Sokoto Journal of Veterinary Sciences

Risk factors for the occurrence and spread of Highly Pathogenic Avian Influenza H5N1 in commercial poultry farms in Kano, Nigeria

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Abstract

Outbreaks of Highly Pathogenic Avian Influenza (HPAI) subtype H5N1 occurred previously for three consecutive years, 2006, 2007 and 2008 in Kano State, Nigeria, causing heavy economic losses to farmers and the government. It was against this background that risk factors for the occurrence and spread of HPAI H5N1 among commercial poultry farms in the State were evaluated. A total of 64 farms comprising 32 affected (AF) and 32 non-affected (NAF) farms were enrolled for this study. Questionnaires were designed and administered to the selected farms through interviews with farm owners or farm managers during on-site visits. Information on flock profile including farm characteristics and environment, husbandry practices, biosecurity practices, farm trade practices and employee activities were obtained and analyzed. Pearson Chi square and Fisher's exact tests were used to compare categorical variables. Values of p< 0.05 were considered significant. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to measure the strength and statistical significance of associations between the variables and occurrence and spread of HPAI H5N1 in commercial poultry farms in the State. The most significant risk factors were the presence of untreated surface water on farms (OR 18.6, 95%CI 2.24 – 154.34, p = 0.001), exchange of egg crates between traders and farmers (OR 12.1, 95%CI 1.43 – 102.61, p = 0.006), allowing egg crates of traders into poultry pens (OR 11.67, 95%CI 2.37 – 57.86, p = 0.001) and allowing rodents/wild birds access to poultry feed (OR 3.65, 95%CI 0.23 – 1.87, p = 0.024). It was recommended that veterinary inspection to enforce and encourage best biosecurity practices for the poultry farms should be introduced and sustained.

Keywords: commercial poultry, H5N1, HPAI, Kano, Nigeria, risk factors.

Introduction

Nigeria was the first country in Africa to be affected by the Avian Influenza (AI) type A H5N1 virus, with HPAI outbreaks initially reported at a commercial farm in Kaduna State in January, 2006 (Adene *et al*., 2006; Fusaro *et al*., 2009; Ekong *et al*., 2012). Between 2006 and 2008, a total of 1, 654 suspected outbreaks were reported from 32 of the 36 States and the Federal Capital Territory (FCT), of which 299 were confirmed to be HPAI H5N1 positive from 27 states and FCT (Ekong *et al*., 2012; Henning *et al*., 2012). Considering the previous outbreaks in Asia, Africa, and Europe, the AI H5N1 virus still represents a global threat for the poultry industry (FAO, 2004).

The spread of AI subtype H5N1 virus infection in Asia and beyond poses threats to both human and animal health (Morris & Jackson, 2005). However, little reliable epidemiologic data exists on the routes of AI H5N1 virus transmission and perpetuation in poultry within affected countries (Kung *et al*., 2007). These countries do not have the capacity to effectively manage, eliminate and control animal diseases, and humans generally live closely with poultry (Joannis *et al*., 2006). To minimize the risk of AI H5N1 virus incursion at poultry farm level, it is important to investigate and assess the risk status of poultry farms and to communicate this to the farmers.

Although, studies on HPAI H5N1 risk factors have been conducted in Nigeria (Fasina *et al*., 2011; Metras *et al*., 2012), data on biosecurity practices and contacts in poultry farms in Kano State are rare. The present study aims to complement previous reports on risk factors and further define their roles in the occurrence and spread of HPAI H5N1 in commercial poultry farms in Kano State.

Materials and methods

Areas of the study

Kano State is located on Latitude 11° 30' 0 N and Longitude 8° 30' 0 E in North-Western Nigeria, with an area of 42,592.8 km^2. The State is comprised of 44 local government areas (LGAs), has an estimated human population of 9, 383, 682 people (2006 census) and poultry population of 3, 852, 135 birds; comprising 3, 528, 000 rural and 324, 135 commercial poultry as at 2003 (Adene & Oguntade, 2006).

