ACTA VETERINARIA INDONESIANA

Vol. 14, No. 2: 226-233, July 2026
DOI : 10.29244/avi.14.2.226-233
P-ISSN 2337-3202, E-ISSN 2337-4373

Research Article

OPEN ACCESS

Comparative Histopathological Lesions of *Newcastle Disease* in the Respiratory and Digestive Organs of Domestic and Broiler Chickens in Field Cases

Gema Rivani[1], Siti Raudha Maulina[1], Vita Asyilia[2], Aris Munandar[2], Teuku Reza Ferasyi[3,4], Darniati Darniati[4,5], Faisal Jamin[5], Amiruddin Amiruddin[6], Erwin Erwin[4,6], Ummu Balqis[7], Etriwati Etriwati[4,7]*

[1]Master of Veterinary Science Program, Faculty of Veterinary Medicine, Syiah Kuala University, Banda Aceh, Indonesia
[2]Veterinary Medicine Education Program, Faculty of Veterinary Medicine, Syiah Kuala University, Banda Aceh, Indonesia
[3]Laboratory of Veterinary Public Health, Faculty of Veterinary Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia
[4]Center for Tropical Veterinary Studies-One Health Collaboration Center, Universitas Syiah Kuala, Banda Aceh, Indonesia
[5]Laboratory of Microbiology, Faculty of Veterinary Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia
[6]Laboratory of Clinic and Surgery, Faculty of Veterinary Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia
[7]Laboratory of Pathology, Faculty of Veterinary Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia

*Corresponding author: etriwati.2102@usk.ac.id

Article history:
Received: 11 March 2026
Revised : 22 June 2026
Accepted: 29 June 2026

Keywords:
lung
trachea
proventriculus
hematoxylin-eosin
Newcastle disease

ABSTRACT

Background: Newcastle disease (ND) is a highly contagious viral disease of poultry that causes substantial economic losses worldwide. The Newcastle disease virus (NDV) is pantropic and can induce lesions in multiple organs, particularly the respiratory and digestive systems, resulting in varying pathological manifestations among different chicken types.

Aims: This study aimed to determine and compare the histopathological characteristics and distribution of lesions in the respiratory and digestive organs of domestic and broiler chickens that died from Newcastle disease under field conditions.

Methods: A qualitative observational study was conducted using paraffin-embedded trachea, lung, and proventriculus tissues obtained from domestic and broiler chickens previously confirmed positive for ND by immunohistochemistry. All tissue samples were stained with hematoxylin-eosin (HE) and examined descriptively to evaluate histopathological changes and lesion distribution patterns.

Results: Histopathological examination of the respiratory organs revealed tracheitis and pneumonia characterized by congestion, hemorrhage, edema, inflammatory cell infiltration, epithelial desquamation, and necrosis, with multifocal to diffuse distribution patterns. In the digestive organs, particularly the proventriculus, lesions consisting of hyperemia/congestion, hemorrhage, inflammatory cell infiltration, necrosis, and epithelial desquamation were observed, also exhibiting multifocal to diffuse distribution. Comparative analysis demonstrated that domestic chickens exhibited a more extensive distribution of histopathological lesions than broiler chickens in field cases.

Conclusion: Newcastle disease infection in field cases is characterized by tracheitis and pneumonia in the respiratory organs and proventriculitis in the digestive organs. Histopathological lesions are distributed multifocally to diffusely, with domestic chickens showing a broader extent of lesion dissemination than broiler chickens.

INTRODUCTION

Newcastle Disease (ND) is one of the viral poultry diseases that has a major impact on the global poultry industry. This disease has been reported to be widespread in various regions of the world, including Asia, Africa, and America, and is categorized as a notifiable disease by the World Organisation for Animal Health (OIE, 2013). The first outbreak of ND was reported on the island of Java, Indonesia, in 1926, before becoming widely known through reports in Newcastle-upon-Tyne, England (Dharmayanti et al.,

2024). To date, ND remains a major threat to the sustainability of poultry production, especially in developing countries.

Newcastle Disease is caused by avian paramyxovirus type 1 from the Avulavirus genus in the Paramyxoviridae family (Hui et al., 2019). The Newcastle Disease virus (NDV) is highly contagious and can be transmitted directly or indirectly through contact with infected poultry, feces, respiratory secretions, and contaminated equipment (Snoeck et al., 2013). This virus has been reported to infect more than 250 species of poultry and birds, with virulence levels influenced by host factors and circulating virus strains (OIE, 2021). Broiler chickens are one of the hosts susceptible to ND infection, with mortality rates reaching 100% in infections by virulent strains, resulting in significant economic losses (Etriwati et al., 2023b).

