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# Seroprevalence and risk factors associated with peste des petits ruminants in goats from Sokoto, Northwestern Nigeria

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**ABSTRACT:** Peste des Petits Ruminants (PPR) is a highly contagious viral disease affecting small ruminants, with significant socio-economic impacts in Nigeria and other endemic regions. The study was carried out to determine the seroprevalence and risk factors associated with PPR in Sokoto, Nigeria. A total of 304 goat serum samples were collected from herds and the Sokoto main abattoir between August 2023 and May 2024. Samples were stratified by sex, age, breed, location, and season. Antibodies against the PPR virus were screened using a competitive ELISA (Idvet®), and data were analysed using chi-square and binary logistic regression analysis to identify associations and differences between risk factors and seroprevalence. Out of 304 samples, 91 tested positive, resulting in an overall seroprevalence of 29.9%. Prevalence varied by sex, breed, location, age and season. Seasonal and breed variations were significantly associated with PPR seropositivity ($p < 0.05$), with the highest prevalence observed during the dry season, followed by the harmattan and rainy seasons. The study confirms that PPR remains endemic among goats in Sokoto State, with a substantial proportion of animals exposed. Although sex, location, and age were not significant risk factors, the seasonal and breed effects highlight the importance of environmental factors and breed differences in disease transmission. These findings emphasise the urgent need to strengthen vaccination campaigns, especially before and during high-risk seasons, and to improve surveillance programs, as these measures are vital for reducing PPR's burden and contributing toward the global eradication target by 2030.

**Keywords:** Epidemiological determinants, seasonal variation, serological survey, small ruminants.

## INTRODUCTION

Peste des Petits Ruminants (PPR) is a highly contagious, frequently deadly transboundary viral disease of sheep and goats with significant economic consequences in the global livestock industry. The disease affects wild ungulates from the families *Gazellinae, Caprinae, and Hippotraginae* and is particularly severe in sheep and goats, leading to nearly 90% morbidity and 100% mortality in unvaccinated flocks (Abdalla *et al.,* 2012). The disease has also been observed in camels, cattle, and buffaloes presented as subclinical or clinical infections in some cases (Khalafalla *et al.,* 2010; Kwiatek *et al.,* 2011).

The disease is endemic in Nigeria, confirmed by different serological and molecular investigations showing widespread virus circulation in small ruminant populations and repeated outbreak reports (Woma *et al.,* 2016; Esonu *et al.,* 2022). Molecular surveillance has demonstrated the presence and co-circulation of multiple PPRV lineages in West Africa (Woma *et al.,* 2015; Mantip *et al.,* 2022). Reviews and national surveys emphasise that transhumance, trade, and porous borders drive frequent

cross-border virus movement between Nigeria and neighbouring countries, emphasising the need for coordinated surveillance and targeted vaccination campaigns across the West African livestock network (Tounkara *et al.,* 2021; Esonu *et al.,* 2022).

The aetiology of the disease, PPR virus (PPRV), is an extremely pleomorphic enveloped RNA virus that belongs to the family *Paramyxoviridae* in the genus morbillivirus. The virus shares genetic ancestry with the viruses that cause rinderpest, canine distemper, measles, and dolphin distemper. The genome of PPRV is approximately 15.9kb negative-stranded RNA encoding nucleoprotein (N), phosphoprotein (P), matrix protein (M), fusion protein (F), hemagglutinin protein (H), and large protein (L) (Bailey *et al.,* 2005). These are often used to classify PPRV isolates into various lineages. To date, four lineages have been discovered and epidemiologically linked to the geographic spread of PPRV. Interestingly, lineage IV, which emerged in new hosts and geographical areas, has higher evolutionary adaptation to sheep and goats than the other three lineages (Munir, 2014).

Transmission of PPRV occurs primarily via aerosolised droplets through direct contact with infected animals, particularly during close congregation in markets, shared water points, or seasonal movements. The virus is shed in nasal and ocular secretions, saliva, faeces, and urine of infected animals, and contaminated fomites may also play a role in mechanical transmission. Environmental and seasonal factors, such as cold and dry periods, may enhance virus stability and facilitate outbreaks in endemic areas (Diallo, 2006).

Outbreaks of PPR have been associated with the identification of PPR virus (PPRV) antigen by antigen-detection enzyme-linked immunosorbent assays (ELISAs), antibodies by antibody-detection ELISAs, and PPRV RNA by reverse transcription polymerase chain reaction (RT-PCR).

