Chapter

Features of Highly Pathogenic Avian Influenza (HPAI) H5N1 in Domestic Poultry

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Abstract

H5 and H7 subtypes are associated with the highly pathogenic form of AI (HPAI), which are extremely virulent, causing up to 100% mortality in domestic poultry. This virulence and ability to cause systemic infection have been attributed to the multibasic cleavage motif in their hemagglutinin molecule, which are recognized by subtilisin-like endoproteases that are virtually present in every tissue, making them capable of replicating in multiple tissue; hence, lesions are multisystemic (i.e., nervous, circulatory, respiratory, integumentary, musculoskeletal, hemopoietic, gastrointestinal, reproductive systems). The myriads of lesion that accompanied outbreaks of HPAI in domestic poultry as seen in Nigeria from 2006 to 2016 are as a result of the above findings. A critical look at the Nigerian HPAI situation not only revealed the general clinic-pathologic features in domestic poultry and factors that support the persistence of the virus in the environment but also gave insight to the flow of the virus in the country. A situation whereby poultry are kept in free-range, multispecies, multiage holdings with low biosecurity supports the spread of HPAI. Also, the live bird markets (LBMs) that have been fed by this unorganized poultry structure have consistently been the nidus for HPAI detection, be it in 2008 after the virus was thought to have been eradicated or in 2015, when the virus resurfaced in Lagos. It is proposed that all factors enhancing the propensity of the virus to remain in poultry should be giving the attention required. Therefore, it is important that the strict biosecurity measures that ensure prevention of HPAI incursion into poultry premises after 2008 are revamped while improving on the organization of the poultry and product supply chain in the country.

Keywords: avian influenza, multisystemic, domestic poultry, pathology, Nigeria

1. Introduction

Intensive poultry production units are an ideal viral breeding ground due to genetic homogeneity which decreases the number and variability of resistance genes resulting in little variation between individuals and therefore high infection potential for viruses [1]. Also, in the aforementioned environment, these birds do not undergo any form of reproduction; therefore, there is no coevolution with the pathogen, and this presents the conditions for the maintenance of a highly lethal strain [1]. The artificial increased density of individual host pathogens increases spread to other hosts, and the short life cycles of the virus prevent the host from developing immunity against the organism [2]. With high density and short life span, contagiousness is not under selective pressure, and a selection criteria on strains allow strains to be selected mainly on virulence, i.e., harm to the host [2]. In addition, inadequate disinfection measures between batches allow the virus to survive in the environment [2]. Three potential clinical outcomes have been observed with AI infection in birds; these are (a) no clinical signs, (b) mild disease, and (c) severe disease with death [3]. The H5 and H7 subtypes of avian influenza (AI) virus associated with HPAI, which is extremely virulent, cause up to 100% mortality in domestic poultry. The virulence and ability to cause systemic infection have been attributed to the multibasic cleavage motif (minimal consensus sequence of -R-X-K/RR-) in their hemagglutinin molecule, which are recognized by subtilisin-like endoproteases that are virtually present in every tissue of their host and preferentially expressed at the surface of respiratory and gastrointestinal epithelia [4], making them capable of replicating in multiple tissue [5, 6]; hence, lesions are multisystemic (i.e., nervous, circulatory, respiratory, integumentary, musculoskeletal, hemopoietic, gastrointestinal, reproductive systems [7]). This chapter considers avian influenza virus infection with a special X-ray on the Nigerian outbreak scenario, general clinicopathologic features in domestic poultry and factors that support the persistence of the virus in the environment, and, when not adequately controlled, how these can lead to an endemic and/or a pandemic state.