Based on clinical manifestations, NDV is classified into five pathotypes, namely viscerotropic velogenic, neurotropic velogenic, mesogenic, lentogenic, and asymptomatic enteric (Alexander & Senne, 2008). In general, NDV circulating in the field often belongs to virulent strains (Walker et al., 2022). The report by AK et al. (2019) shows that 93.66% of isolates from the cloaca-oropharynx of poultry in Aceh Besar Regency and Banda Aceh City fall into the high-virulence category. This finding is reinforced by Etriwati et al. (2023a), who reported that of 106 chicken carcasses necropsied at the Pathology Laboratory of the Faculty of Veterinary Medicine, Syiah Kuala University, 44.4% were confirmed positive for ND. Furthermore, Maulina et al. (2024) reported that 120 chicken carcasses were confirmed to be infected with ND, consisting of layer, domestic, and broiler chickens.

NDV replication is known to cause damage to various organ systems, particularly the respiratory, digestive, and nervous systems (Hartaputera et al., 2024). Common pathological and histopathological lesions of ND include tracheitis, pneumonia, proventriculitis, enteritis, pericarditis, myocarditis, interstitial nephritis, splenitis, atrophy of the bursa of Fabricius, and encephalitis (Etriwati et al., 2017). In addition, the ND virus has a relatively high mutation rate, which can increase virulence, expand tissue tropism, and strengthen viral replication ability, thereby affecting the pattern and severity of tissue damage (Ramey et al., 2013; Lu et al., 2022).

The severity of lesions caused by NDV infection is influenced by various factors, including viral virulence, the age of the chickens, genetic factors, environmental conditions, and the host's immune status (Kapczynski et al., 2013). One factor that plays a key role in the development of immunity against ND is vaccination. Hu et al. (2022) state that vaccination is the primary strategy for the prevention and control of ND in the poultry industry. Nakamura et al. (2014) and Regmi et al. (2024) reported that the protective efficacy of vaccines is associated with a reduction in tissue damage and the severity of lesions in chickens infected with ND. The severity of ND infection can also vary among different chicken breeds. Walugembe et al. (2022) demonstrated that genetic factors contribute to differences in chickens' responses to NDV infection, resulting in varying disease severity across breeds. Therefore, histopathological studies of internal organs in ND field cases, particularly in the context of comparisons between chicken types, are important for understanding variations in tissue responses to ND virus infection.

MATERIALS AND METHODS

Ethical Approval

This research has been approved by the Animal Experimentation Ethics Committee of the Faculty of Veterinary Medicine, Syiah Kuala University Ref: 214/KEPH/2023.

Research Procedure

This study used a qualitative observational method with respiratory and digestive organ samples consisting of the trachea, lungs, and proventriculus from 5 domestic chickens and 5 broiler chickens that had been confirmed positive for NDV based on immunohistochemical testing. Hematoxylin and eosin staining preparations were then made, hematoxylin and eosin staining were performed, and histopathological images were observed.

Preparation of Hematoxylin and Eosin (HE) Staining

Paraffin blocks are cut into 5 µm thick sections using a rotary microtome. The resulting paraffin strips are floated in a water bath at a temperature of 45°C. The tissue preparations are then placed on an object glass. The object glass containing the preparation is then incubated in a slide warmer at a temperature of 37.5°C for 12 hours (Gamble, 2008).

Hematoxylin and Eosin (HE) Staining

The staining procedure begins with deparaffinization using xylol I and II for 5 minutes each, followed by immersion in absolute alcohol I and II, 96% I and II, and 90% I and II for 3 minutes each. Next, the specimen is immersed in water for 3 minutes, then immersed in hematoxylin for 2 minutes and rinsed with running

water. Then the specimen is dipped into acid alcohol twice or more if the blue color is too intense. After that, it is rinsed with water three times. Next, the specimen is immersed in eosin for 2 minutes and dipped five times in water.

The specimen is dipped in 96% alcohol I and II, and absolute alcohol I and II for 2 minutes each. Then the specimen is soaked in and dipped three times in xylol. After the staining process is complete, the specimen is dripped with entellan and immediately covered with a cover glass (Gamble, 2008).