Sample Size and Sampling Technique

Based on the assumption of a worst case scenario that 50% of the farms being investigated may have HPAI problems (Salman *et al*., 2007), 64 commercial poultry farms comprising 32 affected (AF) and 32 non affected (NAF) farms were selected by simple random sampling (through balloting) from a list of 128 registered poultry farms obtained from Avian Influenza Control Project (AICP) office, Kano and enrolled for this study.

Questionnaire Design and Administration

A questionnaire developed and designed for this study was first pretested at five farms (However, the farms were not subsequently used in the study). The questionnaire was then modified according to new variables encountered during prestesting. In the final questionnaire, 57 variables covering information about farm characteristics and environment, husbandry practices, biosecurity measures employed on the farm, feed and water sources and employee activities, farm trade practices and employee protection were evaluated. The questionnaires were administered to farm owners or managers through interviews during on-site visits. Personal observations of farm premises and activities were used to validate the responses of the respondents during the questionnaire administration. The non affected farms were first visited for biosecurity reasons.

Data Analysis

Data obtained from the 64 registered commercial farms were analyzed using the Statistical Package for Social Sciences (SPSS) software package, version 15 (SPSS Inc., Chicago, IL, USA). Pearson Chi square (x^2) and Fisher's exact tests were used to compare categorical variables. Values of p≤ 0.05 were considered significant. Odds ratios (OR) and 95% confidence intervals (CI) were calculated to measure the strength and statistical significance of associations between risk factors and HPAI occurrence.

Results

The most significant risk factor associated with farm characteristics and environment for AI H5N1 occurrence was the presence of untreated surface water on farms, which had the strongest point estimate of risk (odds ratio (OR) 18.6), and a high statistical significance (p = 0.001), despite a wide 95% confidence interval (CI) of 2.24-154.34 (Table 1). Other significant risk factors associated with farm environment include: presence of open water reservoir on farm (OR 2.26, 95% CI 0.80-6.36, p = 0.011), with more AF farms (46.9%) at risk than non NAF farms (28.1%); dense vegetation around farm (OR 2.17, 95% CI 0.03-0.87, p = 0.020), with more NAF farms (93.8%) at risk than AF farms (71.9%); presence of bush around poultry pens (OR 1.99, 95% CI 0.70-5.62, p = 0.013), with more AF farms (71.9%) at risk than NAF farms (56.3%); presence of tall trees around farm (OR 1.51, 95% CI 0.42-5.38, p = 0.022), with majority of AF farms (84.4%) at risk than NAF farms (78.1%); and sharing of fence between farms (OR 3.46, 95% CI 0.64-18.65, p = 0.031), with more AF farms (18.8%) at risk than NAF farms (6.3%) (Table 1). Of the risk factors associated with husbandry practices, allowing rodents/wild birds to access poultry feed (OR 3.65, 95% CI 0.23-1.87, p = 0.024) and vaccination of birds against AI (OR 3.21, 95% CI 0.32-32.6, p = 0.002) were most significant (Table 2). Other significant risk factors associated with husbandry practices include: relying on middlemen (distributors) for the supply of day-old or point-of-lay birds (OR 1.21, 95% CI 0.06-0.68, p = 0.007), with more AF farms at risk; presence of free range and water birds (ducks, geese, local chickens, etc) on farm (OR 2.71, 95% CI 0.63-11.59, p = 0.018), with more AF farms (21.9%) at risk; keeping flocks of different ages on farm (OR 2.16, 95% CI 0.79-5.92, p = 0.031), with more AF farms (65.6%) at risk; and farm employee also keeping

Table 1. Risk factors associated with farm characteristics and environment for the occurrence of avian influenza in commercial poultry farms in Kano State

