Sub-total	39	14	35.9 (20.8 - 51.0)
Kafa	Chena	21	4	19.0 (2.3 - 35.8)
	Bita	36	0	0
	Zone Sub-total	57	4	7.0 (0.4 - 13.6)
Overall	96	18	18.8 (10.9 - 26.6)	

Table 4: Species-wise seroprevalence of PPR in Bench Maji and Kafa zones of Ethiopia

		Sheep (n=487)			Goats (n=481)		
Zone	District	Tested samples	Positive samples	Prevalence in % (95% CI)	Tested samples	Positive samples	Prevalence in % (95% CI)
Bench Maji	Menit Shasha	72	4	5.6 (0.3 - 10.8)	182	6	3.3 (0.7 - 5.9)
	North Bench	105	4	3.8 (0.1 - 7.5)	70	2	3.4 (0.3 - 9.9)
	Zone Sub-total	177	8	4.5 (1.5 - 7.6)	252	8	3.2 (1.0 - 5.3)
Kafa	Chena	98	1	1.0 (0 - 5.6)	99	3	3.0 (0.6 - 8.6)
	Bita	212	0	0	130	0	0
	Zone Sub-total	310	1	0.3 (0 - 1.8)	229	3	1.3 (0.3 - 3.8)
Overall	487	9	1.8 (0.7 - 3.0)	481	11	(1.0 - 3.6)	

of newly purchased sheep/goat into the flock during the last 6 months and agroecology were factors which had P-value less than the critical value and moved forward for multivariable logistic regression analysis. Accordingly, univariable logistic regression analysis identified age (P=0.006), flock size (P=0.006), grazing management (P=0.010), introduction of newly purchased sheep/goats into a flock during the last 6 months (P=0.000) and agro-ecology (P=0.020) as statistically significantly associated risk factors with PPR seropositivity

Multivariable Logistic Regression Analysis of Risk Factors for the Occurrence of PPR: Multivariable logistic regression analysis was conducted with factors less than the critical p-value set in univariable analysis. Based on this, flock size (P=0.012) and introduction of newly purchased sheep/goat into the flock during the last 6 months (0.001) were statistically significantly associated risk factors for the occurrence and distribution of PPR.

Table 5: Overall univariable logistic regression analysis of risk factors for PPR seropositivity

Variables	Category	Tested samples	Positives	Prevalence in % (95% CI)	Odds Ratio (95% CI)	P-value
Species	Caprine	481	11	2.3 (1.0 - 3.6)	1.243(0.510 - 3.027)	0.632
	Ovine (ref)	487	9	1.8 (0.7 - 3.0)		
Age	Young	254	12	4.7 (2.1 - 7.3)	3.149 (1.002 - 9.897)	0.006
	Adult	456	4	0.9 (0.0 - 1.7)	0.562 (0.139 - 2.266)	
	Old (ref)	258	4	1.6 (0.0 - 3.1)		
Sex	Female	545	12	2.2 (1.0 - 3.4)	1.168 (0.473 - 2.883)	0.736
	Male (ref)	423	8	1.9 (0.6 - 3.2)		
Flock size	Small (ref)	419	2	0.5 (0.1 - 1.7)		
	Medium	195	3	1.5 (0.3 – 4.4)	3.258 (0.540 - 19.656)	0.006
	Large	354	15	4.2 (2.1 - 6.3)	9.226 (2.095 - 40.623)	
Grazing management	Communal	516	17	3.3 (1.8 - 4.8)	5.099 (1.484 - 17.514)	0.010
	Private (ref)	452	3	0.7 (0.1 - 1.9)		
Housing system	Housed	758	16	2.1 (1.1 - 3.1)	1.111 (0.367 - 3.358)	0.853
	Fenced (ref)	210	4	1.9 (0.1 - 3.8)		
Introduced new animal	Yes	93	8	8.6 (2.9 - 14.3)	6.769 (2.692 - 17.017)	0.000
	No (ref)	875	12	1.4 (0.6 - 2.1)		
Available vet. clinic	Present	658	15	2.3 (1.1 - 3.4)	1.409 (0.508 - 3.913)	0.510
	Absent (ref)	310	5	1.6 (0.2 - 3.0)		
Agro-ecology	Lowland	254	10	3.9 (1.5 - 6.3)	1.117 (0.343 - 3.639)	0.020
	Midland	601	6	1.0 (0.2 - 1.8)	0.275 (0.076 - 0.990)	
	Highland (ref)	113	4	3.5 (0.1 - 6.9)		