Histopathological Observation

Histopathological observation of the trachea, lungs, and proventriculus, in domestic chickens and broiler chickens infected with Newcastle disease virus was performed by observing lesions found in HE-stained samples. Histopathological lesion assessment was performed according to parameters, namely congestion, edema, hemorrhage, inflammatory cell infiltration, and desquamation in the trachea. In the lungs, the parameters were congestion, edema, hemorrhage, inflammatory cell infiltration, and necrosis. In the proventriculus, the parameters were hyperemia/congestion, hemorrhage, inflammatory cell infiltration, necrosis, and desquamation.

The degree of lesion distribution in the tissue was assessed based on the modified theory of Barros & Rissi (2021), namely distributed at a single small site (focal) with a mild degree of lesion, distributed across several separate sites (multifocal) with a moderate degree of lesion, and extending across nearly the entire tissue (diffuse) with a severe degree of lesion. Observations were made using 100x magnification in five fields of view.

Data Analysis

The results of the observations were analyzed descriptively based on the degree of lesion spread presented in the form of images and tables.

RESULTS AND DISCUSSION

Histopathological observations in broiler chickens and domestic chickens infected with ND in field cases showed lesions in the respiratory and digestive organs with multifocal to diffuse degrees of spread. In general, the types of lesions found in both types of chickens were relatively similar, but the degree of spread and severity of the lesions varied between groups (Tables 1). Domestic chickens showed a more severe degree of spread compared to broiler chickens (Figure 1). Based on anamnesis and maintenance history, broiler chickens in the observed ND field cases were known to have received vaccination against NDV, while domestic chickens did not have a history of vaccination against NDV.

In the respiratory organs, the trachea of domestic chickens showed signs of tracheitis characterized by multifocal congestion, diffuse edema, diffuse hemorrhage, diffuse infiltration of inflammatory cells, and diffuse desquamation of the epithelium. The trachea of broiler chickens also showed tracheitis, characterized by multifocal congestion, diffuse edema, multifocal hemorrhage, diffuse infiltration of inflammatory cells, and diffuse epithelial desquamation.

Histopathological examination of the lungs in domestic chickens revealed pneumonia characterized by diffuse congestion, diffuse edema, diffuse hemorrhage, and diffuse infiltration of inflammatory cells. Additional lesions, including necrosis, thrombi, emphysema, and purulent exudates, were also observed in domestic chickens. In broiler chickens, pneumonia was characterized by multifocal congestion, diffuse edema, multifocal hemorrhage, and multifocal infiltration of inflammatory cells. Additional lesions such as necrosis and thrombi were also found in broiler chickens, whereas emphysema and purulent exudates were not observed.

In the digestive organs, the proventriculus of domestic chickens showed features of proventriculitis characterized by diffuse hyperemia/congestion, diffuse hemorrhage, diffuse infiltration of inflammatory cells, diffuse necrosis, and diffuse epithelial desquamation. The proventriculus of broiler chickens also exhibited proventriculitis, characterized by multifocal hyperemia/congestion, multifocal hemorrhage, diffuse infiltration of inflammatory cells, diffuse necrosis, and diffuse epithelial desquamation.

Histopathological lesions with a diffuse distribution were more predominant in domestic chickens than in broiler chickens. Overall, the pattern of histopathological lesions observed in the respiratory and digestive organs indicates that domestic chickens tend to exhibit a wider distribution of lesions and a greater degree of severity than broiler chickens in field cases.

The differences in the appearance and distribution of ND histopathological lesions in domestic chickens and broilers in field cases indicate variations in tissue response to viral infection. Although both types of chickens show involvement of the respiratory and digestive organs, the pattern of lesion distribution in domestic chickens is more often diffuse than in broilers. This indicates that NDV infection in domestic chickens tends to involve a wider range of tissues, which may reflect differences in host resistance, immune status, and husbandry conditions in field cases.