S/N	Variable	Response (%)		p value	Odds ratio	95% Confidence interval
		Non affected farms	Affected farms			
1	High poultry density in the area:					
	No	25 (78.1)	11 (34.4)	0.001	6.82	2.24 – 20.71
	Yes	7 (21.9)	21 (65.6)			
2	Open water reservoir on farm:					
	No	23 (71.9)	17 (53.1)	0.011	2.26	0.80 – 6.36
	Yes	9 (28.1)	15 (46.9)			
3	Dense vegetation around farm:					
	No	2 (6.3)	9 (28.1)	0.020	2.17	0.03 – 0.87
	Yes	30 (93.8)	23 (71.9)			
4	Bush around poultry pens:					
	No	14 (43.8)	9 (28.1)	0.013	1.99	0.70 – 5.62
	Yes	18 (56.3)	23 (71.9)			
5	Presence of tall trees on farm:					
	No	7 (21.9)	5 (15.6)	0.022	1.51	0.42 – 5.38
	Yes	25 (78.1)	27 (84.4)			
6	Untreated water surface on farm:					
	No	31 (96.9)	20 (62.5)	0.001	18.6	2.24 – 154.34
	Yes	1 (3.1)	12 (37.5)			
7	Farm shares fence with another farm:					
	No	30 (93.8)	26 (81.3)	*0.031	3.46	0.64 – 18.65
	Yes	2 (6.3)	6 (18.8)			

*Fisher's Exact Test

poultry (OR 2.78, 95% CI 0.50-15.52, p = 0.030), with more AF farms (15.6%) at risk (Table 2). The most significant risk factor associated with movement of personnel, equipment and waste disposal were parking of vehicles close to poultry pen (OR 3.78, 95% CI 0.92-15.60, p = 0.05), allowing free access to poultry pens (OR 1.88, 95% CI 0.33-2.37, p = 0.012), with NAF farms (43.8%) at higher risk; non restriction of visitors (OR 2.60, 95% CI 0.83-8.13, p = 0.025), with AF farms (37.5%) at higher risk; non use of farm-specific clothes for staff (OR 2.70, 95% CI 0.63-11.59, p = 0.018), with AF farms (21.9%) at higher risk; non use of pen-specific foot wear (OR 1.72, 95%

CI 0.23-2.23, p = 0.054), with AF farms at higher risk; disposal of dead birds through refuse dump (OR 2.13, 95% CI 0.12-2.16, p = 0.052), with more case farms (25.0%) at risk; and improper disposal of poultry litter (OR 1.12, CI 042-3.07, p = 0.008), with NAF farms at higher risk (Table 3). The most significant risk factors associated with farm trade practices were the exchange of egg crates between traders and farmers (OR 12.13, 95% CI 1.43-102.61, p = 0.006) and allowing egg crates of traders into poultry pens (OR 11.67, 95% CI 2.37-57.86, p = 0.001). Other significant risk factors include: poultry dealers and catchers wearing the same clothing

between farms (OR 2.22, 95% CI 0.06-0.93, p = 0.030) and allowing entry of poultry traders into factors may pose significant risks for human infection with AI H5N1 viruses among workers in the poultry farms. These include non use of farm-specific clothes (OR 2.70, 95% CI 0.63-11.59, p = 0.018), non wearing of hand gloves during farm operation (OR 1.56, 95% CI 0.16 – 1.93, p = 0.051), non use of face mask during operation (OR 1.44, 95% CI 0.43-4.77, p = 0.015) and non washing of hands before and after farm operations (OR 1.73, CI 025-2.19, p = 0.008). The aforementioned risks were all higher in the AF farms (Table 5). This study revealed that 29 (51%) of

farm premises (OR 3.81, 95% CI 0.88-11.52, p = 0.030) (Table 4). The study also revealed that some the 57 risk factors evaluated were significant (p≤0.05). Based on the principles of biosecurity, 21(72.4%) of the 29 significant risk factors were observed in the AF farms; with 6 (20.7%), 5 (17.2%) and 10 (34.5%) associated with isolation, traffic control and sanitation, respectively (Table 6). Based on behavioral practices and physical infrastructure, 22 (75.9%) of the 29 significant factors were also observed in the AF farms; with 16 (55.2%) and 6 (20.7%) associated with behavioral practices and physical infrastructure, respectively (Table 7).

