

## Genetic and non-genetic factors affecting prevalence of *Peste des petits ruminants* in West African Dwarf sheep and goats

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**Target Audience:** Stakeholders in small ruminant's disease control, Government agencies, Animal and Veterinary Scientists, Agricultural extension workers, Farmers and Students.

### Abstract

After the groundbreaking eradication of rinderpest, *peste des petits ruminants* (PPR) is currently the target for global eradication by 2030. Understanding the factors affecting its prevalence is imperative for effective, evidence-based planning for the eradication of the disease. Genetic and non-genetic factors affecting PPR prevalence in sheep and goats (403) kept by smallholder farmers were investigated using the positivity of faecal samples to haemagglutination assay (HA). Data on positivity to HA, HA titre and rectal temperature of the animals were statistically analyzed. Overall PPR prevalence of 86.0% was recorded for West African Dwarf sheep and goats. Effect of species and coat colour were significant on PPR prevalence with an indication that goats had a higher ( $P < 0.05$ ) estimate (84.9%) compared to the PPR prevalence (65.9%) in sheep. Location affected PPR prevalence with highest prevalence (87.6%) recorded in Oyo compared to Ogun (67.9%), while Osun State had 76.2%. The effects of sex and age were not significant ( $p > 0.05$ ). PPR is endemic in three southwestern States of Nigeria and its prevalence in small ruminants may be influenced by coat colour, species and location, thus farmer sensitization, advocacy and public enlightenment on PPR control require urgent attention.

**Keywords:** Small ruminant plague, prevalence, predisposing factors, haemagglutination assay, sheep and goats.

### Description of Problem

Small ruminant plague, widely recognized as *peste des petits ruminants* (PPR) is an acute and highly contagious viral

disease plaguing both domestic and wild small ruminant species. It is characterized by high fever, oculo-nasal discharge, pneumonia, necrotic, erosive and ulcerative

stomatitis and inflammation of the gastrointestinal tract leading to severe diarrhea and death [1]. It causes severe economic loss to some developing countries (e.g. Nigeria, Ghana, Cote d'Ivoire, Mali, Mauritania, Liberia, Republic of Benin, Cameroon, Sudan, Saudi Arabia etc.) where the disease is endemic [2,3]. Annual economic loss in Nigeria due to PPR outbreak in small ruminants was estimated at 1.50 million USD [4]. Generally, the disease is more pathogenic in goats than sheep [5].

Significant differences exist in the epidemiology of PPR in diverse ecological and geographical areas. For instance, the arid and semi-arid regions were observed to record low PPR fatality which may exist as a subclinical or mild infection, giving chances to many opportunistic infections such as pasteurellosis, contagious caprine pleuropneumonia, orf and anthrax etc [6]. Some risk factors have been identified to contribute to the transmission of PPR disease. Among these are the migration and exchange of animals between flocks [7]. The enzootic form of PPR in recovered animal may be responsible for how PPR virion is sustained between seasons of varying prevalence. A reason why the introduction of new sheep or goats into healthy flocks often leads to fresh outbreaks of PPR, thus stands as a major factor in the transmission of PPR infection [10]. Sex, age, species, breed and season were also acknowledged as factors influencing the susceptibility of small ruminant to PPR [8]. Idowu and Adelabu [9] reported coat colour variations (black, brown, badgerface, grey, buckskin, lateral belly, white and black, white and brown, white and black marking, black and white marking, spotted white, spotted black blackmash, tan, white, bezoar, spotted brown lateral stripes and swiss marking) in WAD goats. However, the effect of such important traits with huge

variations, on PPR prevalence has not been reported. Such information could help in the selection for improved resistance to PPR in small ruminants. After the eradication of rinderpest (RP), PPR is target for global eradication by 2030 [11]. The eradication program would benefit from understanding and reporting of the factors influencing its prevalence. It could guide in planning effective control measures, targeting eradication of the disease. In the light of this, the current study aimed at evaluating the genetic factors and non-genetic factors affecting PPR prevalence in small ruminants in three southwestern States of Nigeria.

## **Materials and Methods**

### **Ethics statement**

The animal experiment was carried out in accordance with the ethical standards of the Federal University of Agriculture Abeokuta, College of Animal Science and Livestock Production Committee on animal experimentation for the care and handling of experimental animals.