In the respiratory organs, the trachea and lungs, the lesions observed were vascular and inflammatory changes such as congestion, hemorrhage, edema, and inflammatory cell infiltration, accompanied by epithelial damage in the form of desquamation and necrosis. These findings are consistent with those of Kabiraj et al. (2020), in chickens infected with NDV, histopathological lesions in the lungs were in the form of edema, congestion, hemorrhage, alveolar rupture, and extensive mononuclear cell infiltration, while in the trachea there was edema, epithelial desquamation, tracheitis with inflammatory cell infiltration, and desquamated epithelium was found in the tracheal lumen. Several previous studies have mentioned that hemorrhage and inflammatory cell infiltration are common lesions found in the lungs of chickens infected with NDV (Putra et al., 2012; Lu et al., 2022; Hartaputera et al., 2024). This is reinforced by Etriwati et al. (2017), who stated that the lungs of both young and adult chickens showed severe microscopic damage, characterized by congestion, edema, and mononuclear cell infiltration within and on the walls of the alveoli.

The difference in lesion distribution between domestic chickens and broilers indicates that the respiratory epithelium is the primary target of the ND virus, but the severity and extent of tissue involvement may vary. The more extensive lesions in domestic chickens are thought to be related to longer or uneven exposure to the virus and generally lower biosecurity measures compared to intensive broiler farming systems. This is consistent with the views of Saelao et al. (2018) and Zhang et al. (2023), who state that the severity of Newcastle disease pathological manifestations is influenced by virus virulence, host immune response, and environmental factors.

In the digestive organ proventriculus, lesions in the form of hemorrhage, inflammatory cell infiltration, necrosis, and epithelial desquamation indicate that the ND virus has a high affinity for digestive tract tissue.

Table 1. Degree of Histopathological Lesions in Each Organ. Not observed (-), the distribution of focal lesions with a mild degree (F), multifocal with a moderate degree (M), diffuse with a severe degree (D)

Organ	Parameters Lesion	Type Chicken	
		Domestic	Broiler
Trachea	Congestion	M	M
	Edema	D	D
	Hemorrhage	D	M
	Infiltration of inflammatory cells	D	D
	Desquamation	D	D
Lungs	Congestion	D	M
	Edema	D	D
	Hemorrhage	D	D
	Infiltration of inflammatory cells	D	M
	Necrosis	D	M
	Emphysema	M	-
	Purulent exudate	M	-
Proventriculus	Hyperemia/Congestion	D	M
	Hemorrhage	D	M
	Infiltration of inflammatory cells	D	D
	Necrosis	D	D
	Desquamation of the epithelium	D	D

Farhana & Khaton (2024) found lesions in the proventriculus of 9-week-old commercial chickens on a farm, including congestion around the lobules, necrosis and inflammatory cell infiltration, and hyperemia in the proventriculus gland epithelial cells. Joao et al. (2022) stated that hemorrhage can be found in the proventriculus of chickens infected with Newcastle disease. Research by Etriwati et al. (2017) also mentioned that epithelial cell desquamation, hyperemia, and inflammatory cell infiltration can be observed in the proventriculus of chickens infected with NDV.

Variations in lesion distribution patterns between domestic chickens and broilers in the digestive organs reinforce the assumption that local and systemic immune responses play a role in determining the severity and extent of mucosal damage. Lesions that spread more diffusely in domestic chickens indicate that the pathological process is more extensive than in broilers. The larger extent and greater severity of lesions observed in domestic chickens compared to broiler chickens in this study are likely associated with differences in vaccination status. Broiler chickens had a history of ND vaccination, whereas domestic chickens had not been vaccinated. Khader et al. (2020) reported that vaccinated chickens developed milder lesions than unvaccinated chickens following NDV infection, suggesting that vaccination plays an important role in reducing the degree of tissue damage caused by viral infection. According to Etriwati et al. (2023b), unvaccinated domestic chickens show diffuse hemorrhagic lesions, while vaccinated

