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Newcastle disease virus and antibodies in rural poultry in some selected local government areas of Zamfara State, Nigeria

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Abstract

Newcastle disease (ND) poses a persistent threat to rural poultry production in Nigeria. This cross-sectional study investigated the prevalence of Newcastle disease antigen and seroprevalence of ND antibodies among rural poultry species in three Local Government Areas (LGAs) of Zamfara State's western senatorial zone. A total of 300 samples each for cloacal swabs and sera were collected from indigenous chickens, ducks, turkeys, and guinea fowl. Newcastle disease viral antigen and antibodies analyses were achieved using haemagglutination (HA) and haemagglutination inhibition (HI) tests. The overall ND virus antigen prevalence was 59.7%, and the overall ND antibody seroprevalence was 38.0%. Chickens recorded the highest ND antigen prevalence of 64.1%, followed by ducks with 60.0%. Ducks showed the highest ND seroprevalence of 51.4%, followed by turkeys with 40%, while the chickens had the lowest seroprevalence of 35%. Female birds had a higher prevalence of 64% and a higher seroprevalence of 49.3% than the males. ND virus prevalence and antibody titres varied significantly across the LGAs, with Anka recording the highest rates. Despite widespread exposure, the mean antibody titres across all species were below the OIE-recommended protective threshold of 4.0 Log2, indicating increased vulnerability to ND outbreaks. These findings confirm that ND is circulating and endemic in the study area, posing a potential risk of transmission to commercial farms, which may lead to significant economic impacts. It also emphasizes the role played by ducks in the epidemiology of the disease. The study highlighted the need for the State government to implement ND control policies, including a statewide vaccination campaign, and recommended that further studies should be carried out to characterize the virus in this region.

Keywords: Newcastle disease, Newcastle disease antigen, Rural poultry, Seroprevalence, Nigeria, Zamfara State

Introduction

Poultry production supplies low-cost protein, which makes it one of the most important livestock farming in the world (Absalon *et al.,* 2019). The sector is endangered globally by a devastating disease called

Newcastle disease (ND) (Bashir *et al.,* 2018), which is an important viral disease of poultry.

The disease is caused by a virulent strain of Avian paramyxovirus serotype 1 (APMV -1), which has a wide range of hosts and varies genetically (Welch *et al.,* 2019). Depending on the viral strain and virulence, the ND viruses are grouped into three; velogenic (highly virulent), mesogenic (moderately virulent) and lentogenic (avirulent) based on phylogenic analysis, intracerebral pathogenicity index (ICPI), intravenous pathogenicity index (IPI) as well as mean death time (MDT) (OIE, 2012).

The disease is acute, rapidly spreading, and highly contagious, and affects all ages (Abdu & Musa, 2019). The virus affects a wide range of poultry species (Abdu & Musa, 2019; Absalon *et al.,* 2019). The disease is also reported to occasionally affect humans. It was first reported in England and was named after the place it was discovered, "New Castle Upon Tyne" in 1927 (Alexander, 2001), and in Indonesia around the same time (Alexander, 2009).

The first recorded outbreak in Nigeria occurred in Ibadan in the year 1952 as cited by Sa'idu *et al.* (2006). The disease was reported from several parts of the country, indigenous chickens were reported to serve as a reservoir of ND to commercial poultry as they scavenge around commercial poultry pens (Fatumbi & Adene, 1979; Ezeokoli *et al.,* 1984)

Additionally, the disease is endemic in Nigeria with outbreaks occurring despite vaccination in some instances (Sa'idu *et al.,* 2004; Nwanta *et al*., 2008; Sa'idu & Abdu, 2008). Newcastle disease is a major constraint causing annual outbreaks in rural poultry (Jibril *et al.,* 2014; Alamian *et al.,* 2019; Daodu *et al*., 2019), and economic losses (Musa *et al.,* 2008; Abdu & Oladele, 2016).

In Zamfara state, women in the agro-villages raise Rural poultry (RP) extensively. The sector (free-ranging) represents 46% of the population of poultry in the state (FAO, 2019). Lack of awareness among the rural families regarding vaccination against ND in local poultry and inadequate information on the extent of ND and its economic concern in the study area has been a serious problem for the Zamfara state government.