Table 6: Final multivariable logistic regression model output of factors associated with PPR seropositivity in sheep and goats (n=968) from Bench Maji and Kafa zone, SNNPR, Ethiopia

Variables	Category	Odds Ratio (95% CI)	P value
Flock size	Small (ref)	-	
	Medium	3.717 (0.605 - 22.845)	0.012
	Large	8.730 (1.956 - 38.974)	
Introduced new animal	No (ref)	-	
	Yes	5.455 (2.081 - 14.303)	0.001
Constant		0.03	0.000

DISCUSSION

The overall seroprevalence of this study (2.1%) agrees with the seroprevalence of 1.7% found in Oromia and 1.8% in Southern Nations Nationalities and Peoples Region (SNNPR) which was reported by Waret-Szkuta *et al.* [9]. However, it is lower than the report of Kifle and Tsegaw [10] in Metema district of Amhara region (26.3%), Megersa *et al.* [20] in Gambella region (27.3%), Biruk [11] in Amhara region (28.1%) and Wondemagegn [21] in Somali region (41%). In contrast to this result, higher overall seroprevalence was recorded in other African and Asian countries like 43.3% in Pakistan [22], 45.8% in Tanzania [23], 45.0% in Republic of Niger [24], 54.9% in Nigeria [25], 67.9% in India [26], 45.6% in Sudan [27], 23.2% in Nigeria [28] and 38.2% in Saudi Arabia [29].

The seroprevalence in the current study area is low (2.1%) and the differences with other areas can be explained by sample size difference, geographical and seasonal effects, host population density, disease control programs, the social environment that can influence the contact rates and husbandry practices [21,30- 34].

In the current study, the overall flock level seroprevalence of 18.8% (95% CI=10.9% - 26.6%) was recorded assuming that antibody against PPRV was detected at least in one flock (Table 3). The current overall flock level prevalence is much lower than the prevalence of 96.9% (22/23) and 100% (9/9) which was found by Megersa *et al.* [20] in Gambella and Afar regions of Ethiopia, respectively.

An overall true prevalence at individual animal and flock level was 1.6% and 19.4%, respectively. This finding was very low compared to true prevalence of 43% at animal and 104% at flock level found by Wondimagegn [21] in Somali region. The true prevalence of 1.3% in sheep and 1.8% in goats is lower than 29% and 49%, respectively, found in Jordan [35] and 23.9% and 22.9% found in Nigeria [28]. At species level, the flock level

prevalence in sheep was calculated to be 8.3% (antibodies were detected from 8 flocks out of 96) whereas in goats, flock-level prevalence of 10.4% was recorded (antibody detected from 10 flocks out of 96). The flock level true prevalence in sheep and goats was 8.2% and 10.4%, respectively. This finding is also much lower than the flock level true prevalence of 60% in sheep and 74% in goats recorded in Jordan [35].

The seroprevalence of 1.8% (Table 4) of the current finding in sheep is lower than the previous report of 13.0% by Abraham *et al.* [31] in pastoral areas of Ethiopia (Afar, East Shewa, Jigjiga, Borena and Gambella), 26.9% by Biruk [11] in Eastern Amhara region and 39.0% by Wondemagegn [21] in Somali region. Apart from Ethiopia, higher seroprevalence was reported in sheep than the result of the current study in other countries (using C-ELISA): Pakistan: 51.3% [22], 28.8% [36], 51.5% [37] and 37.2% [38]; Saudi Arabia: 33.2% [29]; Republic of Niger: 42.0% [24]; India: 41.4% [32] and 65.3% [26]; Nigeria: 73.2% [25], 19.4% [39] and 23.9% [28]; Tanzania: 39.8% [23]; Sudan: 43.7% [33]and 62.9% [27] and Kenya: 32.0% [40].

