In January, 2015 the National Veterinary Research Institute, Vom, Nigeria received some chicken carcasses from the Kano state Ministry of Agriculture. The carcasses were from a backyard-commercial poultry farm and a live bird market (LBM) in Kauna and Sabon gari, Kano state, northwestern Nigeria respectively. The farm kept different types of chickens of various ages and stages and was experiencing high mortality of 350 birds daily with eventual 100% mortality observed in the older birds (54weeks). In a concurrent incidence, reports were received of unusual high mortality of birds brought from the northern part of the country at two LBMs in Onipanu and Mushin, Lagos state, southwestern Nigeria. A total of 8 chicken carcasses from the Kano suspicion were subjected to postmortem examination and testing. One broiler-chicken (4weeks old), 4 layer-chicken (22 weeks old) and 3 indigenous bred-chickens (from LBM) showed severe pathological lesions consistent with highly pathogenic avian influenza (HPAI). Moribund birds from the Lagos suspicion had cyanotic comb and wattles, torticollis and paralysis of the limbs. Parenchymatous organs, nasal and trachea swabs were collected from the dead and moribund birds respectively. The specimens were analyzed by RT-PCR and virus isolation in embryonating chicken eggs. All samples were found to be positive for HPAI (H5N1) subtype. This marks the re-introduction of HPAI (H5N1) subtype into Nigeria for a second time in the space of 9-years. So far, over 542 cases (January to December, 2015) have been confirmed positive for HPAI (H5N1) in 20 states of the country. Possible circumstances surrounding the resurgent and spread are discussed herein.

**Keywords:** Epidemiology, Resurgent HPAI H5N1, Pathology, Nigeria
Introduction:

Exactly 9-years ago, highly pathogenic avian influenza (HPAI) H5N1 strain was detected in a commercial poultry farm in Kaduna state, north central Nigeria for the first time on the African continent (Joannis et al., 2006; De Benedictis et al., 2007). Subsequently, the virus spreads to approximately 70% (25 out of 36) of the states of the Federation including the Federal Capital Territory (Abuja) within a short period of time with several waves of the outbreaks observed across the country during the 2006-2008 episode (Joannis et al., 2008; Fusaro et al., 2009; Métras et al., 2013). The disease also disseminated to eleven other African countries and has since become endemic in Egypt affecting both humans and animals (ELbayoumi et al., 2013; Métras et al., 2013). As a follow up to reported outbreaks in both commercial and scavenging rural poultry, the Avian Influenza Control Project resident with the Federal Livestock Department under the country Ministry of Agriculture in conjunction with other stakeholders conducted targeted, active surveillance in high risk areas especially live bird markets (LBMs). During the course of the surveillance activities in July, 2008 a new sub-clade of HPAI (H5N1 clade 2.2.1.1) hitherto unreported in Africa was recovered from Gombe a northeastern state in Nigeria (Fusaro et al., 2009). After two years of intense surveillance, testing and culling of infected farms with adequate compensation, and strict biosecurity measures, the disease was eventually stamped-out of Nigeria in 2008. Following the introduction and subsequent control of HPAI in Nigeria (Akanbi and Taiwo 2014a, 2014b) there has not been any official report of HPAI (H5N1) in Nigeria since July, 2008. HPAI is known to be a fatal disease of gallinaceous birds, causing up to 100% mortality (Klopfleisch et al., 2006; Alexander 2008). The source of the 2006-2008 outbreaks caused by multiple strains of HPAI (H5N1) were attributed to commercial poultry, trade (Fasina et al., 2009) and wild birds (Ducatez et al., 2006; Fusaro et al., 2010). All together, around 939,620 commercial type chickens on 127 farms (Akanbi and Taiwo 2014a) and 14,512 local chickens on 80 backyard farms were lost to HPAI H5N1 between 2006 and 2008 (Akanbi and Taiwo 2014b). This significantly affected the economy not only because a sum of N631 million (US$5.43 million) was paid as compensations to farmers (Durosinlorun et al., 2010), but also because poultry contribute huge resources to the national economy and this emphasizes the importance of commercial poultry (Fasina et al., 2007). In addition, a case of human infection was documented (Nasidi et al., 2007) but no antibodies were detected in laboratory and poultry workers tested...
(Ortiz et al., 2007) during the 2006-2008 HPAI (H5N1) outbreaks. Given that Nigeria lies within the migratory routes of wild birds from Asia and Europe coupled with the poorly regulated poultry trade within the sub region, the country remains at risk of re-introduction of HPAI (H5N1). This paper is therefore aimed at reporting the epidemiology, clinicopathologic characteristics and examines the circumstances surrounding the re-introduction of the resurgent HPAI (H5N1) into Nigeria.