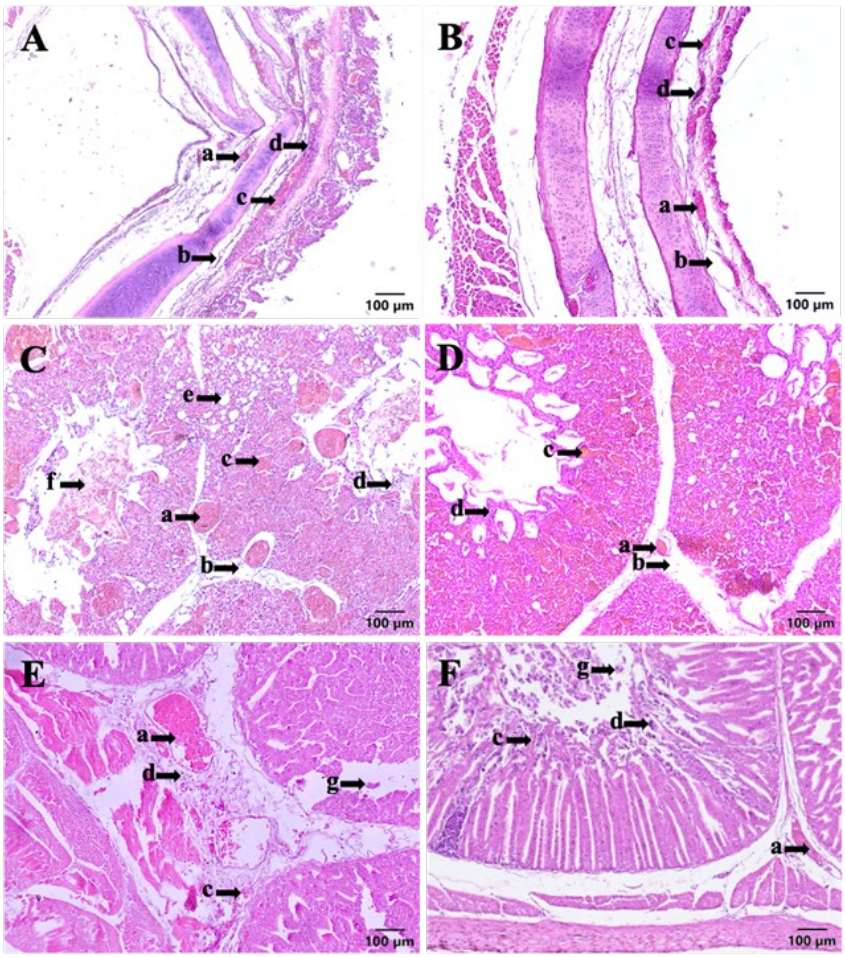

Figure 1. Histopathological lesions in domestic and broiler chickens infected with ND. A, C, E: domestic chickens; B, D, F: broiler chickens A and B. Trachea, C and D. Lung, E and F. Proventriculus. Hyperemia (a), edema (b), hemorrhage (c), inflammatory cell infiltration (d), emphysema (e), purulent exudate (f), epithelial desquamation (g). Hematoxylin and eosin staining. Magnification 100x.

broilers only show petechial lesions that are focal to multifocal in distribution. This indicates that lesions observed in domestic chickens appear more severe compared to other chickens infected with NDV. Therefore, the difference in vaccination status between the two groups of chickens is presumed to have contributed to the variation in lesion severity observed in this study.

Overall, Newcastle disease in field cases causes pathological manifestations in the respiratory and digestive organs of both domestic and broiler chickens. Although the types of lesions observed are relatively similar, including vascular changes, inflammation, and epithelial damage, domestic chickens tend to exhibit a more diffuse distribution of lesions than broiler chickens. According to Kusumawardani and Robin (2018), severe inflammation is characterized by extensive tissue damage, diffuse infiltration of inflammatory cells, and widespread edema and hemorrhage. Differences in the distribution and severity of these lesions indicate variations in the host response to NDV infection. Broom and Kogut (2019) stated that differences in immune responses among chicken strains can influence the level of susceptibility to the disease and the development of associated lesions. Therefore, comparing the histopathological features of domestic and broiler chickens can provide a better understanding of the variations in ND manifestations under field conditions.

CONCLUSION

Newcastle disease infection in the respiratory organs is characterized by tracheitis and pneumonia, while proventriculitis is found in the digestive organs. Histopathological lesions are multifocal to diffuse. Comparatively, domestic chickens exhibit a more widespread distribution of lesions than broiler chickens in field cases.

ACKNOWLEDGEMENT

The authors would like to express their sincere gratitude to Rector of Universitas Syiah Kuala and the Ministry of Education, Culture, Research, and Technology of the Republic of Indonesia for the Master's Thesis Research Grant (PNBP) No. 434/UN11.2.1/PT.01.03/PNBP/2023, 03 May 2023.