Diagnosis of PPR involves a combination of clinical observation, serological testing, and molecular techniques. Antigen-capture ELISA, competitive ELISA (c-ELISA) for antibody detection, and reverse transcription polymerase chain reaction (RT-PCR) are widely employed for surveillance and confirmation of infection (Couacy-Hymann *et al.,* 2002; Libeau *et al.,* 2014).

PPR is characterised by high fever, nasal and ocular discharges, and severe stomatitis, which are critical for initial diagnosis (Mahmoud *et al.,* 2022). The disease can lead to high mortality rates, reaching up to 90%, emphasising the need for prompt diagnosis (Niedbalski *et al.,* 2021). c-ELISA is widely used for antibody detection, providing a reliable method for identifying PPRV exposure in small ruminants (Michael *et al.,* 2017). RT-PCR is a highly sensitive method for detecting PPRV RNA, allowing for rapid diagnosis from clinical samples (Abdel-Rady, 2022).

Following the global eradication of rinderpest, PPR was identified by the Food and Agriculture Organisation (FAO) and the World Organisation for Animal Health (WOAH, formerly OIE) as the next priority disease for eradication. A global strategy for the control and eradication of PPR was launched in 2015, targeting elimination by 2030 (FAO and OIE, 2016). Effective live attenuated vaccines are available, significantly aiding control efforts (Vinayagamurthy, 2017). Vaccination is crucial for reducing morbidity and mortality rates, which can reach up to 70% in affected populations (Diallo *et al.,* 2019).

Improved veterinary infrastructure is essential for timely disease reporting and response (Niedbalski *et al.,* 2022). Training and resources for local veterinarians enhance disease management capabilities (Njeumi *et al.,* 2020). Enhanced epidemiological studies can inform targeted vaccination strategies and control measures (Bodjo *et al.,* 2024).

While the eradication of PPR presents significant challenges, including resource mobilisation and socio-economic impacts, the potential benefits for food security and poverty alleviation in vulnerable communities show the importance of this initiative (Njeumi *et al.,* 2020; Niedbalski *et al.,* 2022).

Goats and sheep, which serve as the primary hosts, are particularly vulnerable, and outbreaks often result in high morbidity and mortality, devastating the livelihoods of smallholder farmers who rely heavily on these animals for income, nutrition, and cultural value. Given PPRV's potential to affect a range of vulnerable hosts, it is imperative to strengthen disease control measures to prevent transmission. Since sheep and goats are easily transported and border trade is difficult to regulate in Nigeria, there is a high risk that this disease may spread across borders.

PPR results in the death of livestock that is heavily relied upon by poor people in developing countries, which poses a threat to food security and worldwide trade of livestock and livestock products (Gifford-Gonzalez, 2017). Economically, PPR imposes a heavy burden by reducing productivity through loss of meat, milk, hides, and market value, thereby worsening poverty among resource-poor communities. At the global level, persistence of the disease in endemic hotspots like Sokoto poses a threat to the FAO/OIE target of eradicating PPR by 2030.

Despite the recognised importance of PPR, there remains limited up-to-date information on the current prevalence and associated risk factors in goats within Sokoto. This knowledge gap hinders the development of targeted control and vaccination programs. At the policy level, the FAO and OIE have set a goal for the global eradication of PPR by 2030. Achieving this target will require countries like Nigeria to strengthen surveillance, improve vaccination coverage, and close epidemiological gaps through research. The outcomes of this study will directly benefit smallholder farmers by promoting improved disease control, reducing livestock losses, enhancing food

security, and strengthening rural livelihoods. Therefore, this study was carried out to determine the seroprevalence and risk factors for the occurrence of the disease in goats from Sokoto, Nigeria.

## MATERIALS AND METHODS

### Study area

Samples from herds were taken from Local Government Areas that comprise the Sokoto metropolis, namely, Sokoto North, Sokoto South, Wamakko, Kware, Dange-Shuni, and Bodinga. All abattoir samples were taken from the Sokoto main abattoir. Sokoto is located at the coordinates 13°05'N and 05°15'E in the extreme northwest of Nigeria. It covers an area of approximately 25,973 square kilometres. The last national census in 2006 reported the state's human population to be 3,702,676, with an annual rainfall of between 500 and 1300 mm and humidity varying from 10 to 90% (NPC, 2006). The state is endowed with livestock resources with an estimated 3 million cattle, 3 million sheep, 5 million goats, 4600 camels, and a host of other local and exotic poultry species (MOCIT, 2002).