### **Animals sampled and sampling techniques**

A multi-stage sampling procedure was adopted to investigate the effect of genetic and non-genetic factors affecting PPR prevalence in 403 randomly selected West African Dwarf (WAD) breeds of small ruminants consisting of 216 goats and 107 sheep of both sexes, 3 different age groups ( $\leq 1$  year,  $>1-2$  years and  $>2$  years) and 7 categories of coat colours reared under different management systems in the 3 southwestern States (Oyo, Osun and Ogun State), Nigeria. Four different locations per State (Table 1) were included in this study. Faeces were collected from the animals directly from the rectum, transferred into a plain bottle and kept in a cold box before transporting to the laboratory.

**Table 1: Sampling location and animal management**

State	Location	Latitude and Longitude	Management system
Ogun	Ilisan	6.89°N, 3.71°E	Intensive
	Olubori	6.95°N, 3.51°E	„
	FUNAAB	7.24°N, 3.34°E	Semi-intensive
Oyo	Ogbun	6.56°N, 3.30°E	Intensive
	NACGRAB	7.36°N, 3.83°E	Extensive
	ILRI	7.49°N, 3.91°E	Semi-intensive
	Oyo	7.84°N, 3.94°E	„
	IART	7.36°N, 3.85°E	„
Osun	Gbongan	7.47°N, 4.35°E	Extensive
	Odeomu	7.54°N, 4.40°E	„
	Iwo	7.64°N, 4.18°E	„
	Ikire	7.37°N, 4.19°E	„

FUNAAB-Federal University of Agriculture Abeokuta, Nigeria;

NACGRAB-National Centre for Genetics and Biotechnology;

IART-Institute of Agricultural Research and Training

ILRI-International Livestock Research Institute

### PPR viral antigen detection

A total of 3ml of phosphate buffer saline (PBS) of pH 6.8 was added to 1g of faecal sample and incubated for 12hrs at - 20°C. Homogenate was thawed and centrifuged at 2000xg for 10 min. The supernatant was used as an antigen source. A digital thermometer was disinfected, lubricated and inserted into the rectum of the animal to measure the rectal temperature.

Chicken whole blood was collected in EDTA bottles and washed three times using PBS. A 1% concentration of the washed chicken red blood cells (CRBCs) was prepared and used as an indicator for the HA [12]. A total of 50µl of PBS was added to the U-bottom wells of a microtitre plate, equal volume of antigen source was added to well 1, two-fold serially diluted across the row to well 11, leaving only well 12 without antigen to serve as the Control. Fifty microlitre of 1% CRBCs was added to each well and incubated at 4°C for 20 minutes. A well was considered positive when CRBCs were suspended in the reaction, while a well with settled CRBCs was considered negative. HA titre was estimated as 2<sup>n</sup>, where n denote the

number of last well in the row of a microtitre plate where haemagglutination has occurred.

### Data collection and analysis

Data on HA titre and rectal temperature were collected from each animal and positivity to HA was used for PPR prevalence determination. Analysis of variance was used to test for significance in the prevalence among age groups, locations and coat colours also, t-test was used to test significant difference in PPR prevalence between sexes and species-. Univariate analysis of genetic and non-genetic effects on HA titre and rectal temperature were determined using factorial design included in SAS version 9.1.3 [13]. Pearson correlation (r) between rectal temperature and HA titre was determined.

### Results

Sampled sheep and goats in this study did not show clinical signs yet, were were infected with the virus as revealed by haemagglutination assay and the rectal temperature. Generally, a PPR prevalence of 86% was recorded in WAD sheep and goats

in the studied areas.

**Effects of genetic factors on PPR prevalence**

Effect of species on the PPR prevalence in WAD small ruminants was significant for the three southwestern states of Nigeria. The prevalence (84.98%) was higher ( $p < 0.05$ ) in goats compared to the prevalence (65.95%) in sheep (Figure 1).

Coat colour had a significant effect ( $p < 0.05$ ) on the PPR prevalence among sheep and goats. The prevalence of 88.89% was recorded for brown coat colour and 85.71% for black/white coat colour which

were significantly higher than the prevalence (61.26%) recorded for completely white coat colour (Figure 2). However, brown, black/white; white/black; white/brown; completely black and brown/white were statistically similar ( $p > 0.05$ ) as shown in Figure 2. Also, prevalence in sheep and goats with white coat colour was slightly lower but statistically similar ( $p > 0.05$ ) with the prevalence in white/black; white/brown; black and brown/white. As shown in Figure 3, both males and females showed statistically similar ( $p > 0.05$ ) PPR prevalence (78.57 and 74.82%, respectively).