**Materials and Methods**

**Cases history and spatial distribution**

**Kano outbreaks**

On the 24th December, 2014, at a LBM in Sabon gari, Kano state, large number of death in chickens, geese and turkeys were recorded. This incidence was reported to the authority of the Ministry of Agriculture and whole carcass samples of the birds were collected and sent to National Veterinary Research Institute, Vom, (NVRI) Plateau state. The following signs were observed before death; respiratory distress, watery faeces, cyanotic comb and haemorrhagic shanks. Daily mortality was said to exceed 300 birds, and majority of the birds were sourced from Kanya market, Jigawa state, Nigeria and from Adare town in Maradi governorate in Niger republic (Figure I).

In a similar scenario, a poultry farm in Kauna (12.037N, 8.487E), Kano state, northwest Nigeria with a poultry population (4 week-old broiler) of about 3000 observed a sudden, high mortality of more than 200 birds on the 1st of January, 2015 and 350 birds on the 2nd, and more than 300 birds on the 3rd in its laying flock of 22 weeks old. In addition, 100% (n=500) mortality was observed in a 54 weeks old laying flock kept on the same facility.

**Lagos outbreak**

In December 2014 just before the Christmas festival, live birds were transported from the northern part of the country by road for sale in markets in Lagos metropolis. Shortly after, there were reports of unusual high mortality with moribund birds showing cyanotic comb and wattles, torticollis and paralysis of the limb. These signs were observed following the introduction of
those birds to the live bird markets particularly in Onipanu and Mushin areas (03.423N, 06.612E). Nasal and trachea swabs were collected from two birds (one live, one dead) in virus transport medium and transported on cold chain to the National Veterinary Research Institute, Vom, Plateau state, Nigeria.

For the spatial analysis, direct farm visits to obtain coordinates of affected farms, for terrains that could not be visited, coordinates were obtained by picking points in the affected local government areas. Coordinates were fed into Arc Map version 10.2.1

**Post-mortem and Histopathological examination:**

Post-mortem examination (PME) of the carcasses was performed and the findings documented. Parenchymatous organs (trachea, lung, heart, spleen, liver and intestine) from PME of all the chickens were collected for histopathology, virus detection and isolation.

Formalin-Fixed tissues were then embedded in paraffin, sectioned at 5 μm, mounted on clean glass slides, and stained with hematoxylin and eosin (H&E) stains for histopathological examination using low and high powered field of Carl Zeiss or Nikon binocular microscope.

**Molecular Analysis:**

Pooled tissues (trachea, lung, liver and spleen) were homogenized and centrifuged using standard procedure (OIE 2015). Nucleic acid extraction was carried out on the supernatant using Qiagen RNA kit (Hilden, Germany) according to the manufacturer’s instruction. Thereafter, one-step RT-PCR assay targeting the matrix gene (M-gene) (Fouchier et al., 2000) was performed using GeneAmp® Gold RNA PCR core kit (Applied Biosystems, Foster City, CA, USA) on 9700 thermocycler system (Applied Biosystems, Foster City, CA, USA). Samples that were positive for the M-gene were subtyped with H5 protocol as previously described by Slomka et al., (2007) and Huang et al., (Huang et al., 2013) respectively. The amplicons were run in 1.5% agarose stained with ethidium bromide and electrophoresed at 120 volts for 30 minutes and thereafter visualized with a Gel Documentation system (Biorad). Samples that were positive for the M-gene were subtyped with H5 protocol as previously described (Slomka et al., 2007). The N1 typing of the index cases from Kano and Lagos were determined as previously described (Monne
et al., 2015). Subsequent determination of the N1 subtypes were carried out using the procedure of Huang et al., (2013)

**Virus Isolation**

Virus isolation was carried out by inoculating 9-day old embryonating chicken eggs with 0.1ml of the supernatant fluid of homogenized tissues. Egg embryo that died after 24 hours post inoculation were chilled and harvested. This was subsequently tested by haemagglutination and haemagglutination-inhibition for AIV performed according to OIE protocol (OIE, 2015).