AUTHOR CONTRIBUTIONS

E.W. conceived and designed the study, coordinated its implementation, supervised all laboratory activities, interpreted the data, and critically reviewed the manuscript as the corresponding author. G.R., S.R.M., V.A., and A.M. were responsible for sample collection, tissue processing, staining, and assisting with histopathological observations, as well as preparing the initial draft of the manuscript. T. R.F., D.D., F.J., A.A., U.B., and E.E. contributed to the development of the research concept and design, provided critical reviews of the manuscript's content, and revised the manuscript. All authors have read and approved the final version of the manuscript and take responsibility for all aspects of this research.

"The author declares that there is no conflict of interest with the parties involved in this research".

REFERENCES

AK, M. D., Setiyaningsih, S., & Sudirman, I. (2019). Identification and molecular characterization of Newcastle disease virus circulates in some districts in Aceh. *Jurnal Kedokteran Hewan March*, *13*(1), 10-14.

Alexander, D. J., & Senne, D. A. 2008. Newcastle disease. In: Saif YM, editor. *Diseases of Poultry.* 12th ed. Ames (US): Blackwell Publishing. p. 75–100.

Barros, C. S., & Rissi, D. R. (2021). Down the rabbit hole: a quick guide for histopathology description. *Pesquisa Veterinária Brasileira*, 41, 1-21.

Broom, L. J., & Kogut, M. H. (2019). Deciphering desirable immune responses from disease models with resistant and susceptible chickens. *Poultry science*, *98*(4), 1634-1642.

Dharmayanti, N. L. I., Nurjanah, D., Nuradji, H., Suyatno, T., & Indriani, R. (2024). Newcastle disease virus: the past and current situation in Indonesia. *Journal of Veterinary Science*, 25(1), 1–20.

Etriwati., Agungpriyono, D. R., Setiyaningsih, S., Darniati., Daud, M. Ak., Erwin., & Handharyani, E. (2023a). Comparative pathology and immunohistochemistry of Newcastle disease in domestic chicken (*Gallus gallus domesticus*) and Alabio duck (*Anas platyrhynchos* Borneo). *Open Veterinary Journal*, 13(4), 433–442.

Etriwati., Ratih, D., Handharyani, E., & Setiyaningsih, S. (2017). Pathology and immunohistochemistry study

of Newcastle disease field case in chicken in Indonesia. *Veterinary World*, 10(9):1066–1071.

Etriwati., Salim, M. N., Balqis, U., Aisyah, S., Nazaruddin., Amiruddin., Rusli., & Hayati, D. D. (2023b). Findings of tetelo disease in poultry carcasses sent to the pathology laboratory of the Faculty of Veterinary Medicine, Syiah Kuala University. *Veterinary Journal,*24(3), 313–319.

Farhana, N. N., & Khaton, R. (2024). Clinicopathological investigation of Newcastle disease in commercial poultry farms at Bogura district of Bangladesh. *Asian-Australasian Journal of Bioscience and Biotechnology*, 9(3), 45-55.

Gamble M. 2008. Theory and Practice of Histological Techniques. Churchill Livingstone Elsevier, China.

Hartaputera, I. N. S. T., Kencana, G. A. Y., Adi, A. A. A. M., Sudipa, P. H., & Sulabda, I. N. (2024). Newcastle disease in local hens: a case report. *ARSHI Veterinary Letters*, 8(1):9–10.

Hu, Z., He, X., Deng, J., Hu, J., & Liu, X. (2022). *Current Situation and Future Direction of Newcastle Disease Vaccines*. Veterinary Research, 53, 109.

Hui, S., Zhong, L. P., He, J., Huang, Y., & Zhao, Y. X. (2019). Application of Newcastle disease virus in the treatment of colorectal cancer. *World Journal of Clinical Cases*, 7(16),2143–2154.

Joao, A. A. P. C., Adi, A. A.A. M., Astawa, I. N. M., Soejoedono, R. D., Krisnandika, A. A. K., & Sewoyo, P. S. (2022). Isolation of *Newcastle disease* virus genotype VII from native chicken in Republic Democratic of Timor Leste. *Journal of Advanced Veterinary Research*, 12(3), 248-252.

Kabiraj, C. K., Mumu, T. T., Chowdhury, E. H., Islam, M. R., & Nooruzzaman, M. (2020). Sequential pathology of a genotype XIII Newcastle disease virus from Bangladesh in chickens on experimental infection, *Pathogens.* 9(7), 539.