**Table 2. Least square means (LSM) of HA titre and rectal temperature by species, sex, age and coat colour**

Factor	Sub-classes	Haemagglutination assay titre (HAU)		Rectal Temperature (°C)	
		N	LSM±SE	N	LSM±SE
State	Ogun	137	19.61±4.11 <sup>ns</sup>	140	39.26±0.05 <sup>b</sup>
	Osun	164	17.94±2.52 <sup>ns</sup>	164	39.51±0.09 <sup>a</sup>
	Oyo	97	24.78±10.70 <sup>ns</sup>	57	39.17±0.12 <sup>b</sup>
Species	Sheep	185	16.03±5.80 <sup>ns</sup>	163	39.05±0.05 <sup>b</sup>
	Goat	213	23.78±2.98 <sup>ns</sup>	198	39.62±0.07 <sup>a</sup>
Sex	Male	112	17.77±3.26 <sup>ns</sup>	103	39.30±0.08 <sup>ns</sup>
	Female	286	21.12±4.18 <sup>ns</sup>	258	39.38±0.06 <sup>ns</sup>
Age group	≤1	117	18.31±3.02 <sup>ns</sup>	103	39.64±0.07 <sup>a</sup>
	>1-2	142	22.36±7.71 <sup>ns</sup>	131	39.11±0.10 <sup>c</sup>
	>2	139	19.53±3.52 <sup>ns</sup>	127	39.39±0.06 <sup>b</sup>
Coat colour	White	111	11.96±3.07 <sup>b</sup>	97	38.99±0.06 <sup>c</sup>
	White/black	31	7.81±1.82 <sup>b</sup>	21	39.02±0.17 <sup>c</sup>
	White/brown	33	12.73±3.21 <sup>b</sup>	30	39.23±0.14 <sup>bc</sup>
	Black	107	25.21±4.54 <sup>b</sup>	103	39.70±0.07 <sup>a</sup>
	Black/white	35	26.11±9.87 <sup>b</sup>	34	39.24±0.13 <sup>abc</sup>
	Brown	63	17.49±3.28 <sup>b</sup>	60	39.66±0.19 <sup>ab</sup>
	Brown/white	18	73.78±56.09 <sup>a</sup>	16	39.25±0.16 <sup>abc</sup>

<sup>a,b,c</sup>-superscripts on LSM among sub-classes of a factor indicate significant difference ( $p < 0.05$ ) in the means; ns-superscripts on LSM among sub-classes of a factor indicate insignificant difference ( $p > 0.05$ ) in the means

**Effects of non-genetic factors on PPR prevalence**

Location had a significant effect ( $p < 0.05$ ) on the PPR prevalence in small ruminants. The highest prevalence (87.63%) was observed in Oyo State, which was

significantly higher than the estimate (67.88%) in Ogun State. PPR prevalence (76.22%) in Osun State was statistically similar ( $p > 0.05$ ) with the prevalence in both Oyo and Ogun State as shown in Figure 4. The effect of age was not significant

( $p > 0.05$ ) on the PPR prevalence among sheep and goats in the southwestern States of Nigeria (Figure 5).

**Estimates of HA titre and rectal temperature in small ruminants as affected by genetic factors**

As shown in Table 2, least square means (LSM) of HA titre in sheep was estimated at 16.03 HAU, statistically similar ( $p > 0.05$ ) to the value (23.78 HAU) observed in goats, thus, effect of species on HA titre in WAD small ruminants was not significant ( $p > 0.05$ ). Brown/white coat colour had highest LSM of HA titre (73.78 HAU) significantly ( $p < 0.05$ ) different from HA titre for other coat colours. Males and

females had statistically similar ( $p > 0.05$ ) estimates of LSM of HA titre (17.77 HAU and 21.12 HAU, respectively). LSM of rectal temperature in goats ( $39.62^{\circ}\text{C}$ ) was significantly ( $p < 0.05$ ) different from the value recorded for sheep ( $39.05^{\circ}\text{C}$ ). Sheep and goats with entirely black and solely brown coat colours had rectal temperature ( $39.70^{\circ}\text{C}$  and  $39.66^{\circ}\text{C}$ , respectively) significantly ( $p < 0.05$ ) different from the observed values in sheep and goats with completely white and, white/black coat colours. There was no significant ( $p > 0.05$ ) difference in the LSM of rectal temperature between males ( $39.30^{\circ}\text{C}$ ) and females ( $39.38^{\circ}\text{C}$ ) of WAD sheep and goats.