**Results**

**Spatial Distribution of HPAI H5N1 Cases in Nigeria January to December, 2015**

Following the detection of the virus in the samples from Kano and Lagos states, the virus rapidly spread to other states including Plateau, Bauchi, Delta, Anambra, Edo, Gombe, Imo, Jigawa, Kaduna, Katsina, Nasarawa, Ogun, Rivers, Sokoto, Zamfara, Enugu and Abia. It was observed that the virus rapidly spread most in Kano, Plateau and Bauchi States. In total, Twenty (20) States have been affected by the virus (Figure I) and a total of 542 cases of HPAI H5N1 were recorded on farm premises as at the end of December, 2015. The map also shows the trade road network between Kano and Jigawa states in Nigeria and the Adare town in Maradi governorate in Niger republic.

**Necropsy findings**

A total of 8 carcasses were received and necropsied from the Kano suspicion. One broiler-chicken (4 weeks old), four layer-chicken (22 weeks old) and three indigenous bred-chickens. The combs and wattles were swollen, hyperemic and haemorrhagic (5/8; 62.5%) (Figure IIA) while three were cyanotic (3/8; 37.5%). The broiler showed multifocal, ecchymotic haemorrhages on the pectoralis muscle, while all carcasses showed varying degrees of shank and foot hyperemia and haemorrhages (Figure IIB) and haemorrhagic ulcers (multifocal, ecchymotic) were observed in one local fowl. The upper palate and the oropharynx in one of the indigenous chickens had multifocal areas of ecchymotic haemorrhages, while all the other showed congestion of the distal 2/3rd of the trachea. The lungs were severely edematous, congested, and haemorrhagic (Figure IIC), with fibrinous deposits on the pleura while the air sacs were cloudy.
The histopathology of the lung showed severe interstitial pneumonia with diffuse heterophilic and lymphocytic cellular infiltration and occasional airsac oedema and epithelia loss (Figure IID). Thymus in one of the birds was swollen and enlarged with multifocal ecchymotic haemorrhages while the spleen in one was enlarged up to 5 times. Congested liver and mesenteric vessels were observed in some birds with a haemorrhagic pancreas. The intestine had multifocal up to 0.8 cm in diameter ecchymotic haemorrhages. Summary of varying degrees of lesions and necropsy findings of selected cases of carcasses received for diagnosis from January to December, 2015 suspicion across the country are as shown in Table I. Also, the weekly distribution of cases from January to December are shown in figure III.

**Molecular Detection:**

More than 500 cases have tested positive for Influenza A by M and H5 gene in 20 states of the Federation, with the virus widely disseminated in Kano, Bauchi and Plateau state (Figure I). In all samples, gel electrophoresis revealed bands at 240 and 300 base pair (bp) corresponding to the expected band sizes for the M and H5 gene respectively (Figure IVA and B). Similarly, a 137bp band size was observed for the N1 assay (data not shown). Some of the samples were positive for Newcastle disease virus.

**Virus isolation**

All the positive samples were successfully isolated in embryonated eggs within 48 hours with an HA titer ranging between 7 and 10 Log2. The isolates were also inhibited by H5 reference antiserum.
Discussion

This first reported HPAI (H5N1) case in 2015 in Nigeria occurred on a farm that kept different types of chickens of various ages and stages as was the 2006 H5N1 index case. Rearing of different poultry at different stages have been observed to influence the mortality of H5N1 in the country (De Benedictis et al., 2007). The high mortality and the patho-morphological changes in the chickens are consistent with HPAI which was confirmed by molecular and virological tests as well as sequence analysis. Sequence data of the virus has placed it within the genetic clade 2.3.2.1c (Monne et al., 2015).

Most outbreaks of H5N1 have been reported to occur during January to March (Durand et al., 2015). In this outbreak, reports of high mortality were observed in December. Similarly epidemiological findings suggest that there have been unreported cases of high mortality in poultry farms and live bird markets in Kano and Lagos State during the later part of 2014. This period (December) in Nigeria, is associated with increase travelling of city dwellers to their home towns/villages for Christmas and end of the year celebrations. Majority of these travelers buy and take with them live poultry. This results in increased demands for live poultry during this period, which motivate live bird sellers to move from locations to locations across the length and breadth of the country in search of live poultry. Movement of apparently healthy poultry in anticipation of festivities or holidays have been identified as source of transmission (Nwanta et al., 2008; Durand et al., 2015). This practice easily supports the contamination of farms and introduction of infectious agent among farms.