2. Avian influenza transmission

2.1 The virus

Influenza viruses are segmented negative-sense single-stranded RNA, belonging to the family *Orthomyxoviridae* [8]. This family is classified into influenza viruses' types A, B, and C, *Thogotovirus*, and *Isavirus* [9]. Only influenza type A viruses infect poultry [8], and avian influenza viruses are known to be a diverse group of viruses in the *Orthomyxoviridae* family, genus *Influenza A virus*, and have been categorized into subtypes based on the two surface glycoproteins, the hemagglutinin (H) and neuraminidase (N) [10]. There are now 18 H and 11 N surface glycoproteins [11]. Previously, HA1-16 and NA1-9 have been identified to occur naturally in avian host, mostly waterfowls where they exist in benign form (low pathogenic) [12]. Subtypes HA 17 and 18 and NA 10 and 11 were identified in bats [13] recently. Avian influenza viruses have also been further classified into two different pathotypes (low pathogenicity [LP] and high pathogenicity [HP]), based on the ability to produce disease and death in the major domestic poultry species, the chicken (*Gallus gallus domesticus*) [14]. HPAI has been shown to be caused in susceptible host species by only the avian influenza viruses of H5 and H7 subtypes, which contain multiple basic amino acids at the cleavage site of the hemagglutinin molecule, [15]. However, not all H5 and H7 avian influenza viruses are highly pathogenic. It has been shown that HPAI viruses emerge in domestic poultry from LPAI progenitors of the H5 and H7 subtypes [16–18].

2.2 Transmission

A typical flow of avian influenza virus in poultry mostly begins with the introduction of the virus to a region or country where the virus has not been known to be present. This introduction has been known to occur by way of contact of resident water fowls and/or backyard poultry with an infected migratory wild bird

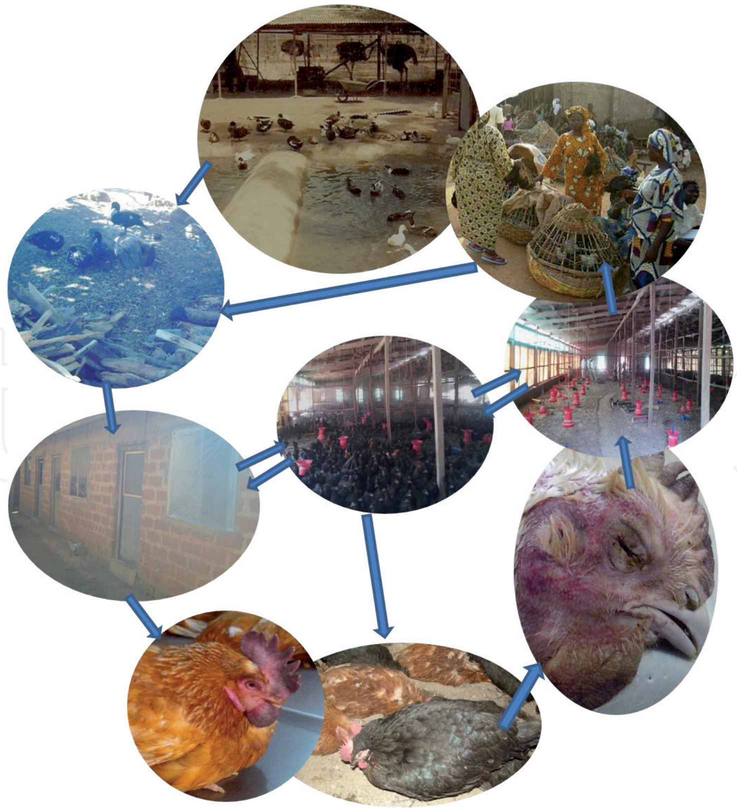

Figure 1.
A flow chart of the typical origin and transmission of avian influenza in poultry.

[19–21] which may carry any of the subtype combinations of hemagglutinin (H) and neuraminidase (N) glycoproteins. This subtype in the case of an infection with HPAI will definitely have H5 or H7 combination. This contact may occur at wetland [22, 23] areas or agroecological regions [24].

In addition, there could be direct introduction of infected bird into poultry. **Figure 1** illustrates the possibilities of the virus flow in poultry which may begin with local ducks or mixed species flock having contact (direct) with the virus by way of resident water fowls and or migratory wild birds. The virus can move by human vectors (indirect) especially when poultry attendants take care of the mixed species flock, after which a contact of free-ranging ducks and/or chickens with semi-intensive or backyard poultry may take place. At this point, the virus enters into intensive poultry directly or indirectly causing deaths.

Experience with farmers/poultry owners and attendants at the Central Diagnostic Laboratory of the National Veterinary Research Institute in Vom, Nigeria, revealed that poultry owners hurriedly sell off supposedly infected chickens to live bird and wet bird markets, from where unsuspecting public and local peasant poultry keepers buy these infected poultry for introduction into local flocks. The circle of infection can continue unabated for a very long time.