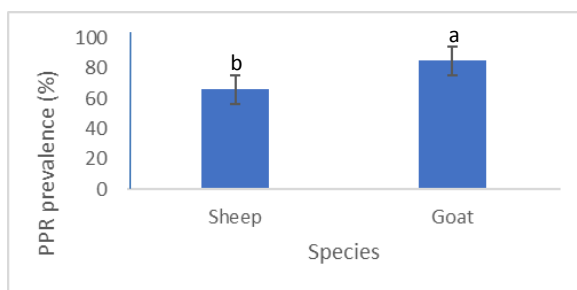


Figure 1: PPR prevalence in WAD sheep and goats across three southwestern states of Nigeria

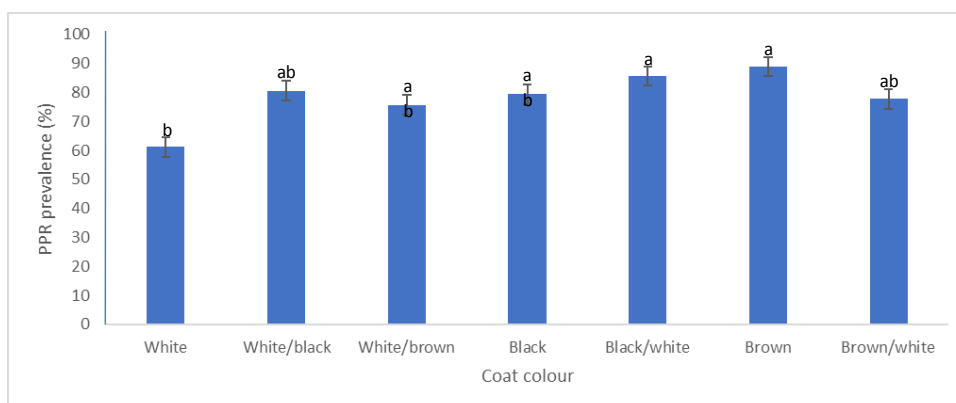


Figure 2: PPR prevalence in WAD sheep and goats based on coat colour

***Estimates of HA titre and rectal temperature in small ruminant as affected by non-genetic factors***

There was no significant difference ( $p>0.05$ ) in the LSM of HA titre of PPR infected domesticated small ruminants in terms of age groups as shown in Table 2. Sheep and goats from Osun State had significantly ( $P<0.05$ ) higher mean rectal temperature ( $39.51\pm 0.09^{\circ}\text{C}$ ) than the mean ( $39.26\pm 0.05^{\circ}\text{C}$ ) of animals from Ogun State and Oyo State ( $39.17^{\circ}\text{C}$ ). Animals below one year of age had the highest ( $P<0.05$ ) rectal temperature ( $39.66 \pm 0.12^{\circ}\text{C}$ ) than animals in the older age groups ( $>1-2$  and  $>2$  years).

***Pearson Correlation between rectal temperature and HA titre***

Pearson correlation estimate (0.11) between HA titre of the faecal samples collected from sheep and goats and the rectal temperature was significant ( $p<0.05$ ).

**Discussion**

An overall PPR prevalence of 86.0% in domesticated small ruminants in the three southwestern States of Nigeria studied was considerably higher compared to estimates ranging from 16.7 to 76.2% reported in different parts of the country [14,15,16]. Based on information from extension agents and the farmers in Ogun and Oyo States, there is annual vaccination of small ruminants (with coverage limited to rural settings). On this account, PPR prevalence is expected to decrease with time. Contrary to this, PPR control has not been very effective [3]. This could be as a result of uncontrolled movement of animals from one part of the country to the other and inconsistencies in implementation of policy on the control of PPR in most parts of the areas where sheep and goats are reared. Another possibility is the re-introduction of the virus by the wildlife reservoir [17].

PPR prevalence of 84.9% in goats was relatively higher than the prevalence (65.9%) in sheep. This could be an indication of differences in species susceptibility to the PPR virus which may not be unconnected with their differences in genetic make-up. PPR is largely seen as a severer disease in goat than sheep [5, 18]. However, a higher seroprevalence in Sudanese sheep (62.1%) than in goat (53.5%) have been reported by Ishag et al. [19]. Dissimilarities in the observations by different authors could be as a result of differences in the climates where the studies were carried out. Some climates may favour one species over the other in susceptibility to PPRV infection due to their differences in their physiology and genetic composition.