A seroprevalence of 2.3% found in goats in the current study (Table 4) is lower than a previous study conducted by Berihun *et al.* [12] in Tigray region of Ethiopia (47.5%). A study conducted in goats in India indicated higher seroprevalence of 13.2% [41]. Higher seroprevalence was reported by different authors (using C-ELISA): in Pakistan: 39.0% by Khan *et al*. [22], 34.8% by Rashid *et al*. [36], 46.5% by Jalees *et al*. [37] and 82.7% by Nizamani *et al*. [38]; in Niger: 47.9% by Farougou *et al*. [24]; in India: 34.9% by Raghavendra *et al.* [32] and 70.4% by Saritha *et al*. [26]; in Nigeria: 50.4% by El-Yuguda *et al*.[25], 22.9% by Bello *et al.* [39]and 73.8% by Woma *et al.* [28]; in Tanzania: 49.5% by Swai *et al*. [23]; in Sudan: 59.7% by Abdalla *et al*.[33] and 47.9% by Salih *et al.* [27]and in Kenya: 40.0% by Kihu *et al*. [40].

Slightly higher prevalence of PPR in goats (2.3%) than sheep (1.8%) of this study agrees with the finding of other reports [9, 23, 26, 29,36, 40, 42]. On the other hand, this finding is in contrast to the report of Abraham *et al*. [31], Khan *et al.* [22], Raghavendra *et al*.[32], Abdalla *et al*. [33], El-Yuguda *et al.* [25], Jalees *et al.* [37] and Woma *et al*. [28], who reported higher seroprevalence in sheep than goats.

The patho-physiology of species-wise difference in seroprevalence remains unclear. Higher recovery rate (lower case fatality rate) and/or a greater longevity of sheep compared with goats have been observed [22, 29, 32, 43]. In other studies, goats showed greater susceptibility to infection with PPRV while recovery rate of goats to infection is considerably less than that of sheep [44, 45]. In a PPR outbreak in Turkey of PPR, goats remained unaffected [46]. Breed susceptibility differences in sheep and goats in different parts of infected areas were reported [27, 37, 47- 49]. In one experimental study conducted by Diop *et al*. [50] different breeds of goats have been shown to respond differently to infection with the same virus strain.

With respect to the age of sheep and goats, young age category showed the highest prevalence (Table 5). This finding is in line with Saker and Islam [48] and Bello [39]. To the contrary, the result disagrees with the report of Singh [30], Waret-Szkuta [9], El-Yuguda[25], Nizamani [38] and De [51] who found more seropositivity in adult and above age groups. Susceptibility in young age groups might be due to the decline of maternal antibodies and nutritional related factors [39].

With respect to the sex of sheep and goats, PPR seroprevalence of 2.2% (95% CI= 1.0% - 3.4%) found in females was slightly higher than the prevalence of 1.8% (95% CI= 0.6% - 3.2%) in males (Table 5). This finding agrees with the reports of Waret-Szkuta [9], Megersa [20], Farougou [24], Salih [27], Bello [39] and Shuaib [52]. This finding disagrees with the reports of Saker and Islam [48], Subir and Hemayeatul [53] and Nizamani [38]. Females are more susceptible to PPR may be the fact that they are usually kept longer in a flock for the breeding purposes while males are either sold out or slaughtered for meat purposes. Additionally, this may be due to when females become pregnant and lambing/kidding, the immunity status becomes lowered as a result their ability to resist the challenge of the infection will be low [52, 54, 55].

This study showed slightly higher PPR prevalence than private land grazing (or tethering) (Table 5). This finding agrees with Salih [27]. This can be due to vulnerability of small ruminant flocks for infection since open communal grazing systems infect pastures and watering points [27, 52]. In contrast to this, Mahmudul [56] reported non-grazing small ruminants showed higher seroprevalence. Although PPRV survives in the environment for short period of time, regular and continuous use of grazing pastures might have facilitated the exchange/transmission of the virus among small ruminant flocks. Although droplets containing virus particles in the expired air is the main route, oral transmission is possible by contact with secretions or excretions (saliva, feces, urine, vaginal, nasal or ocular discharges) of infected animals [57- 59].