3. The Nigerian scenario

3.1 Index outbreak

Nigeria experienced an outbreak of HPAI H5N1 virus in both commercial and local poultry populations during January 2006 as an extension of the global outbreaks [7]. The index HPAI-H5N1 was confirmed in Nigeria at a commercial poultry farm in Kaduna State, and by the end of the initial outbreak, over 46,000 poultry

[25, 26] had been destroyed. This outbreak brought the Asian strain of highly pathogenic avian influenza (HPAI) H5N1 into Africa for the first time in the beginning of January 2006 [7, 27–29] in Nigeria. During this first incursion of the virus into Nigeria, the country lost excess of 1 million birds of various species [30, 31]. Since its emergence in Africa in 2006, avian influenza viruses of the H5N1 subtype have spread rapidly to poultry farms in several African countries.

This acute, generalized, fatal disease [32] affected free-ranged domestic poultry, backyard poultry, and commercial poultry comprising of chickens, ducks, geese, turkeys, guinea fowls, other gallinaceous birds, and ostriches in the poultry industry of the country. Although elsewhere in the world quails, ratites, passerine bird, flamingos, herons, raptors [32], and mammals have also been found to be susceptible to HPAI, this was not so in Nigeria. HPAI which is known to be caused by avian influenza viruses (AIVs) that are extremely virulent, resulting in up to 100% mortality in domestic chickens [33], was isolated in several outbreaks that occurred in Nigeria.

3.2 Source of the virus

Several sources have been found to be responsible for the introduction and reintroduction of the virus; these include wild bird sources, trade in poultry [29], and direct source introduction. Following the waves of outbreaks during the 2006–2007 periods, phylogeographic analysis [22] identified the north-central (Katsina, Jigawa, Yobe, Kano, Kaduna, Bauchi, and Gombe) and southwest (Lagos, Ogun, Oyo, Ekiti, and Kwara) regions as the two major sources for the HPAIV in Nigeria [22]. This supports the hypothesis that the introduction of the virus into Nigeria may be by wild birds and trade in poultry [29] and its products. Wild birds are strongly believed to be a major source of the virus to the northeastern states of Jigawa and Yobe, which are home to the Hadejia-Nguru wetlands and are said to be characterized by permanent and seasonal lakes and numerous population of migratory and residential waterfowl [22]. It is also known that this area sustains a large backyard poultry population and the highest concentration of domestic ducks, reared under free-range conditions, providing opportunities for contact between wild birds and backyard poultry [24].

3.3 The poultry structure

The poultry structure in Nigeria is comprised of two major systems, rural poultry production and commercial poultry production [34], as classified by the Food and Agricultural Organization (FAO) of the United Nation (UN). In the rural poultry production, it is a common practice to keep poultry in free-range, multispecies, multiage holdings with low biosecurity levels, thus exposing them to many at-risk contacts, and they could act as the epidemiologic link between the wild reservoir of AI viruses [22, 35] and industrial poultry. The commercial poultry production can be fully intensive or semi-intensive, depending on the level of automation and husbandry. **Figure 2A–D**, gives an insight to the poultry structure practiced in Nigeria.

3.4 Surveillance and outbreaks investigation

As far back as early February 2004, the veterinarians have been saddled with the responsibility of gearing efforts toward managing HPAIV outbreaks [37] if Nigeria was at risk or eventually experience an outbreak. Prevention strategy document for the emergency preparedness and response plan (EPP) [37] was ready as early as 2005. This included a risk analysis of the 24 wetlands in Nigeria and the two major

Figure 2.
(A) Intensive poultry production system in the tropics [36]. (B) A semi-intensive poultry production system in the tropics [36]. (C) A mixed species backyard poultry production system comprising of ostriches, geese, Muscovy, mallard, and Pekin ducks before the introduction of HPAI [36]. (D) An extensively (free-ranging) reared Muscovy/mallard duck flock [36].

migratory routes of wild birds, evaluation and upgrading of veterinary services, ban on importation of poultry and poultry products, and increased surveillance for the virus [37]. Surveillance and disease reporting included passive and active surveillance and regular disease reporting. The active surveillance component involved epidemiological surveillance of network of 170 points within the country and targeted surveillance of wetlands and farms [37]. Surveillance was carried out between September and November 2005 at the Nguru-Hadejia wetlands [37]. Similarly, active surveillance was carried out in the same period in the high-risk agroecological farming areas and among live bird (poultry) markets, but all these surveillance activities failed to detect H5 or H7 avian influenza virus [37]. Several investigations have been carried out and are available to the public about the HPAI H5N1 outbreaks in Nigeria, including the virological identification and confirmation [26, 28, 37, 38], epidemiology and pathology of early [7] and resurgent outbreaks [39], and molecular characterization [29], including regional mortality and morbidity characteristics [40].