Effect of coat colour showed that sheep and goats with brown coat colour had highest PPR prevalence (88.9%) than animals with other coat colours, while the least PPR prevalence (61.3%) was recorded for individuals with completely white coat colour. This is an indication that there may be association between coat colour determinant gene and sensitivity to PPR infection which needs further investigation. To the best of our knowledge, no report on the effect of coat colour on sheep and goats' susceptibility to PPR has been documented. Coat colour in animals does not only play an aesthetic role, but also has substantial impact on many factors, indispensable for survival [20].

PPR prevalence in male and female were equally high in this study (78.6% and 74.8%, respectively). Sex has previously been mentioned as a risk factor for PPR, with females mostly identified to be at higher risk [21]. However, some studies have reported a higher risk for males than females [22, 23]. Based on the findings from this study both males and females were equally at risk of PPR infection.

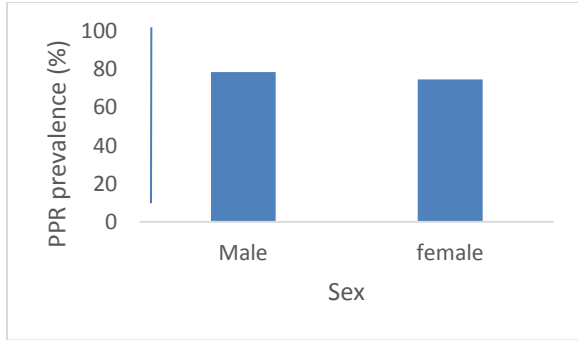


Figure 3: PPR prevalence WAD sheep and goats based on sex

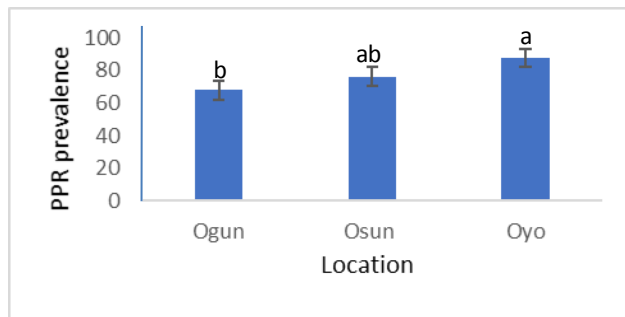


Figure 4: PPR prevalence in WAD sheep and goats among three southwestern State of Nigeria

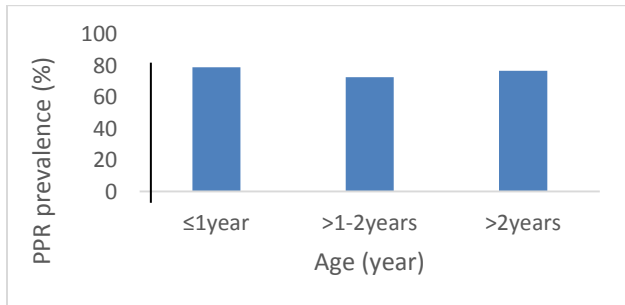


Figure 5: PPR prevalence in WAD sheep and goats based on age group

Effect of location on PPR prevalence revealed higher prevalence (87.6%) in Oyo State compared to Osun and Ogun States. This might not be unconnected with the fact that Oyo State serves as a major transit and sales point for sheep and goats transported from the North to the South, from where they are distributed to other states in the southwest. Thus, high influx of livestock from northern states could serve as potential

carriers of the virus, thereby contributing to the higher PPR prevalence recorded in Oyo State. The observed estimate for Oyo State was also higher than previously reported estimate of 75.0% by Lawal et al. [24], which is likely expected over time with high influx of potential carriers of the virus and limited coverage in vaccination concentrating in rural than urban and peri-urban areas. The least PPR prevalence

(67.9%) among ruminants in the rural settings was recorded in Ogun State, which was lower than 80.0% earlier reported by [25] from animals under semi-intensively and intensively managed systems within the urban and peri-urban settings. Osun had 76.2% PPR prevalence which is considerably higher than 24.5% reported by [26]. This increase in PPR prevalence overtime may be due to factors such as uncontrolled movement of animals from other states, and lack of proper awareness for PPR disease control among the farmers in the State.