Table 2: Risk factors for the occurrence of avian influenza through husbandry practices in commercial poultry farms in Kano State

	Variable	No. of responses (%)		p value	Odds ratio	95% Confidence interval
		Non affected farms	Affected farms			
1	Source of bird:					
	Middlemen	17 (53.1)	27 (84.4)	0.007	1.21	0.06 – 0.68
	Hatchery	15 (46.9)	5 (15.6)			
2	Free range birds on farm:					
	No	29 (90.6)	5 (78.1)	*0.018	2.71	0.63 – 11.59
	Yes	3 (9.4)	7 (21.9)			
3	Birds of different ages on farm:					
	No	17 (53.1)	11 (34.4)	0.031	2.16	0.79 – 5.92
	Yes	15 (46.9)	21 (65.6)			
4	Farm vaccinates against avian influenza:					
	No	31 (96.9)	29 (90.6)	*0.002	3.21	0.32 – 32.60
	Yes	1 (3.1)	3 (9.4)			
5	Rodents/wild birds access feed:					
	No	9 (28.1)	12 (37.5)	0.024	3.65	0.23 – 1.87
	Yes	23 (71.9)	20 (62.5)			
6	Farm employee also keep poultry;					
	No	30 (93.8)	27 (84.4)	*0.030	2.78	0.50 – 15.52
	Yes	2 (6.3)	5 (15.6)			

*Fisher's Exact Test

Table 3: Risk factors for the occurrence of avian influenza through movement of personnel, equipment and waste disposal in commercial poultry farms in Kano State

	Variable	Response (%)		p value	Odds ratio	95% Confidence interval
		Non affected farms	Affected farms			
1	Free access to poultry pens:					
	No	18 (56.3)	19 (59.4)	0.012	1.88	0.33 – 2.37
	Yes	14 (43.8)	13 (40.6)			
2	Visitors restriction into farm;					
	No	26 (81.3)	20 (62.5)	0.025	2.60	0.83 – 8.13
	Yes	6 (18.8)	12 (37.5)			
3	Vehicles park close to poultry pens;					
	No	29 (90.6)	23 (71.9)	*0.05	3.78	0.92 – 15.60
	Yes	3 (9.4)	9 (28.1)			
4	Staff restriction to specific pens:					
	No	4 (12.5)	20 (62.5)	0.002	1.09	0.02 – 0.30
	Yes	28 (87.5)	12 (37.5)			
5	Farm-specific clothes for staff:					
	No	29 (90.6)	25 (78.1)	*0.018	2.70	0.63 – 11.59
	Yes	3 (9.4)	7 (21.9)			
6	Use of pen-specific foot wears:					
	No	23 (71.9)	25 (78.1)	0.054	1.72	0.23 – 2.23
	Yes	9 (28.1)	7 (21.9)			
7	Method of manure disposal					
	No	19 (59.4)	18 (56.3)	0.008	1.12	0.42 - 3.07
	Yes	13 (40.6)	14 (43.8)			
8	Dead bird disposal by refuse dump					
	No	29 (90.6)	24 (75.0)	*0.052	2.13	0.12 – 2.16
	Yes	3 (9.4)	8 (25.0)			

*Fisher's Exact Test

Table 4: Risk factors for the occurrence of avian influenza through trade practices in commercial poultry farms in Kano State

	Variable	Response (%)		P value	Odds ratio	95% Confidence interval
		Non affected farms	Affected farms			
1	Poultry dealers/catchers wear same clothing between farms:					
	No	3 (9.4)	10 (31.3)	0.030	2.22	0.06 – 0.93
	Yes	29 (90.6)	22 (68.8)			
2	Poultry trader enter farm:					
	No	28 (87.5)	22 (68.8)	*0.030	3.81	0.88 – 11.52
	Yes	4 (12.5)	10 (31.3)			
3	Egg crates of traders allowed into pens:					
	No	30 (93.8)	18 (56.3)	*0.001	11.67	2.37 – 57.36
	Yes	2 (6.3)	14 (43.8)			
4	Exchange of egg crates between traders and farm:					
	No	31 (96.9)	23 (71.9)	*0.006	12.13	1.43 – 102.61
	Yes	1 (3.1)	9 (28.1)			

*Fisher's Exact Test

Table 5: Risk factors associated with avian influenza infection among workers in commercial poultry farms in Kano State