3.5 Reintroduction of the virus into domestic poultry

Reintroduction of the virus to Nigeria was first detected in January 2015, when the National Veterinary Research Institute (NVRI), Vom, Nigeria, received some chicken carcasses from the Kano State Ministry of Agriculture [39]. The carcasses were gotten from a backyard-commercial poultry farm and also from a live bird market (LBM) in Kauna and Sabon Gari, Kano State, northwestern Nigeria, respectively. The farm husbandry was mixed poultry species system where different types of chickens of various ages and stages were kept and were experiencing high mortality of 350 birds daily with eventual 100% mortality observed in the older birds (54 weeks) [39]. Also, in a concurrent incidence, unusual high mortality of birds brought from the northern part of Nigeria to two LBMs in Onipanu and Mushin, Lagos State, Southwestern Nigeria, was reported [39]. The specimens were analyzed by RT-PCR and virus isolation in embryonating chicken eggs, and all samples were found to be positive for HPAI (H5N1) subtype [39]. This ended the 9-year silence of the activity of the virus in Nigerian poultry [39]. Again, a strong genetic link between viruses isolated in Nigerian poultry and wild bird from Europe has been established [21, 22, 41, 42], thereby suggesting that wild birds are the major possible source of introduction and reintroduction of HPAI viruses into Nigeria's poultry. On the other hand, rural poultry mainly kept in free-range, multispecies, multiage holdings with low biosecurity levels are exposed to many at-risk contacts and therefore act as the epidemiologic link between the wild reservoir of AI viruses and industrial poultry [22, 35]. The predominant species in the rural poultry sector of Africa is the scavenging indigenous domestic fowl (*Gallus gallus domesticus*) [43], which in most African countries has no regular health control program, may or may not have shelter, and scavenges for most of their nutritional needs [43]. In fact, village chickens have been reported to act as potential reservoirs and carriers of infections to themselves and to the more susceptible exotic breeds in commercial poultry farms [44].

3.6 Factors supporting occurrence of outbreaks

Following initial introduction of the virus from a possible migratory wild bird [22] or water fowl [20] through direct means into commercial poultry or by resident water fowls and ducks that form bridges of virus transmission from migratory wild birds [35], the virus is further spread by inadequate farm biosecurity, trade in poultry, human and vehicular exchanges between farms, and uncontrolled farm visits by poultry and poultry product vendors. Live bird markets have also been shown to harbor [39] and transmit the virus among birds and finally to household poultry upon introduction of poultry bought from live bird markets [20]. Mixed-species poultry farming has been shown to have higher odds of HPAI virus infection [39] and could harbor apparently healthy but infected duck species which may transmit the virus to susceptible chickens and turkeys. In a study conducted during the first introduction of HPAI into Nigeria, it was shown that mortality rate was much higher in mixed species flocks ($P < 0.0001$) and ranged from 4.92 to 73.15% with the chicken-duck-turkey mixed flock farms having the highest rate (73.15%) [39]. Also, it was established that higher risk of HPAI disease occurred in multiple, mixed species poultry than in single species poultry production [39]. **Figure 3** depicts a typical live bird scenario.

3.7 Control measures

Enforcement of movement control, surveillance (active and passive), and prompt payment of the revised compensation to the affected farmers, including reorganization of the LBMs which led to the successes recorded during the

Figure 3.
A typical live bird market where poultry from different origins are sold. ©Prof. T. U Obi, University of Ilorin.

2006–2007 epizootics [45], is necessary to control HPAI in Nigeria. In these current HPAI epizootics, it has been observed that coordination and other instituted control measures, including biosecurity and compensation of affected farmers, seem to be less rigorous, and this may explain the rapid spread from the index cases to 25 states of the federation as of March 2016 [42].