Generally, the LSM of HA titre was lower in this study (7.81 HAU to 73.8 HAU) compared to the HA titre range of 8.00 HAU to 256 HAU reported [19]. This could be as a result of the fact that most animals sampled in this study were healthy but carriers of the virus and thus expected to have low HA titre. Lower LSM HA titre could mean a reduction in the PPR antigen in the faeces during the recovery stage or the animals acquired the virus newly. It was noted by [10] that there could be a reduction in mean titre of PPR virus haemagglutinins shed in the faeces with time.

LSM of rectal temperature of sampled goats revealed some were pyrexia as they had rectal temperature of greater than 39.0°C, according to [27]. Pyrexia is recognized as one of the clinical signs of PPR in infected animal [27] which can be accompanied by depression, anorexia and dryness of muscle [1]. Correlation between the HA titre and rectal temperature showed that increase in HA titre will increase in rectal temperature (pyrexia) and could be a reliable means of suspecting PPR infection in animal. This is in agreement with [24] who classified a temperature range of 39.8 – 41°C (pyrexia) as a sign of PPR infection.

### Conclusions and Applications

1. Findings from this study revealed that

peste des petits ruminants' virus is endemic in the study areas.

2. Species, coat colour and location were observed to be risk factors for the susceptibility of small ruminant to PPR infection.
3. Selection in favour of white coat colour and regulation of animal movement could help reduce prevalence of the disease.
4. Sensitization of farmers, advocacy, public enlightenment on the PPR disease control measures and mass vaccination require urgent attention.

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### References

1. Parida, S., Selvaraj, M., Gubbins, S., Pope, R., Banyard, A. and Mahapatra, M. (2019). Quantifying levels of peste des petits ruminants (PPR) virus in excretions from experimentally infected goats and its importance for nascent PPR eradication programme, *Viruses*, 11(3): 249-261
2. Otsyina, H.R., Arthur, C.T., Ayim-Akunnor, M. and Obese, F.Y.

- (2013). Sero-prevalence of peste des petits ruminants (PPR) in sheep, goats and cattle in Ghana, *Bulletin of Animal Health and Production in Africa*, 61(3): 473-479
3. National Strategy for the control of peste des petits ruminants in Nigeria (2017) Strategy and roadmap for the control and eradication of PPR in Nigeria taking into consideration the global, pan-African and ECOWAS strategies and the peculiarities of Nigeria, pp. 6-16.
  4. Kaukarbayevich, K.Z. (2019) Epizootological analysis of PPR spread on African continent and in Asian countries, *African Journal of Tropical Agricultural*, 7(1).001-004.
  5. Banyard, A.C., Parida, S. Batten, C. Oura, C. Kwiatek, O. and Libeau, G. (2010). Global distribution of peste des petits ruminants virus and prospects for improved diagnosis and control, *Journal of General Virology*, 91: 2885–2897.
  6. Lefevre, P.C. and Diallo, A. (1990). Peste des petits ruminants, Review of Science and Technology office of International des Epizooties, 9: 951–965.
  7. Elsawalhy, A., Jeffrey, C., Mariner, J. Dickens, C., Henry, W., Samuel, W., William, O. and Philip, T. (2010). Pan African Strategy for the Progressive Control of PPR. *Bulletin of Animal Health Production in Africa*, 185-193.
  8. Abubakar, M., Hadder, A.K., Muhammed, J.A., Manzoor, H. and Qurban, A. (2011). Review: peste des petits ruminants (PPR): disease appraisal with global and Pakistan perspective,” *Small Ruminants Research*, 96,(1): 1-10.
  9. Idowu, P.A. and Adelabu, O.A (2018). An investigation of coat colour distribution of WAD goats. *Agricultural Science*,” *Journal of Agricultural Science*, 10(3): 228.
  10. Ezeibe, M.C.O., Eze, I.C. and Ngene, A.A. (2008). Persistent Detection of Peste de Petits Ruminants Antigen in the faeces of Recovered Goats. *Tropical Animal Health and Production*, 40: 517–519.
  11. FAO (2014). Peste des petits ruminants,” New program to eradicate deadly livestock disease by 2030.. [www.fao.org/ppr/news-and-events/news/detail/en/c/1190866/](http://www.fao.org/ppr/news-and-events/news/detail/en/c/1190866/)
  12. Latif A., Akhtar Z., Ullah R.W. Zahur A.B., Ullah A., Irshad H., Malik A.R., Mahboob M., Hussain K. and Afzal S. (2014). Evaluation of Haemagglutination Assay (HA) for the Detection of Peste des Petits Ruminants Virus (PPRV) in Faecal Samples of Recovered Goats. *Research Journal for Veterinary Practitioners*, 2(1): 11 – 13.
  13. SAS Institute Inc. (2004). SAS Campus Drive, Cary, North Carolina 27513.
  14. Abdullahi, U.S., Shehu, L.M. and Shuaibu, M.T. (1999). The epidemiology of peste des petits ruminants in Bauchi State,” *Proceedings of the 36<sup>th</sup> Annual congress of the Nigeria Veterinary Medical Association*, pp.26-29.
  15. Luther N.J., Umoh J.U., Majiyagbe K.A., Shamaki D., Nwosu C.I. and Dogo G. (2005). Studies on the prevalence of antibodies to peste des petits ruminants virus (PPRV) among Goats in Bauchi State, *Nigerian Veterinary Journal*, 27(1): 17-22.
  16. Bukar, B.A., El-Yuguda, A. and Said, L. (2020). The first seroprevalence investigation of peste des petits ruminants virus among sahel goat in