The state veterinary surveillance and disease control have been constrained mainly by a lack of information on the disease morbidity. The monthly disease data collection and report by the area veterinary officers in the state are also not being accomplished due to insufficient manpower, poor laboratory diagnostic support, and general failure of conventional veterinary service. The study is designed to provide information on the prevalence of ND viruses and their antibodies in rural poultry in Zamfara Western Senatorial Zone for a proper control program of Newcastle disease in the state.

Materials and Methods

Study area

The study was conducted in three Local Government Areas (LGAs) of Zamfara Western Senatorial Zone, comprising Anka, Bukkuyum, and Gummi LGAs. The state lies between latitudes of 10°50N and 13°58N, and longitudes of 4°16E and 7°13E. with an approximate land mass of 38,418 sq.km. The state bordered by Katsina, Sokoto, Kebbi states and Niger Republic to the East, West, South and North respectively.

The vegetation of the state is Sudan and North Guinea Savannah and experiences three seasons (weather conditions) annually. The dry harmattan period which starts from late October to February followed by a warm tropical climatic weather with temperature raising up to 38℃ (100℉) and above, which runs from March to May leading to rainy season with an average rainfall that varies from northern to southern part of the state which starts mostly from late May to early November. The state has fourteen (14) LGAs and is divided into three senatorial zones: the central. Eastern and western zones.

The sampling locations in this study were situated between the latitudes and altitudes of 11° 50'0" N to 12° 20'0" N and 5° 0' 0' E to 5' 40'0"E, which is characterized by numerous rivers, streams, and Fadama areas (Figure 1). Rural poultry are extensively kept in virtually all households of the rural communities. According to the record of Nigeria's poultry population, the total poultry population is estimated to be 5,845,508 (FDLPCS, 2006). Out of which 84% (4,910,226) are indigenous poultry and 16% (935,281) are exotic breeds (FDLPCS, 2006).

Study population

The study population consisted of the free-range (extensively managed) RP kept in purposively selected households in the chosen villages. The population excluded commercial poultry farms, while exotic breeds of poultry found extensively managed together with indigenous poultry that are mixed with indigenous poultry and other animals were included in the study population.

Study design

A cross-sectional study was carried out. A sampling frame containing a list of all local governments and their respective wards and villages was obtained from the Ministry for Local Government and Chieftaincy Affairs. The multistage sampling method was applied based on the three senatorial zones (North, Central and West) of the state. The Western zone was selected for the study, of which three (3) out of six (6) LGAs were randomly selected.

Four villages were considered from each of the three selected LGAs; hence, a total of 12 villages participated in the study. However, in the final stage, convenience sampling was used based on Rural Poultry (RP) owners' compliance to select households with RP. The sample size determined was divided among the RP to be sampled as shown in Table 1.