	Variable	Response (%)		p value	Odds ratio	95% Confidence interval
		Non affected farms	Affected farms			
1	Farm-specific clothes for staff:					
	No	29 (90.6)	25 (78.1)	*0.018	2.70	0.63 – 11.59
	Yes	3 (9.4)	7 (21.9)			
2	Use of pen-specific foot wears:					
	No	23 (71.9)	25 (78.1)	0.054	1.72	0.23 – 2.23
	Yes	9 (28.1)	7 (21.9)			
3	Hand washing before and after farm operation:					
	No	22 (68.8)	24 (75.0)	0.008	1.73	0.25 – 2.19
	Yes	10 (31.3)	8 (25.0)			
4	Staff wears hand gloves:					
	No	24 (75.0)	27 (84.4)	0.051	1.56	0.16 – 1.93
	Yes	8 (25.0)	5 (15.6)			

*Fisher's Exact Test

Table 6: Summary of risks for the occurrence of avian influenza in commercial poultry farms in Kano State based on principles of biosecurity

	Risk area	32 HPAI-Affected farms	32 Non-Affected farms
1	Isolation	6 (20.7%)	1 (3.5%)
2	Traffic control	5 (17.2%)	2 (6.9%)
3	Sanitation	10 (34.5%)	5 (17.2%)
	Subtotal	21 (72.4%)	8 (27.6%)
	Total	29 (51%)	

Table 7: Summary of risks associated with behavioral practices and physical infrastructure that may contribute to the occurrence of avian influenza in commercial poultry farms in Kano State.

S/n	Risk area	32 HPAI-Affected farms	32 Non-Affected farms
1	Behavioral practices	16 (55.2%)	6 (20.7%)
2	Physical infrastructure	6 (20.7%)	1 (3.5%)
	Subtotal	22 (75.9%)	7 (24.1%)
	Total	29 (51%)	

Discussion

In view of the fact that this study was conducted in 2009, 2 years after HPAI H5N1 was first reported in Nigeria, it is expected that the AF farms would have improved in their biosecurity practices. However, the finding that these farms were at very high risk of contracting the disease implies that there was no veterinary inspection to enforce or encourage best biosecurity practices after the outbreaks, despite the rigorous prevention and control campaign embarked upon by the Nigerian government and other international organizations against HPAI. Untreated surface water in farms was considered to be the most significant risk factor likely to contribute to the occurrence of AI H5N1 in the commercial poultry farms studied. The roles of untreated surface water, which is mostly contaminated, and could come from an AI-infected premise causing transmission to another premise, have been reported (Power, 2005). The possible risks could be; run-off from infected premises may enter either surface or ground water

and might travel in ditches downstream to another uninfected premise possibly carrying along AI H5N1 viruses in washed-off manure that was spread onto agricultural fields, depopulation, removal or composting of infected carcasses (Cardona, 2007). It is important to note that AI H5N1 viruses have been isolated from surface water in Canada and Minnesota, and contaminated surface water has been suggested as a short and long term source of AI viruses for domestic birds (Hinshaw *et al.*, 1979; Halvorson *et al.*, 1985). The observation that most of the commercial poultry farms were located close to the metropolitan area of Kano State, in eight of the 12 LGAs enrolled for this study, might be explained by the fact that these farms were sited to be in close proximity to the Kano main market, for easy channeling of products. This has resulted in the creation of high density of poultry farms in the area, particularly Kumbotso L.G.A. Consequently, this might have been responsible for the high frequency of outbreaks reported in the area (AICP, 2008). The finding that the AF farms were more concentrated in one area when compared with NAF farms is consistent with previous reports that high density of poultry farms in an area could be a risk factor for the introduction and maintenance of AI H5N1 (Kung *et al.*, 2007; Swayne, 2008).