- Yobe State, Nigeria. *Asian Journal of Medicine and Health*, 18 (4): 33-38.
17. Albina, E., Kwiatek, O. Minet, C., Lancelot, R., de Almeida, S.R. and Libeau, G. (2013). Peste des petits ruminants, the next eradicated animal disease? Review," *Veterinary Microbiology*, 165: 38–44.
  18. Dilli, H.K., Geidam, Y.A. and Egwu, G.O. (2011). Peste de Petits Ruminants in Nigeria: A Review," *Nigerian Veterinary Journal*, 32(2): 112 – 119.
  19. Ishag, O.M., Intisar, K.S. and Ali, Y.H. (2014). Detection of antibodies to peste des petits ruminants virus using passive haemagglutination test and cELISA in the White Nile state-Sudan, comparative study," *African Journal of Microbiology Research*, 8(38): 3475-3481.
  20. Charon, K.M. and Lipka, K.R. (2015). The effect of a coat colour-associated genes polymorphism on Animal Health- A review. *Annual Animal Science*, 15(1): 3-17.
  21. Kivaria F.M., Kwiatek O., Kapaga A.M., Swai E.S., Libeau G., Moshy W., Mbyuzi A.O. and Gladson J. (2013). The incursion, persistence and spread of peste des petits ruminants in Tanzania: epidemiological patterns and predictions. *Onderstepoort Journal of Veterinary Research*, 80(1): 593-604.
  22. Mahajan, S., Agrawal, R., Kumar, M., Mahan, A. and Pande, N. (2012). Risk of seroconversion to peste des petits ruminants (PPR) and its association with species, sex, age and migration. *Small Ruminant Research*, 104:195–200.
  23. Mbyuzi, A.O., Komba, E.V., Kimera, S.I. and Kambarage, D.M. (2014). Sero-prevalence and associated risk factors of peste des petits ruminants and contagious caprine pleuro-pneumonia in goats and sheep in the Southern Zone of Tanzania," *Preventive Veterinary Medicine*, 116(1-2): 138–144.
  24. Lawal A., Lasisi O.T., Emikpe B.O. and Ogundipe G.A.T. (2011). Outbreak of peste des petits ruminants in West African Dwarf Goats in Eruwa, Southwestern Nigeria. *Nigerian Veterinary Journal*, 32(4): 331-335.
  25. Okwelum, N., Adewumi, O.O., Akinduti, P.A., Mshelbwala, F.M. and Williams, T.J. (2017) Prevalence of suspected peste des petits ruminants infection and complicating bacteria in goats in Abeokuta, Ogun State, Nigeria," *Nigerian Journal of Animal Production*, 44(3): 43-48.
  26. Olayode, A.B., Adebayo, L.A. and Afolabi, J.A. (2008). Prevalence and effects of peste des petits ruminants (PPR) disease on goats production in Osun State. Postgraduate Thesis, Federal University of Technology, Akure, Institutional Repository, <http://hdl.handle.net/123456789/971>
  27. Bamouh, Z., Fakri, M., Jazouli, O., Safini, F., Tadlaoui, N. and El-harrak, M. (2019). Peste des petits ruminants pathogenesis on experimental infected goats by the Moroccan 2015 isolate. *Veterinary Research*, 15:452.