### Study design and sampling technique

A cross-sectional study and systematic random sampling were conducted, following standard procedures as described by Thrusfield (2018), to obtain whole blood from goats. The samples were collected from herds and abattoirs. Apparently, healthy and sick goats were sampled for this study.

### Sample size determination

Sample size was estimated using the formula described by Thrusfield (2018).

$N=Z^2pq / d^2$

Where N = sample size, Z = standard normal deviation at 95% confidence interval (1.96), and P = prevalence rate from previous study. Nkamwesiga *et al.* (2023) reported a prevalence of 27.3% in goats.

### Sample collection

A total of 304 blood samples were collected between August 2023 and May 2024 from Sokoto North, Sokoto South, Wamakko, Dange-Shuni, Kware, and Bodinga Local Government Areas. For samples collected at farms and herds, approximately 5 ml of blood was aseptically drawn from the jugular vein of each animal using sterile disposable needles and plain Vacutainer tubes.

For abattoir samples, blood was collected at the point of slaughter from the Sokoto main abattoir only. Immediately after collection, samples were transported to the Central Research Laboratory, Faculty of Veterinary Medicine, Usmanu Danfodiyo University, Sokoto, in ice-packed coolers to maintain a cold chain.

In the laboratory, samples were allowed to clot and were centrifuged at 5,000 × g for 5 minutes to separate serum. The resulting sera were carefully harvested into sterile cryovials, labelled, and stored at –20°C until further analysis.

Among the 304 samples collected, 133 were from males and 171 from females. The seasonal distribution was as follows: rainy (n = 49), harmattan (n = 137), and dry (n = 118) from August 2023 to May. 2024. By location of the samples, 176 samples were collected from the abattoir, while 128 were obtained from herds. 165 samples were obtained from young animals, while 139 were obtained from adults. Based on the breeds, samples were taken from Red Sokoto, Sahelian, and West African Dwarf goats.

This stratified sampling across sex, age, breed, season, and source was designed to provide representative coverage of the study population and to enable assessment of potential risk factors influencing seroprevalence.

### Enzyme-Linked Immunosorbent Assay (ELISA)

A competitive ELISA kit for the detection of anti-PPRV nucleoprotein antibodies in goat serum obtained from ID.vet Innovative Diagnostics Grabels, France, was used to test serum samples for the presence of PPRV antibodies at the Central Research Laboratory, Faculty of Veterinary Medicine, Usmanu Danfodiyo University, Sokoto. Briefly, the wells were coated with purified recombinant PPR nucleoprotein (NP). The samples to be tested and the controls were added to the microwells. Anti-NP formed an antibody-antigen complex, which masked the NP epitopes. An anti-NP-peroxidase (HRP) conjugate was added to the microwells and fixed to the remaining free NP epitopes, forming an antigen-conjugate-HRP complex. After washing to eliminate the excess conjugate, the substrate solution (TMB) was added. The resulting colouration was dependent on the quantity of specific antibodies present in the sample tested. In the absence of antibodies, a blue colouration appeared, which became yellow after the addition of the stop solution. In the presence of antibodies, no colouration appeared. The microplate was read at 450nm. Based on the interpretation of the results, samples that were ≤50% were positive, those that were more than 50% to ≤ 60% were doubtful, and those above 60% were negative.