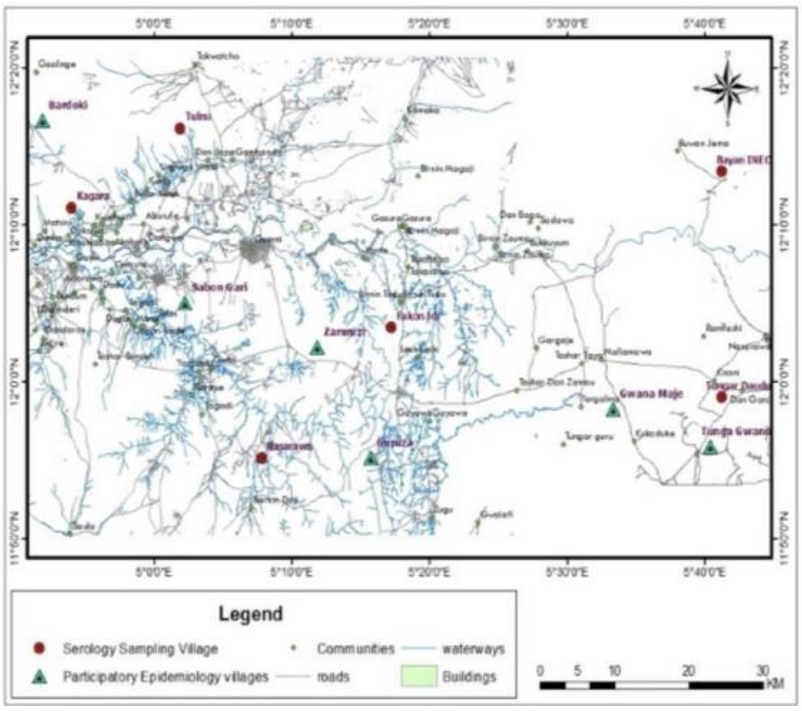

Figure 1: Map of Zamfara state showing the Geo Spatial Distribution of Sampling Locations.Source: GIS Lab Department of Geography ABU Zaria, Using Arc GIS 10.3 Software

Sampling frame and sample size determination

The sampling frame consisted of a list of Local Government Areas and villages obtained from Ministry for Local Government and Chieftaincy Affairs, Gusau, Zamfara State. The villages were selected considering the security situation, or villages that have had previous outbreaks of ND.

The sample size was determined using the formula described by Thrusfield (2007).

$$n = \frac{Z^2\,p(1-q)}{d^2}$$

Thus:

Where: n = Sample size.

Z = 1.96 (Given confidence level of 95%)

P = Sample prevalence (proportion).

d = Desired absolute precision 5% (0.05)

Sample size for cloacal swab samples

Prevalence of ND = 12.5% (Hamisu, 2016).

$$n = \frac{(1.96)^2 \times 0.125 \times (1 - 0.125)}{(0.05)^2}$$

n = 170

Sample size for cloacal swabs = 170

Sample size for blood (sera) samples

Prevalence of ND = 26.7% (Jibril, 2014).

$$n = \frac{(1.96)^2 \times 0.267 \times (1 - 0.268)}{(0.05)^2}$$

n = 300

Sample size for blood (sera) samples = 300

In order to attain representativeness of the samples and to generalize the result. A total of 300 were sampled for both sera and cloacal swab samples.

Sample collection and shipment

Blood collection

About 2 ml of Blood samples were collected from sampled birds (chicken, ducks, turkey and guinea fowls) through the brachial vein. The birds were properly restrained, and their wings were extended to expose the brachial vein. The vein was wiped with a swab containing 70% alcohol, a 21-gauge needle and a 5ml syringe was used to collect the blood, thereafter a pressure was applied with a piece of cotton on the site of insertion of the needle to stop bleeding.

The blood was then transferred into labelled plain blood collecting tubes without anticoagulant and allowed to stand in a slanting position for about two hours at room temperature to clot. The serum was collected and transferred into sterile serum bottles (vacutainers), and was placed into an icepack carrier and transported to the Immunology laboratory, Department of Veterinary Medicine, Ahmadu Bello University, Zaria, and analysed accordingly.

Collection of cloacal swab / fresh faecal sample
With proper restraint, cloacal swabs were taken by inserting a swab stick into the cloaca and the cloacal mucosal wall was gently swabbed until the swabs were deeply stained with faecal materials. The swab was then placed into 2.0 ml of virus transport medium contained in a sterile plastic screw-cap vial and transported on ice to the Immunology Laboratory of the Department of Veterinary Medicine, Ahmadu Bello University, Zaria, where it was kept at 4℃ for 24 hours prior processing.

Heamagglutination inhibition test
Preparation of chicken red blood cells
A 0.25% suspension of RBC was prepared for use in haemagglutination (HA) and haemagglutination Inhibition (HI) tests according to the procedure of OIE (2000).

Antigen
Newcastle Disease *Lasota* virus antigen obtained from the National Veterinary Research Institute (NVRI), VOM, was used as the antigen for the HI test. The HA titres of the ND *Lasota* antigen were determined as described by OIE (2000). The antigen was diluted to contain 4HA units, and this concentration was used for the HI test.

Haemagglutination test for determination of Newcastle disease viral antigen in cloacal swabs
The Haemagglutination was carried out using the method described by OIE (2000).

Haemagglutination inhibition test for detection of ND antibodies
This was carried out using the method of OIE (2000).