4. Clinicopathologic features of avian influenza infection in domestic commercial and rural poultry: chickens and ducks

4.1 General outcome of disease

Three possible clinical outcomes have been shown to occur with AI infection in birds: there may be no clinical signs, it may result in a mild disease, and severe disease with death may occur [3]. Virus replication within the cell, tissue, organ, or a combination results in pathobiological changes which are abnormal physiological and anatomic changes. Therefore, in general, as virus replication titers increase, so do the severity of pathobiological changes such as gross and microscopic lesions with the most pathogenic virus strains causing major cell damage and death if it is sufficiently severe to affect critical organs [3] **Figure 4**.

4.2 Clinical signs

In gallinaceous domestic poultry, infection with HPAI viruses produces severe depression, severe decrease in feed and water consumption, high morbidity and mortality rates, sudden death, and occasionally nervous signs if they survive the peracute syndrome. However, the frequency of clinical signs and gross lesions varies with virus and species of bird and is not consistent in all birds [3] (**Figure 5**).

4.2.1 Chickens

Individual birds are listless and exhibit edema; cyanosis of the comb, wattles, and legs; and diarrhea. Sudden deaths without any symptoms may also occur. Signs observed and reported are sudden death, high mortality, weakness, and

Figure 4.
(A) An open-sided layer chicken pen infected with highly pathogenic avian influenza virus. (B) The flock in A when the pen was already depopulated. (C) The poultry birds been placed in an open dug pit after depopulation. (D) The flock in A been burnt after depopulation. A and B courtesy of Dr. Luka Pam; C and D received anonymously.

Figure 5.
(A) Testing for influenza virus using oropharyngeal swab stick. (B) Examining suspected outbreak of influenza virus infection in poultry.

recumbency. Others ranged from nasal discharges, dyspnea, coughing, sneezing, shank hyperemia and hemorrhage, inability to stand, ataxia, and torticollis. In layers, egg structural abnormalities such as shell-less egg, white-colored eggs, and soft eggs were reported.

4.2.2 Backyard poultry

In backyard poultry, sudden death is most common especially in turkeys, ducks, guinea fowls, and local chickens [31]. Signs were rarely observed and reported in these poultry species, as they were seen to die suddenly without premonitory signs although paralysis, ataxia and torticollis, dyspnea, coughing, sneezing, and diarrhea were occasionally seen and reported [31].

4.2.3 Ducks

Less vulnerable poultry species such as ducks, geese, ratites, and pigeons typically exhibit nervous symptoms including ataxia, torticollis, and seizures [46, 47].

4.3 Pathologic lesions

The frequency of gross lesions is also dependent on virus and species of bird and is not consistent in all birds [3].

4.3.1 Chickens

The main clinical and pathologic findings of HPAI are usually observed in the nervous, circulatory, respiratory, integumentary, musculoskeletal, gastrointestinal, and reproductive systems, and occasionally lesions are multisystemic. Chickens being the most frequently infected species with HPAI viruses exhibit common lesions including edema to necrosis of comb and wattle, edema of the head and legs, subcutaneous hemorrhage of legs, lungs that fill with fluid and blood, and small hemorrhages on internal organs such as the coronary fat. All of these lesions point to alternations in the cardiovascular system, which principally affects vascular endothelium and the resulting viremia. HPAI infections in gallinaceous birds have been shown to result in mortalities of up to 100% within 48 hours [48, 49]. Lesions observed in the circulatory system included congestion and cyanosis of comb and wattle, comb and wattle edema, and facial and subcutaneous edema. Within the respiratory system, there were airsacculitis and pneumonia. There was petechiation to ecchymoses of the proventricular and intestinal mucosa with resultant enteritis in the gastrointestinal system [31]. Integumentary system lesions are mainly cyanosis, edema, and ecchymotic hemorrhages, while there were inflammatory, degenerative, and necrotic lesions in the musculoskeletal system. In adult birds, mainly layers reproductive lesions were observed, and they were mainly ovarian follicular ecchymotic hemorrhages [31]. **Figure 6A**–**C** depicts the lesions in chickens naturally infected by HPAI virus.