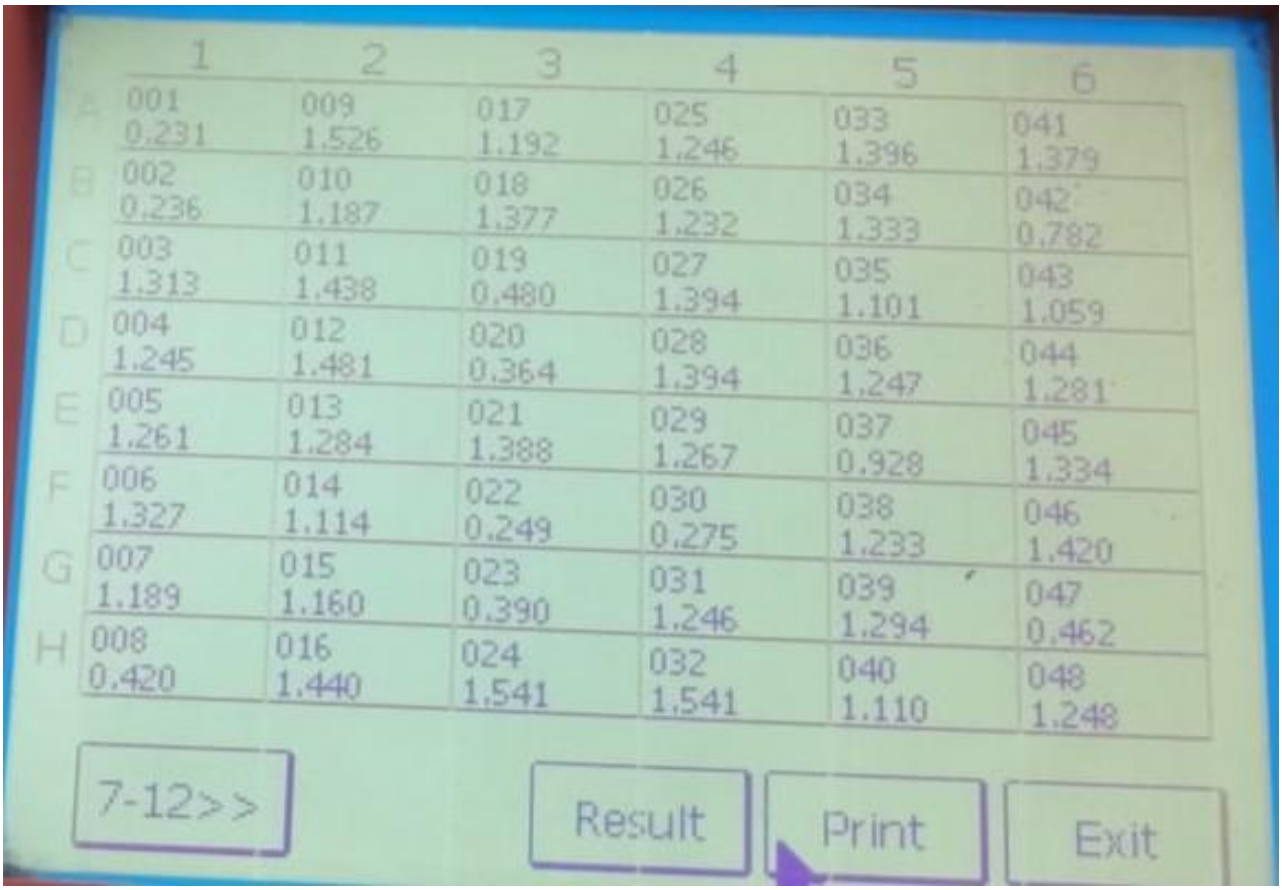


**Figure 1.** ELISA OD values.

### Data analysis

The data obtained from the study were subjected to both descriptive and inferential statistics to determine the association of the variables (age, sex, location, breed, and season) with the presence of PPRV. The value of $p<0.05$ was considered significant in the studies, and statistical software 'SPSS' version 22.0 was used for the analysis.

## RESULTS

A total of 304 blood samples from goats were collected from herds and Sokoto's main abattoir in Sokoto. These samples were screened for the presence of Peste des Petits Ruminants antibodies using a competitive ELISA kit from Idvet® (Figure 1). Among the goats, 91 out of 304 sera were positive, indicating an overall seroprevalence of 29.9%.

Table 1 shows the Z-Test for proportions of samples by sex, location, age, breed, and season in goats. Table 2 shows the Chi-Square test for positive vs. negative cases of PPR in goats by sex, location, and age. No statistically significant association was found between the variables and the infection. Table 3 shows the binary logistic regression analysis for positive vs. negative cases of PPR in goats by breed and season. A statistically significant association was found between breed, season, and the occurrence of the infection in goats.

## DISCUSSION

The findings of this study indicate a seroprevalence rate of 29.9% for Peste des Petits Ruminants (PPR) among goats in Sokoto State, Nigeria. This result signifies the ongoing circulation of the PPR virus in this region, raising significant concerns regarding its impact on goat production and food security.