Data management and analysis
Data obtained from serology were subjected to SPSS for analysis. GraphPad Prism was used to analyse the association between the categorical variable using chi Chi-square test, and the odd ratio at a 95% confidence interval to determine the strength of association between variables and the prevalence of Newcastle disease. Statistical significance was determined based on the values of $p< 0.05$.

Results
The rural poultry species sampled were chicken, ducks, turkeys and guinea fowl. A total of 300 samples of both cloacal swabs and sera were collected. The proportion of rural poultry sampled was 195(65%) for indigenous chicken, 35(11.7%) for ducks, 35(11.7%) for turkeys and guinea fowl, 35(11.7%) (Table 1).
Table 2 shows the distribution of Newcastle disease viral antigen among the different poultry species sampled in the study area. Out of the 300 samples, a total of 179(59.7%) tested positive, with the highest prevalence found in chickens (64.1%), followed by ducks (60%), and the lowest in guinea fowl (42.9%).
The overall seroprevalence of the ND Antibodies in 300 samples from the rural poultry species across the three selected LGAs was 38.0%, the highest seroprevalence was observed in the duck samples (18, 51.4%), followed by the turkey samples (14, 40%), then the lowest was from chicken samples (69, 35%) (Table 3).
A total of 211(70.3%) of the rural poutry species sampled were females and the males were 89(29.7%). Of this, 135(64%) of the females and 44(49.4%) of the males sampled were positive for NDV antigens. The mean HA antigen time for the males and females was 2.9 Log2 and 3.0 Log2, respectively (Table 4).
Table 5 shows the distribution of mean Newcastle disease titre according to sex, 35(39.3%) of the males and 79(46%) of the females were positive for ND antibodies.
Among the three selected LGAs, Anka recorded the highest prevalence of ND virus antigen (71%) and the highest seroprevalence of ND antibodies (48%). In contrast, Gummi had the lowest prevalence of ND virus antigen (52%) and the lowest seroprevalence of ND antibodies (31%). The differences in the prevalence of both ND virus antigen and ND antibodies across the LGAs are statistically significant (Table 6).
The mean viral antigen titre for the rural poultry in the study area was 3.16 ± 0.32 log2, 3.09 ± 0.36 Log2, 2.93 ± 0.20 log2 and 2.10 ± 0.67 Log2 in chickens, ducks, turkeys and guinea fowl, respectively (Table 7).
The mean ND antibody titre of the sampled poultry was highest in the ducks (2.03 ± 0.09 Log2), followed by that in the guinea fowl (1.50 ± 0.27 Log2), and the least was observed in the chickens (1.44 ± 0.8 Log2) as shown in Table 8.

Discussion
In the study area, chickens constituted 65% of the rural poultry species sampled. This is because chickens are the most commonly kept rural poultry in most parts of the area and many villages across Nigeria. Musa *et al.* (2009) reported that 20.3, 6.0, 0.3, and 1.2 were the mean number of chickens, ducks, turkeys and guinea fowl kept per rural household in Plateau State.

Table 1: Distribution of rural poultry species sampled for serology from the selected LGAs in the study area

LGAs	Rural poultry species				Total
	Chickens (%)	Ducks (%)	Turkeys (%)	Guinea fowls (%)	
Anka	63 (21)	13 (13)	12 (12)	12 (12)	100
Bukuyum	69 (23)	10 (10)	11 (11)	10 (10)	100
Gummi	63 (21)	12 (12)	12 (12)	13 (13)	100
Totals (%)	195 (65)	35 (11.7)	35 (11.7)	35 (11.7)	300 (100)

Table 2: Distribution of ND antigen among rural poultry in the three selected LGAs of Zamfara State

Rural Poultry	No. tested	No. positive (%)	No. Negative (%)	Total
Chicken	195	125 (64.1)	70 (35.9)	195
Ducks	35	21 (60)	14 (40)	35
Turkeys	35	18 (51.4)	17 (48.6)	35
Guinea Fowl	35	15 (42.9)	20 (57.1)	35
Total (%)	300	179 (59.7)	121 (40.3)	300

Table 3: Distribution of ND Antibodies among Rural Poultry in the three selected LGAs of Zamfara State