4.3.2 Backyard poultry

The main pathologic findings were observed in the nervous, circulatory, respiratory, musculoskeletal, and intestinal systems, and occasionally lesions are multi-systemic. Lesions observed in the circulatory system included cyanosis of comb and wattle, comb and wattle edema, and facial and subcutaneous edema. Within the respiratory system, there were nasal discharges, airsacculitis, and pneumonia [31]. Petechiation to ecchymoses of the proventricular and intestinal mucosal with resultant enteritis in the intestinal system were observed [31]. There were inflammatory, degenerative, and necrotic lesions in the musculoskeletal system [31].

4.3.3 Ducks

Ducks oftentime show one or more lesions of the circulatory system and showed nervous lesions of neuronal and Purkinje cell necrosis of the cerebrum and cerebellum [31]. There was nasal exudation, airsacculitis, and pneumonia in some ducks [31]. Enteric petechiation and ecchymoses were also observed [31] (**Figure 7**).

Figure 6.
(A) A layer chicken showing clinical signs of weakness and sitting on hock; the comb and wattles are congested, and the wattles are swollen. (B) The feet and shank are severely hemorrhagic. (C) The abdominal fat depot shows petechiae to ecchymotic hemorrhages which are sometimes diffuse; the liver is necrotic and friable, i.e., color is bleached and has fatty appearance.

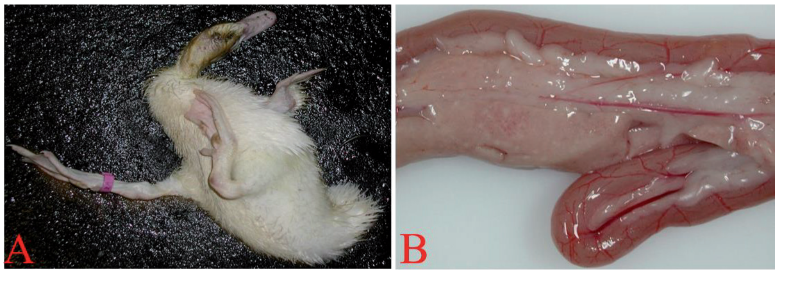

Figure 7.
(A) The Pekin duck is showing signs of nervous involvement which include loss of balance and inability to stand upright and ataxia. (B) The pancreas between the intestinal loops of the duodenum of this chicken is necrotic, i.e., shows chalky appearance otherwise known as bleaching.

5. Persistence of avian influenza viruses in poultry population

Many countries and regions have successfully controlled the virus after its occurrence, whereas some other countries face occasional reoccurrences despite intensive control efforts [50]. By the last quarter of 2007, outbreaks of HPAIV in Nigeria appeared to have been successfully controlled by measures such as "stamping out with compensation," restrictions on movement of poultry, and enhanced surveillance [19]. But the detection of new cases of HPAIV in farms from Kano and Katsina States and in apparently healthy ducks in live bird markets in Gombe and Kebbi States [19, 22, 51] proved otherwise. The viruses in sublineage H which were isolated from vultures, pigeon, guinea fowl, free-range chicken, and other birds from a wildlife park were observed to be geographically and chronologically dispersed in Nigeria following infection of the LBMs. Thus, the importance of the live bird markets in the spread of the virus in West Africa is particularly evident [52]. Also, a resurgent outbreak was recorded in January 2015, after almost 8 years following the end of the last epizootics, [39, 41]. Thus far, the outbreak has spread to several other African countries including Burkina Faso, Cote d'Ivore, Niger, Ghana, Cameroon, and Togo [42].

Influenza A viruses are known to circulate in their natural hosts and wild aquatic birds predominantly of the orders Anseriformes (ducks, geese and swans) and Charadriiformes (gulls, waders, and terns). These wild ducks are natural reservoirs of avian influenza (AI) viruses [10, 53, 54], and epidemiologic evidence and experimental infections show that domestic ducks are also susceptible to AI viruses [55, 56].

The circulation and reemergence of highly pathogenic avian influenza viruses of H5N1 subtype (HPAIV-H5N1) raise major concerns in public health and poultry industries [57]. Tens of millions of birds have died of HPAIV-H5N1 in the global poultry industry, and hundreds of millions of poultry have been slaughtered to control the spread of the virus [58]. Urgent revised control measures are required to stem waves of outbreaks and to prevent the virus from becoming enzootic in poultry if the ongoing trend of recent outbreaks in Nigeria persists, [42]. If not, this may result in severe public health consequences, as observed in countries where the virus has become enzootic in poultry [59]. In a little over a year of the reported resurgent into Nigeria, several waves of outbreaks were reported in 25 states including the Federal Capital Territory (Abuja) [42].