The seroprevalence rate observed in this study aligns with findings from similar research in Nigeria and other parts of Africa. In Nigeria, studies conducted revealed a similar prevalence of 29.51% and 28.31% in Taraba and Imo states, respectively (Woma *et al.,* 2016). Beyond Nigeria, a seroprevalence of 28.96% was found in Nepal, highlighting similar challenges in PPR management

**Table 1.** Z-Test for proportions of samples by sex, location, age, and season in goats.

| Variable | Comparison | Z-value | P-value |
|---|---|---|---|
| Sex | Male vs Female | -0.2411 | P >0.05 |
| Breed | RSG Vs Sahelian | -0.4938 | P >0.05 |
| | RSG vs WAD | 1.1548 | P >0.05 |
| | Sahelian vs WAD | 1.3757 | P >0.05 |
| Location | Abattoir vs Herds | -1.2377 | P >0.05 |
| Age | Young (Less than 2 years) vs Adult (Above 2 years) | 0.5235 | P >0.05 |
| Season | Dry vs Harmattan | 1.2529 | P >0.05 |
| | Dry vs Rainy | -1.0570 | P >0.05 |
| | Harmattan vs Rainy | -1.9365 | P <0.05 |

Note: Significant results are marked with p<0.05.

**Table 2.** Distribution and analysis of variables associated with PPR in goats in Sokoto State, Northwestern Nigeria.

| Variable | Group | Positive | Negative | Chi-square ($X^2$) | ($X^2$) Yates | P-value |
|---|---|---|---|---|---|---|
| Sex | Male | 39 (29.32%) | 94 | 0.094 | 0.0322 | P =0.711 |
| | Female | 52 (30.41%) | 119 | | | |
| Location | Abattoir | 51 (28.98%) | 125 | 0.183 | 0.0902 | P =0.0236 |
| | Herd | 40 (31.25%) | 88 | | | |
| Age | Young | 49 (29.7%) | 116 | 0.009 | 0.0007 | P=0.0300 |
| | Adult | 42 (30.22%) | 97 | | | |

**Table 3.** Distribution and analysis of breeds and seasons associated with PPR in goats in Sokoto State, Northwestern Nigeria.

| Variable | Group | Positive | Negative | P-value | OR | 95%CI |
|---|---|---|---|---|---|---|
| Breed | Red S G | 53 (31%) | 118 | 0.0001 | 0.86 | 1.00-1.01 |
| | Sahelian G | 21 (34.4%) | 40 | Ref | NA | NA |
| | West A D | 17 (23.6%) | 55 | 0.2777 | 0.59 | 0.28- 1.26 |
| Season | Dry | 46 (39.0%) | 72 | 0.0004 | 1.01 | 1.37- 4.13 |
| | Harmattan | 29 (21.2%) | 108 | Ref | NA | NA |
| | Rainy | 16 (32.7) | 33 | 0.0262 | 1.81 | 0.88- 3.73 |

(Shrestha *et al.,* 2024). The prevalence obtained is, however, lower than the prevalence obtained in other studies. For instance, Bello *et al.* (2018) reported a seroprevalence of 40.24%. Similarly, El-Yuguda *et al.* (2013) reported a seroprevalence of 51.6% in goats in the semi-arid region of northeastern Nigeria, further supporting the endemic nature of the disease in Nigeria. A study in Pakistan by Abubakar *et al.* (2015) documented a higher prevalence of 48.5% in goats, which was attributed to the number of animals sampled during the study and the lack of proper vaccination.

Among the 91 positive cases, 39 were from males, while 52 were from females, suggesting a slightly higher susceptibility among female goats. However, there was no statistically significant difference in PPR prevalence between male and female goats. This suggests that

susceptibility to the disease is likely unrelated to sex. This finding contradicts earlier studies that reported slightly higher prevalence rates in females (Kihu *et al*., 2015; Bello *et al.,* 2018). Similarly, other studies have reported higher prevalences in females than in males. A study in Bauchi and Gombe states by Bello *et al.* (2016) found a significantly higher PPR seroprevalence in females (70.4%) compared to males (51.4%). A higher prevalence in females was also reported in India (Acharya *et al.,* 2018). The higher prevalence observed in females is attributed to the fact that female small ruminants are kept longer for breeding and milk production, while males are often sold earlier for meat. This prolonged exposure to the PPR virus increases the chances of females becoming seropositive. These findings align with studies conducted in regions such as Ethiopia, where no significant differences in PPR prevalence between male and female goats were observed (Senbeto *et al.,* 2024). This finding was attributed to local husbandry practices where exposure and stress factors are distributed equally among both sexes, resulting in similar infection rates. Environmental stressors like harsh weather or poor nutrition can affect both sexes equally, negating any physiological differences in immune response. In addition, in areas where PPR is widespread, the entire small ruminant population is more uniformly exposed to the virus, levelling out potential sex-based differences.