Rural Poultry	No. tested	No. positive (%)	No. Negative (%)	Total
Chicken	195	69 (35)	126 (65)	195
Ducks	35	18 (51.4)	17 (48.6)	35
Turkeys	35	14 (50)	21 (60)	35
Guinea Fowl	35	13 (37.1)	22 (62.9)	35
Total (%)	300	114 (38)	186 (62)	300

Table 4: Sex distribution of the mean HA Log2(Antigen) titre of rural poultry in the three LGAs of Zamfara

Sex	No. tested (%)	No. positive (%)	Mean HA	Odd ratio	95% CI	P value
Male	89 (29.7)	44 (49.4)	2.9 ± 3.0	0.551	(0.333 – 0.909)	0.019
Female	211 (70.3)	135 (64.0)	3.0 ± 0.70			
Total (%)	300	179 (59.7)				

Table 5: Sex distribution of the mean HI Antibodies Log2 titre of rural poultry in the three LGAs of the study area

Sex	No. tested (%)	No. positive (%)	Mean HI ≥2Log_2 titre	Odd ratio	95% CI	P value
Male	89 (29.7)	35 (39.3)	1.15 ± 0.34	1.082	(0.942 – 1.978)	0.758
Female	211(70.3)	79 (46)	1.30 ± 0.20			
Total (%)	300	114 (38)				

Table 6: Newcastle disease virus antigen and antibody among the rural poultry in the three LGAs of Zamfara state study

LGAs	No. tested	HA			HI		
		No. positive (%)	X^2	P value	No. positive (%)	X^2	P value
Anka	100	71 (71)	19.99	0.001	48 (48)	6.70	0.0356
Bukuyum	100	56 (56)			35 (35)		
Gummi	100	52 (52)			31 (31)		
Total	300	179 (59.7)			114 (38)		

LGAs: Local government areas; HA: Heamagglutination assay; HI: Heamagglutination inhibition; X^2: Chi-square value

The overall prevalence of ND antigen was 59.7%, indicating that the ND virus is actively circulating in the study area. Chickens had the highest prevalence at 64%, further signifying their role in the transmission of the virus, as noted in previous studies (Musa *et al.,* 2009). Ducks showed a 60% prevalence, suggesting they may serve as reservoirs for the ND virus, shedding it continuously and contaminating the environment. Despite the low number of ducks sampled, a 60% prevalence is significant and could contribute to the annual outbreaks of ND (Sa'idu *et al.,* 1994; Halle *et al.,* 1999). A highly virulent ND virus

strain for chickens was isolated from apparently healthy ducks (Echeonwu *et al.,* 1993). This study also shows that a considerable number of guinea fowls and turkeys carried ND antigens despite their lower sample populations.

The overall seroprevalence of ND in the study area was higher than the 32.5% reported by Jibril *et al.* (2014) in Zamfara State and by Balami *et al.* (2022). This difference may be due to the displacement of several communities caused by ongoing insecurity in the region, which has led displaced persons to move with their livestock and birds. However, the seroprevalence observed here is lower than the 55.5% reported in Gombe State by Lawal *et al.* (2015), the 52.23% in Maiduguri (Saddiq *et al.,* 2011), and the 51.9% in Plateau (Musa *et al.,* 2009). Differences in seroprevalence rates could be attributed to variations in environmental factors, study design, location, types of birds sampled, and the serological tests employed.

In this study, ND seroprevalence in chickens was 35%, which is lower than in ducks (51%), turkeys (40%), and guinea fowls (37.1%). The observed seroprevalences are likely due to natural exposure to the ND virus, as there was no history of ND vaccination. A similar finding was reported by Abdu & Garba (1989). The higher ND seroprevalence in ducks is concerning because ducks are known asymptomatic carriers of ND. A similar pattern was reported in Brisbane, Australia (Bouzari, 2014). Much higher seroprevalence rates of 92% in chickens, 76% in guinea fowls, 68% in turkeys, and 44% in ducks were reported by Sa'idu *et al.* (2004). These discrepancies may be due to differences in study sites as their study was conducted in the Zaria Abattoir live bird market, while this study involved rural household poultry. The indiscriminate mixing of birds of different health statuses, sexes, species, and ages in live bird markets encourages disease spread.