Concerning the housing system of herders, using house for small ruminants during day and/or night for shading showed higher seroprevalence than those kept in open fence (Table 5). Herders construct fences under trees or bushes in front of the main house hold residence for the purpose of barn. This could be explained by when small ruminants congregate in a house barn can aggravate transmission of the virus since close contact with an infected animal facilitates virus transmission [4].

As to the agro-ecology of study sites lowland agroecology showed the highest seroprevalence (Table 5). The finding of this study agrees with the report of Waret-Szkuta [9]. Saritha [26] and Nizamani [38] also reported varying seroprevalence in different agro-climatic zones of India and Pakistan, respectively. Wondimagegn [21] reported higher seroprevalence of PPR in lowland areas of Somali region. This could be due to different production systems with exchanges and movements in areas of lowland being more frequent and involving larger numbers of animals. In Ethiopia small ruminants mainly thrive on free range pasture lands, shrubs and forest grounds. Agro-climatic conditions influence the availability of these resources and the movement of animals becomes necessary in order to ensure the provision of fodder and water. This is particularly important during the dry season and in low altitude areas where resources are scarce [9].

This study revealed the highest seroprevalence) in large-sized flocks (Table 5). This finding is in agreement with Munir [60] and Selvaraju [34] but disagrees with Shuaib [52]. Multivariable logistic regression showed flock size was statistically significant (P=0.012). Large-sized flocks of sheep and goats were 8.7 times at risk of getting PPR infection with increased stocking density (OR= 8.730; 95% CI= 1.956% - 38.974%). The odds of medium-sized flocks of sheep and goats to be seropositive was 3.7 more likely (OR= 3.717; 95% CI= 0.605% - 22.845%) than small flocks (Table 6). This finding is in agreement with Al-Majali [35] while in contrast to Wondimagegn [21]. This could be explained by the increased number of sheep and/or goats (overcrowding) might have increased the transmission of the virus due to the contagious nature of PPRV [4, 28].

This study showed introduction of newly purchased sheep/goat into a flock during the last 6 months revealed higher seroprevalence of 8.6% (8/93; 95% CI= 2.9% - 14.3%) (Table 5). This finding is in contrast to the report of Shuaib [52] in Sudan. The final multivariable logistic regression analysis showed that the likelihood of being seropositive for PPR for newly introduced sheep/goats had 5.5 times more chance than home-borne (OR= 5.455; 95% CI = 2.081% - 14.303%) and this practice was a potential risk factor for the occurrence of PPR (P=0.001) (Table 6). These results are in agreement with the report of Biruk (11) and Wondimagegn [21]. This might be due to farmers do not seek veterinary support before mixing newly purchased sheep and/or goats into the existing flock [4]. The climate change which affected most areas of Ethiopia in the recent was also a problem in some South Western parts of the study areas. This forced sheep and goat herders to sell their animals to escape the shortage of feed and water although other farmers have been increasing their flock size. After buying in animals, owners do not practice separating new comers from existing flock to prevent the spread of animal diseases and those who have large flock size give more attention for the number other than the health status of their animals. Animals including sheep and goats are taken to market and brought to home on foot crossing long distances. During this stress time the animals become susceptible for different infections. This may be explained by the fact that when sheep and goats from different origins come together in one market place and there might be interactions and spread of the virus. Consequently, they come home carrying the virus and play a role in the disease transmission [4, 22, 60, 61].

CONCLUSION

The present study was undertaken with the objective of determining the seroprevalence and investigation of the associated risk factors of PPRV. In general, the difference among comparable values was not wide but slight differences were observed. Based on the results of the current study, the overall seroprevalence (2.1%) was scarce but the study showed that the PPRV infection has been circulating in the study area due to natural infection. The estimated flock level prevalence was 18.8% by considering at least one infected animal in one flock. The disease was found to be slightly more prevalent in Bench Maji than Kafa zone. Infection with PPRV was demonstrated in three districts but not in Bita district. The current study has indicated seroprevalence of PPRV in goats was slightly higher than that of sheep. The study showed overcrowding and the practice of introducing newly purchased sheep and goats increased the disease occurrence and therefore, these factors were identified as the risk factors or predictors for the occurrence and distribution of PPR infection. Therefore, vaccination needs to be practiced to prevent the spread of the PPR virus.

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