Pathological lesions shown by some of the samples are consistent with HPAI (H5N1) as reported earlier especially lesions seen on the comb and wattles (Monne et al., 2015). Although, other lesions such as serosal and fat haemorrhages, shank hyperemia, pancreatic necrosis and pneumonia can be seen in outbreak of velogenic Newcastle disease in unvaccinated flock as early observed in 2012 at our laboratory in Vom, Nigeria (NVRI database 2012, unpublished report).

It has also been observed that the lessons learnt and the control measures implemented for the 2006 outbreaks have been relaxed, some of which include: ban on the indiscriminate movement of poultry and poultry products in and across the country’s borders and poor biosecurity
measures. In addition, it has been observed that improper disposal of poultry carcasses, poor biosecurity measures including disregard for farm isolation and perimeter fencing, indiscriminate movement of poultry and poultry products, porous borders for poultry smuggling, uncontrolled and unregulated live bird market activities, indiscriminate importation of poultry and its products are some of the factors responsible for the transmission and spread of the current H5N1 outbreak. Furthermore, the circumstances surrounding resurgent of HPAI in Nigeria can be better appreciated by taking a critical look at both wild and domestic birds’ ecology and pattern of distribution of poultry and poultry products in Nigeria. Though the epidemiological link between this H5N1/2015 isolate in Nigeria and previously identified strains in Asia is yet unclear, it is suggested to be probably associated with human activities, migratory bird movements, or both (Monne et al., 2015).

Kano State shares border with Jigawa state a region with known migratory bird flyway and activities (Snoeck et al., 2011; Coker et al., 2014) with adjoining wetlands which appears to be the major hub of current HPAI outbreaks and may be the source of virus transmission and spread to other parts of the country (Saidu et al., 2008; Fusaro et al., 2010) (Figure 1). The outbreaks in Lagos were mainly in live bird market and some of the birds were brought from the northern part of Nigeria, apparently from Kano and Jigawa State adjoining the Hadejia wetlands. During the 2006-2008 outbreaks of HPAI in Nigeria, the north central and southwestern part were identified as possible sources of infection and spread to other regions (Fusaro et al., 2010). Hence, interaction of wild migratory birds with backyard flocks and subsequent interstate movement of live birds are strongly suspected to be the source of the virus re-introduction into Nigeria for the second time. Effective control of HPAI in Nigeria and preventing future outbreaks and rapid spread must take into cognizance such elements as wild bird interaction with free-range domestic poultry, backyard poultry, cluster farming and live bird market chain as well as in between farm transmission. It has been predicted that minimizing contacts between commercial/free range chickens and wild birds in the north central part of Nigeria may help to avert future outbreaks (Fusaro et al., 2010). Deciphering the mechanism of spread including, birds movement and fomite movement is an important biosecurity step that must be strictly adhered to in order to control transmission, devastating economic losses and the potential public health threat. The resurgence of HPAI in Nigeria by our investigation is a new introduction of a virus earlier eradicated and is a reminder that infectious pathogen especially those that are involved in
transboundary transmission could occur when the condition for introduction is favorable. Continuous surveillance and monitoring is therefore canvassed for early detection and control.

**Conclusion**

In view of all of the factors identified above, it is therefore concluded that sustained passive and active surveillance for HPAI H5N1 should be implemented in live bird markets, poultry farms and at border posts and other high risk areas. The established Avian Influenza desk offices during the 2006-08 outbreaks should be funded and encouraged to submit surveillance samples for laboratory diagnosis at regular intervals and especially intensify surveillance and monitoring during October - January periods of the year.
Figure I: Spatial distribution of HPAI H5N1 outbreaks in poultry, Nigeria, January-December, 2015.
Figure II: Gross pathological lesions and immunohistochemistry (A) Swollen comb and wattle with subcutaneous hemorrhagic face (arrow), (B) shank and feet with diffuse subcutaneous hemorrhages, (C) Lung with severe congestion (arrow) and oedema, (D) Lung with bronchiolar epithelia necrosis and desquamation, vascular congestion and expansion of the interstitial by mixed cellular infiltrates.
Table I: Summary of gross morphological changes in selected H5N1 positive cases