The mean ND antigen prevalence was higher in females (64%) than in cocks (49%), likely because 70.3% of the tested rural poultry were females, while only 29.7% were cocks. In rural household settings, females are usually more numerous, followed by growers and chicks. Cocks are generally fewer, as they are often culled. Musa *et al.* (2008) reported that household flock composition included hens (25.7%), growers (39.1%), chicks (29.4%), and cocks (5.8%). The distribution of ND antibodies followed a similar pattern to that of the antigen, with a seroprevalence of 49.3% in hens and 39.3% in cocks.

The prevalence of ND and the seroprevalence of ND antibodies were highest in Anka LGA, compared to Bukuyum and Gummi. This may be because Anka, particularly Anka town, has become a centre for internally displaced persons (IDPs) from within and outside the study area due to banditry. These displaced individuals often bring their livestock and poultry with them. Another possible reason is the increased poultry activity in Anka town and the

Table 7: Mean Haemagglutination titres Log_2 of ND Virus Antigen in Rural Poultry Species in three LGA of Zamfara State

Rural poultry species	HA antigen titre Log_2 ± SD			Overall mean ± SD
	LGAs			
	Anka	Bukuyum	Gummi	
Chickens	3.31 ± 2.44	2.81 ± 2.69	3.38 ± 2.58	3.16 ± 0.31
Ducks	3.33 ± 2.77	3.27 ± 2.43	2.67 ± 1.93	3.09 ± 0.36
Turkeys	3.00 ± 3.18	2.70 ± 2.41	3.08 ± 1.06	2.93 ± 0.20
Guinea fowl	1.90 ± 2.88	3.00 ± 1.58	1.40 ± 2.68	2.10 ± 0.67

LGAs: Local government areas; HA: Heamagglutination assay

Table 8: Mean Heamagglutination Inhibition antibodies titres (Log2) of ND Virus Antigen in Rural Poultry Species in three LGAs of Zamfara State

Rural poultry species	Mean HI antibody titre ± SD			Overall mean ± SD
	LGAs			
	Anka	Bukuyum	Gummi	
Chickens	1.56 ± 1.86	1.23 ± 1.59	1.52 ± 1.82	1.44 ± 0.80
Ducks	1.93 ± 1.75	2.07 ± 1.58	2.09 ± 1.04	2.03 ± 0.09
Turkeys	1.33 ± 2.13	1.08 ± 0.90	2.00 ± 2.10	1.47 ± 0.47
Guinea fowl	1.63 ± 2.13	1.67 ± 2.66	1.19 ± 1.17	1.50 ± 0.27

LGAs: Local government areas; HI: Heamagglutination inhibition

presence of the popular Bagega market, which may contribute to the high prevalence and seroprevalence of ND in the area. Sa'idu *et al.* (2004) also reported high ND seroprevalence in rural poultry sampled from the Zaria Abattoir.

The mean ND antigen titre in chickens, ducks, and turkeys in Anka LGA was slightly above 3.0 Log2. Although the OIE (2000) recommends that titres below 4.0 Log2 be considered negative, a titre of 3.0 Log2 in ducks is alarming due to their role in ND epidemiology. Guinea fowls in Anka and Gummi LGAs had lower titres, possibly due to their semi-domesticated nature. The mean ND antibody titre across all LGAs studied was below the protective threshold recommended by the OIE (2000), which is 4.0 Log2. Sa'idu *et al.* (2004) reported that only ducks had a titre of 1.5 Log2 in their study. The low antibody titres in the LGAs suggest that the birds are vulnerable to ND infection, which may explain the frequent ND outbreaks during the harmattan season (Halle *et al.,*1999; Sa'idu *et al.,* 1994; Musa *et al.,* 2009).