The breed-specific analysis revealed that Red Sokoto Goats had the highest number of positive cases (53), followed by Sahelian Goats (21) and West African Dwarf Goats (17). The study found a statistically significant association between breed and seropositivity. We attributed this finding to the number of animals sampled during the study period, as the Red Sokoto Goat is the most predominant breed in the study area, and this may increase their exposure to the virus. This finding is consistent with those of other studies carried out in Nigeria and beyond. Woma *et al.* (2016) reported that goat breed was a risk factor in their study. Similarly, it was reported that a local Moroccan goat breed had a high susceptibility rate to PPR, suggesting a clear breed-level variation in susceptibility (Fakri *et al.,* 2017). However, this finding is not consistent with the work of Senbeto *et al.* (2024), who reported no breed-specific differences in PPR prevalence in Ethiopia. Some studies also suggest that indigenous breeds such as Red Sokoto Goat may exhibit enhanced resistance to infectious diseases, including PPR, due to their long-term adaptation to harsh environmental conditions and the possibility that they are genetically more susceptible to PPR infection than the other breeds sampled in the study (Bello *et al.,* 2018).

A higher number of positive cases were observed in goats sampled from the abattoir (51) compared to those sampled directly from herds (40). However, no statistically significant difference in PPR prevalence was detected between the two groups. Since goats brought to the abattoir originate from multiple locations and management systems, it is difficult to attribute the observed difference to any specific husbandry practice. The higher number of positives among abattoir samples may instead reflect the mixing of animals from different sources, increasing the likelihood of exposure and transmission. This finding, therefore, suggests that PPR is likely widespread across various production systems in the study area rather than being confined to a particular one. Similar observations have been reported in endemic regions where the frequent movement and aggregation of small ruminants for trade and slaughter facilitate viral dissemination irrespective of herd management type (Abubakar *et al.,* 2017). These findings highlight the importance of region-wide control measures, such as mass vaccination and strict movement control, to effectively curb disease spread.

Age-related differences were also notable, with young goats showing a higher number of positive cases (49), than adults (42). No significant statistical association was found between age and PPR. Even though it is generally known that dams infected with the PPR virus can passively transfer maternal antibodies to their young ones (Parida *et al.,* 2015), this study did not show significance between age and PPR. This could be attributed to the influence of widespread exposure and seroconversion in endemic regions. Regular exposure to the virus may lead to the development of herd immunity across all age groups, potentially masking age-related susceptibility differences. This finding is not consistent with other studies that reported significant differences between PPR and age. A study in Sokoto state found a statistically significant association between age and PPR (Bello *et al.,* 2018). Similarly, El-Yuguda *et al.* (2013) and Victor *et al.* (2017) found statistically significant differences between age and PPR in North Eastern states and Makurdi, respectively. Beyond Nigeria, Dubie *et al.* (2022) and Senbeto *et al.* (2024) reported similar findings in Ethiopia.

Seasonal variation indicated that the number of cases was highest in the dry season (46), followed by Harmattan (29) and the rainy season (16). A significant statistical association was found between PPR and season, as well. This significant association between PPR prevalence and seasonality signifies the critical role of environmental factors in shaping disease transmission dynamics. The dry season was found to have a significantly higher prevalence of PPR compared to the harmattan season. This finding aligns with observations from other PPR-endemic regions, where dry-season outbreaks are frequently reported (Wosu *et al.,* 1990). Similar patterns were reported in studies from Ethiopia, where higher PPR prevalence was linked to periods of water scarcity and increased animal congregation (Kwiatek *et al.,* 2011). During this period, resource scarcity is prevalent, including limited access to water and forage. Such environmental stressors weaken the immune system of goats, making them more susceptible to infections. Moreover, the

concentration of livestock around limited water and grazing points during the dry season could facilitate close contact between animals, thereby enhancing virus transmission. However, studies in southern Nigeria have not consistently observed this pattern, possibly due to differences in agroecological zones and livestock management practices, where environmental conditions may not exert similar pressures on animals (El-Yuguda *et al.,* 2013).

## Conclusion

This study demonstrated an overall PPR seroprevalence of 29.9% in goats in Sokoto State, confirming the continued endemic circulation of the virus. While sex, location, and age were not significantly associated with infection, seasonality and breed showed a strong influence, with higher prevalence in the dry season and in Red Sokoto Goats. These findings indicate that breed, environmental conditions, and seasonal animal congregations at watering and grazing points are important drivers of PPR transmission from this study. Timely vaccination campaigns before the dry season, strengthened surveillance systems, were recommended, as this will contribute to the FAO/OIE global goal of PPR eradication by the year 2030.

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## CONFLICT OF INTEREST

There is no conflict of interest in this study.

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