<table>
<thead>
<tr>
<th>S/N</th>
<th>Poultry Type</th>
<th>Age (weeks)</th>
<th>Gross Morphological Changes</th>
<th>RT-PCR Matrix gene</th>
<th>H5 gene</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Broiler</td>
<td>3</td>
<td>Facial haemorrhages, myocardial petechial haemorrhages, cloudy airsacs, mesenteric vascular congestion</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>2</td>
<td>Broiler</td>
<td>4</td>
<td>Lungs congestion and oedema, pectoralis muscle ecchymotic haemorrhages</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>3</td>
<td>Broiler</td>
<td>5</td>
<td>Cyanosis of face, myocardial petechial haemorrhages, mesenteric vascular congestion</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>4</td>
<td>Pullets</td>
<td>14</td>
<td>Cyanosis of combs and wattles, swollen face, congested and haemorrhagic trachea, congested and oedematous lungs, cloudy airsacs, myocardial petechial haemorrhages, ecchymotic haemorrhages on proventriculus, duodenum and cecal tonsils, petechiation of pectoralis muscle, congested and haemorrhagic spleen, hyperemic shanks</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>5</td>
<td>Pullets</td>
<td>15</td>
<td>Frothy lungs, congested coronary vessels, friable liver, hyperemic and haemorrhagic shanks</td>
<td>+</td>
<td>+</td>
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<tr>
<td>6</td>
<td>Pullet</td>
<td>16</td>
<td>Congested and swollen liver, haemorrhagic cecal tonsils, petechial splenic haemorrhages, pasted vent, hyperemic and haemorrhagic shank and feet</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>7</td>
<td>Cockerels</td>
<td>30</td>
<td>Cyanotic comb, pale carcass, myocardial petechial to ecchymotic haemorrhages, chalky pancreas, congested and enlarged kidneys</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>8</td>
<td>Layers</td>
<td>17</td>
<td>Emaciation, congested lungs, hyperemic shank</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>9</td>
<td>Layer</td>
<td>22</td>
<td>Lungs congestion and oedema, atresia of the ovarian follicles</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>10</td>
<td>Layer</td>
<td>25</td>
<td>Cyanotic comb and wattle, oedematous lungs, cloudy pericardial sacs, multifocal splenic necrosis, haemorrhagic cecal tonsils, cyanotic shanks</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>11</td>
<td>Layers</td>
<td>34</td>
<td>Cyanotic, and hyperemic combs and wattles, congested and frothy lungs, congested coronary vessels, hyperemic pancreas, pale,</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Layer</td>
<td>Lungs/congestion and oedema, atresia of the ovarian follicles</td>
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<tr>
<td></td>
<td>Edematous lungs, cloudy pericardial sacs and pasted vent</td>
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<tr>
<td></td>
<td>Cyanosis of combs and wattles, cloudy pericardial sac, congested and oedematous lungs, congested liver, hyperemic shank</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Comb and wattle hyperemia, hyperemic trachea and congested lungs, haemorrhagic cecal tonsils, fatty liver, swollen spleen with petechiations</td>
<td></td>
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<tr>
<td></td>
<td>Lungs congestion and oedema, atresia of the ovarian follicles</td>
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<tr>
<td></td>
<td>Cyanosis of combs and wattles, congested trachea and lungs, cloudy airsacs, duodenal petechial haemorrhages, splenic haemorrhages, swollen thymus, hyperemia of shanks</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Cyanosis of combs and wattles, hyperemia of shanks, congested trachea, congested and oedematous lungs, cloudy airsacs congested liver, haemorrhagic cecal tonsils</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Cyanotic and swollen face, hyperemic shank and feet, congested lung, congested and friable liver, haemorrhagic cecal tonsils</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyperemic comb and cyanotic wattle, pectoralis muscle hyperemia, myocardial necrosis, soft, friable liver, multifocal petechial haemorrhages on spleen, hyperemic ovarian follicular, hyperemia of shank and feet</td>
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</table>
Figure III: Weekly distribution of suspected (blue bars) and confirmed (red bars) cases of HPAI (H5N1) from Nigeria, January – December, 2015. A total number of 1137 HPAI H5N1 suspicion from 20 states with 542 confirmed cases.
Figure IVA: Gel electrophoresis of the M-gene of HPAI H5N1 from outbreaks in Nigeria

Figure IVB: Gel electrophoresis of the H-gene of selected HPAI H5N1 from outbreaks in Nigeria
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