6. Endemic situation

Following the detection and reporting of highly pathogenic avian influenza (HPAI) H5N1 virus (clade 2.2) in Nigeria in 2006 [28] and subsequently in other parts of Africa, 11 countries in the region had reported outbreaks in poultry within a few months of its detection and eventually became enzootic in Egypt's poultry [60] causing human deaths. By July 2016, the human cases as a result of infection with HPAI H5N1 in Djibouti, Nigeria, and Egypt stand at 1, 1, and 354 people, respectively, with Egypt having the second highest number of human deaths among countries with H5N1 infections in the world [61]. The exposure of humans at the human-animal interface enzootic circulation of highly pathogenic avian influenza virus (HPAIV) in agricultural scenarios poses one of the greatest public health concerns [41]. The only human case in Nigeria, which was officially reported by the World Health Organization on February 3, 2007, was diagnosed following a thorough investigation of a fever complicated by respiratory distress which finally led to death of an average aged woman [38].

Some of the factors identified to aid the spread of the virus and enzootic situation include indiscriminate disposal of infected poultry carcasses, poor biosecurity measures and disregard for perimeter fencing, uncoordinated movement of poultry and poultry products, porous borders which aid poultry smuggling, uncontrolled and unregulated live bird market structures and activities, and indiscriminate importation of poultry and its products. These are some of the factors responsible for the transmission and spread of the 2015 H5N1 outbreak [39].

In Nigeria, the continuous interfaces of wild migratory birds with backyard flocks and subsequent movement of live birds from one state to another are strongly suspected to be the source of the virus reintroduction for the second time.

Therefore, to effectively control HPAI in Nigeria and to prevent future outbreaks and rapid spread of the virus, the continuous interfaces of wild migratory birds with backyard flocks must be taking into cognizance. Also, cluster farming and live bird market chain needs to be organized, as well as preventing in between farm transmission. In addition, it has been suggested that minimizing contacts between commercial/free-range chickens and wild birds in the northern part of Nigeria may help to avert future outbreaks [19]. Also, previous study has shown that there is a higher risk of HPAI disease occurrence in mixed poultry farming. A more prognostic approach and pragmatic plan is required for the prevention and control of HPAI in Nigeria with this resurgence, in order to elude a likely endemicity of the disease [62].

7. Conclusions

The H5 and H7 subtypes associated with the highly pathogenic form of AI (HPAI), an extremely virulent virus which causes up to 100% mortality in domestic poultry, need special efforts to ensure eradication. Bearing in mind that the intensive poultry production units are an ideal viral breeding ground for these forms of AI, all factors that enhance this propensity should be giving the attention required. A critical look at the Nigerian HPAI situation not only revealed the general clinicopathologic features in domestic poultry and factors that support the persistence of the virus in the environment but also gave insight to the flow of the virus in the country. A situation whereby poultry are kept in free-range, multispecies, multiage holdings with low biosecurity supports the spread of HPAI. Also, the LBMs that have been fed by this unorganized poultry structure have consistently been the nidus for HPAI detection, be it in 2008 after the virus was thought to have been eradicated or in 2015, when the virus resurfaced in Kano and Lagos. It is therefore important that the strict biosecurity measures that ensure prevention of HPAI incursion into poultry premises after 2008 are revamped while improving on the organization of the poultry and product supply chain in the country.

Disclosure of potential conflicts of interest

The author declared that there is no conflict of interest (financial or nonfinancial).

Abbreviations

CDC	Center for Disease Control
AI	Avian influenza

LP	Low pathogenic
HP	High pathogenic
H	Hemagglutinin
N	Neuraminidase
HA	Hemagglutinin
NA	Neuraminidase
HPAI	Highly pathogenic avian influenza
HPAIV	Highly pathogenic avian influenza virus
LBMs	Live bird markets
UN	United Nation
FAO	Food and Agriculture Organization
WHO	World Health Organization
H5N1	Hemagglutinin 5 neuraminidase 1
NVRI	National Veterinary Research Institute
EPP	Emergency preparedness and response plan

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