It was concluded from this study that, ND is endemic in the study area, as evidenced by the high seroprevalence of ND antibodies and the high prevalence of ND antigen. The high prevalence of ND antibodies and antigens in ducks is a serious challenge concerning their role in the epidemiology of ND. The low mean antibody titres suggest that birds in the region remain Vulnerable to ND infection. This result also shows that the ND virus is circulating among the Rural Poultry species, which may pose a potential risk of transmission to commercial farms, leading to significant economic losses. This finding is particularly concerning regarding the ongoing Newcastle disease outbreaks in the area. The study highlighted and recommended the need for the State government to make a policy on control of Newcastle disease through adoption of state-wide vaccination campaign, as it does with other important livestock diseases like CBPP, and further studies should be carried out to characterize the virus in this region.

References

Abdu PA & Garba IM (1989). Newcastle disease haemaglutination antibodies in vaccinate chicks. *Zariya Veterinarian,* **14**(2): 63-65.

Abdu P & Oladele SB (2016). Awareness of farmers on Newcastle disease, its vaccination and antibody titre in commercial chickens in Jos South, Nigeria. *Journal of World's Poultry Research,* **6**(2): 84-91.

Abdu PA & Musa- U (2019). Textbook of Avian Medicine, second edition. Saniez Press, Jos-Plateau State, Nigeria. Pp 120-124.

Absalon AE, Cortés-Espinosa DV, Lucio E, Miller PJ & Afonso CL (2019). Epidemiology, control, and prevention of Newcastle disease in endemic regions: Latin America. *Tropical Animal Health and Production,* **51**(5): 1033-1048.

Alamian A, Pourbakhsh SA, Shoushtari A & Keivanfar H (2019). Seroprevalence investigation of Newcastle disease in rural poultries of the Northern provinces (Golestan, Gilan, and Mazandaran) of Iran. *Archives of Razi Institute,* **74**(4): 365-373.

Alexander DJ (2001). Newcastle disease. *British Poultry Science,* **42** (1): 5-22.

Alexander DJ (2009). Ecology and Epidemiology of Newcastle disease. Avian Influenza and Newcastle Disease. *A Field and Laboratory Manual,* Springer, Milano. Pp 19-26.

Balami AG, Wungak YS, Bata SI & Gang S (2022). Seroprevalence of Newcastle disease virus antibodies in village chickens in the three senatorial zones of Plateau State, Nigeria. *Sokoto Journal of Veterinary Sciences,* **20**(2): 119-124.

Bashir MB, Yusoff KM, Ideris A, Hair-Bejo M, Peeters B P, Jibril AH & Omar AR (2018). Genotype diversity of Newcastle disease virus in Nigeria: Disease control challenges and future outlook. *Advances in Virology,* doi.10.1155/2018/6097291.

Bouzari M (2014). The response of ducks to V4 Newcastle disease virus and its transmission to contact ducks and domestic chickens. *Veterinary Research Forum,* **5**(2): 145–148.

Daodu OB, Aiyedun JO, Kadir RA, Ambali HM, Oludairo OO, Olorunshola ID, Daodu OC & Baba SS (2019). Awareness and antibody detection of Newcastle disease virus in a neglected society in Nigeria. *Veterinary World,* **12**(1): 112-118.

Echeonwu GON, Iroegbu CU & Emeruwa AC (1993). Recovery of velogenic Newcastle disease virus from dead and healthy free-roaming birds in Nigeria. *Avian Pathology,* **22**(2): 383-387.

Ezeokoli DC, Umoh JU, Adesiyun AA & Abdu PA (1984). Prevalence of Newcastle disease virus antibodies in local and exotic chickens under different management systems in

Nigeria. *Bulletin of Animal Health and Production in Africa,* **32**(3): 253-257.

FAO (Food and Agricultural Organization of the united nation) (2019). The Future of Livestock in Nigeria. Opportunities and Challenges in the Face of Uncertainty, Rome. Pp 29-36.

Fatumbi OO & Adene DF (1979). Susceptibility of Nigerian local chicken to a fulminating Newcastle disease outbreak. *Nigerian Veterinary Journal,* **8**(21): 30-32.

FDLPCS (Federal Department of Livestock and Pest Control Service) (2006). Highly Pathogenic Avian Influenza Standard Operating Procedure, Federal Ministry of Agriculture and Rural Development, Abuja. Pp 57.

Halle PD, Umoh JU, Sa'idu L & Abdu PA (1999). Prevalence and seasonality of Newcastle disease in Zaria, Nigeria. *Tropical Veterinarian,* **17**(1): 53-62.