Kapczynski, D. R., Afonso, C. L., & Miller, P. J. (2013). *Immune Responses of Poultry to Newcastle Disease Virus*. Developmental & Comparative Immunology, 41(3), 447–453.

Khader, M. A. A., El-Kady, M. F., & Shaheed, I. B. (2020). *Pathogenesis of Newcastle Disease Virus Genotype VII in Chickens Vaccinated with LaSota and Inactivated Newcastle Disease Vaccines*. International Journal of Veterinary Science, 9(2), 196–202.

Kusumawardani B, RobinDMC. 2019. *Penyakit Dentomaksilofasial*. Intimedia, Malang.

Lu, X., Zhan, T., Liu, K., Chen, Y., Hu, Z., Hu, J., Gu, M., Hu, S., Wang, X., & Liu, X. (2022). Biological significance of dual mutations A494D and E495K of the genotype III Newcastle disease virus hemagglutinin-neuraminidase in vitro and in vivo. *Viruses*, 14(11), 1–17.

Maulina, S. R., Etriwati. E., & Ferasyi, T. R. (2024). Prevalence of Newcastle disease and estimated economic losses in poultry necropsied at the Pathology Laboratory, Faculty of Veterinary Medicine, Syiah Kuala University. *Acta Veterinaria Indonesiana,* 12(2), 154-159.

Nakamura, K., Ito, M., Nakamura, T., Yamamoto, Y., Yamada, M., Mase, M., & Imai, K. (2014). Pathogenesis of Newcastle disease in vaccinated chickens: pathogenicity of isolated virus and vaccine effect on challenge of its virus. *Journal of Veterinary Medical Science*, 76(1), 31-36.

OIE (Office International des Epizooties). 2013. Newcastle disease. In: *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals*. Paris (FR): OIE. p. 1–12.

OIE (Office International des Epizooties). 2021. Infection with Newcastle disease virus. In: *OIE Terrestrial Manual*. Paris (FR), OIE. p. 1–22.

Putra, H. H., Wibowo, M. H., Untari, T., & Kurniasih. (2012). Macroscopic and microscopic lesion studies of chicken embryos infected with a virulent field isolate of Newcastle disease virus. Journal of Veterinary Science, 30(1), 57-67.

Ramey, A. M., Reeves, A. B., Ogawa, H., Ip, H. S., Imai, K., Bui, V. N., Yamaguchi, E., Silko, N. Y., & Claudio L. (2013). Genetic diversity and mutation of avian paramyxovirus serotype 1 (Newcastle disease virus) in wild birds and evidence for intercontinental spread. *Archives of Virology*, 158, 2495–2503.

Regmi, S., Bhatta, R., Pal, P., Shrestha, A., Mató, T., Puri, B., & Paudel, S. (2024). Clinicopathological and molecular investigation of Newcastle disease outbreaks in vaccinated and non-vaccinated broiler chicken floks in Nepal. *Animals*, *14*(16), 2423.

Saelao, P., Wang, Y., Gallardo, R.A., Lamont, S.J., Dekkers, J.M., Kelly, T., & Zhou, H. (2018). Novel insights into the host immune response of chicken Harderian gland tissue during Newcastle disease virus infection and heat treatment. *BMC Veterinary Research*, 14, 280

Snoeck, C. J., Marinelli, M., Charpentier, E., Sausy, A., Conzemius, T., Losch, S., & Muller, C. P. (2013). Characterization of Newcastle disease viruses in wild and domestic birds in Luxembourg from 2006 to 2008. *Applied and Environmental Microbiology*, 79(2), 639–645.

Walker, P. J., Siddell, S. G., Lefkowitz, E. J., Mushegian, A. R., Adriaenssens, E. M., & Alfenas-Zerbini, P. (2022). Recent changes to virus taxonomy ratified by the International Committee on Taxonomy of Viruses. *Archives of Virology*, 167(11):2429–2440.

Walugembe, M., Rowland, K. C., Lwelamira, J., Msoffe, P. L. M., Persia, M. E., & Lamont, S. J. (2022). *Genetic analyses of response of local Ghanaian and Tanzanian chicken ecotypes to a natural challenge with velogenic Newcastle disease virus. Animals, 12(20), 2755.*

Zhang, D., Ding, Z., & Xu, X. (2023). Pathologic mechanisms of the Newcastle disease virus. Viruses, 15(4), 864.