Hamisu TM, Kazeem HM, Majiyagbe KA, Sa'idu L, Jajeri SM, Shettima YM, Baba TA, Olufemi OT, Shittu I & Owolodun OA (2016). Molecular screening and isolation of Newcastle disease virus from live poultry markets and chickens from commercial poultry farms in Zaria, Kaduna state, Nigeria. *Sokoto Journal of Veterinary Sciences*, **14** (3): 18-25.

Jibril AH, Umoh JU, Kabir J, Saidu L, Magaji AA, Bello MB & Raji AA (2014). Newcastle disease in local chickens of live bird markets and households in Zamfara State, Nigeria. *International Scholarly Research Notices,* doi.10.1155/2014/513961.

Lawal JR., Jajeri SM, Mustapha M, Bello AM, Wakil Y & Geidam IA (2015). Prevalence of Newcastle disease in Gombe northestern Nigeria: A ten-year retrospective study (2004-2013). *British Microbiology Research Journal,* **6**(6): 367-375.

Musa U, Abdu PA, Dafwang II, Edache I & Ahmed A (2008). A Survey of Cause of Mortality in Some Local Chicken Flock in Plateau State. In: *Proceedings of the 33rd Annual Conference of the Nigerian Society of Animal Production* held at Ayetoro, Ogun state from 16th to 20th March, 2008. Pp 551-554.

Musa U, Abdu PA, Dafwang II, Umoh JA, Sa'idu L, Mera UM & Edache JA (2009). Seroprevalence, sesosonal occurrence and clinical manifestation of Newcastle disease in rural household chickens in Plateau State, Nigeria. *International Journal of Poultry Science,* **8**(2): 200-204.

Nwanta JA, Egege SC, Alli-Balogun JK & Ezema WS (2008). Evaluation of prevalence and seasonality of Newcastle disease in chicken in Kaduna, Nigeria. *World's Poultry Science Journal,* **64**(3): 416-423.

OIE (2000). Newcastle Disease: Manual of Standard for Diagnostic Tests and Vaccines. Fifth edition. Office International des Epizootic (OIE) Paris, France. Pp 104-124.

OIE (2012). Newcastle disease. *Manual of Diagnostic Tests and Vaccines for Terrestrial Animals: Birds and Bees*, seventh edition (Vol 1. Part 2). Biological Standards Commission. World Organization for Animal Health, Paris, France. Pp 555-574.

Saddiq MA, Nwanta JA, Okolocha EC & Tijjani AM (2011) Retrospective (2000-2009) studies of Newcastle disease (ND) cases in avian species in Maiduguri, Borno State, North Eastern Nigeria. *International Journal of Poultry Science*, **109**(1): 76-81

Sa'idu L, Abdu PA, Umoh JU & Abdullahi SU (1994). Disease of Nigerian indigenous chickens. *Bulletin of Animal Health and Production in Africa,* **42**(1): 19-23.

Sa'idu L, Tekdek LB & Abdu PA (2004). Prevalence of Newcastle disease antibodies in domestic and semi domestic birds in Zaria, Nigeria. *Veterinary Archives,* **74** (4): 309-317.

Sa'idu L, Abdu PA, Tekdek LB, Umoh JU, Usman M & Oladele SB (2006). Newcastle disease in Nigeria. *Nigerian Veterinary Journal,* **27**(2): 23-32.

Sa'idu L & Abdu PA (2008). Outbreak of viscerotropic velogenic form of Newcastle disease in vaccinated six-week-old pullets. *Sokoto Journal of Veterinary Sciences,* **7**(1): 37-40.

Thrusfield, M. (2007). *Veterinary Epidemiology*, third edition, BlackWell Science Limited, A Black Publishing Company, London. Pp 233.

Welch CN, Shittu I, Abolnik C, Solomon P, Dimitrov KM, Taylor TL & Gado DA (2019). Genomic comparison of Newcastle disease viruses isolated in Nigeria between 2002 and 2015 reveals circulation of highly diverse genotypes and spillover into wild birds. *Archives of Virology,* **164**(8): 2031-2047.