The observation that there was a risk associated with relying on intermediaries (distributors) or the so called "middlemen" for the supply of day-old chicks or point-of-lay hens is consistent with the report of Desvaux *et al.* (2010) who confirmed the role of poultry movement and trading activities by middlemen as significant risk factor for the occurrence of AI H5N1 in Vietnam. Of particular concern were those intermediaries, because they may mix birds from different sources and distribute them to different locations. In some cases, these mixing nodes may be important for spreading of AI viruses to different farms (FAO, 2008). The finding that vaccination of chickens against HPAI was also found to be a highly significant risk factor and may likely contribute to the occurrence of the disease may be explained by a few reasons. Firstly, it has been reported that vaccination of chickens against the disease with inactivated oil emulsion influenza vaccines is known to prevent influenza disease signs and reduce virus shedding and spread. However, the vaccines do not induce sterilizing immunity in chickens, for a number of potential reasons, including lack of antigenic match between the vaccine and circulating strain of the virus, and

insufficient viral antigen in the vaccine (Karunakaran *et al.*, 1987; Swayne *et al.*, 2001; Webster *et al.*, 2006). The implication is that vaccinated birds may be protected when infected with the viruses, but may continue to shed the viruses in the environment. Susceptible birds may be infected with the field viruses, and may exhibit clinical signs (Capua & Marangon, 2003).

Secondly, eventhough vaccination of poultry against HPAI has been useful in some countries in preventing infection and controlling the epizootic through limited spread in domestic poultry, no country that has employed it extensively has yet been able to eliminate the viruses (FAO, 2008). While vaccination is certainly a useful tool in the control of HPAI, it is never likely to be sufficient on its own to eradicate the disease. Besides, vaccination of whole populations of poultry requires political commitment and investment and this is difficult to maintain in the long term (FAO, 2008). It is important to note that the long-term circulation of the AI H5N1 viruses in a vaccinated population may result in both antigenic and genetic changes in the virus and this has been reported to have occurred in Mexico (Escorcia *et al.*, 2008).

The non restriction of staff to specific pens may encourage cross-infection between pens, as a staff may carry infection from an infected to an uninfected pen. This may be explained by the fact that, most frequently, the clothes, shoes and hands of these staff may be contaminated with dust, feathers, and excrement containing AI H5N1 viruses and may be carried to pens (Cardona, 2007; Cardona, 2008). Of particular concern is the risk for the occurrence and spread of AI H5N1 viruses through poultry litter. It is important to note that the practice of accumulating poultry litter (which is mostly used as manure meant for crop farming or sold to crop farmers) is common among the poultry farms in Kano State. The implication is that, accumulated manure might serve as a source for AI H5N1 viruses. Given that large quantities of AI H5N1 viruses are shed in the faeces of infected poultry, an emerging market for poultry manure as fertilizer may also facilitate the rapid spread of AI H5N1 viruses from farm to farm (Power, 2005). It has been reported that AI H5N1 viruses could survive for many weeks in wet poultry manure at cool temperatures (4°C), and for up to 10 days at 25°C (Power, 2005). The concentration of the AI H5N1 viruses shed in poultry faeces is usually very high. Consequently, spread of AI H5N1 viruses through contaminated

manure from infected premises to a separate susceptible flock could occur through the movement of people, equipment, vehicles and wild birds (e.g egrets) (Power, 2005).

The finding that highly significant risks for the spread of AI H5N1 were associated with allowing egg crates of traders into pens and the exchange of egg crates between traders and farmers is consistent with previous reports that egg crates were found to be significant risk for the spread of AI H5N1 viruses between farms (Thomas *et al*., 2005). It has been reported that AI H5N1 viruses may be found on egg crates and outer surfaces and inside of egg shells (Cardona, 2007). The transfer of eggs on crates contaminated with AI H5N1 viruses is a potential means of spreading of HPAI between farms that allow both entry and exchange of egg crates (Power, 2005; Cardona, 2007). The significant risk observed for human infection with AI H5N1 viruses through non washing of hands before and after farm operations among commercial poultry workers is consistent with previous reports (Dinh *et al*., 2006). Although AI type A H5N1 viruses rarely infect humans, it is important to mention that as at October 7, 2011, 331 (58.6%) of 565 persons infected with the viruses and have died of the disease in 15 countries of the world (one in Nigeria and 52 in Egypt) between January, 2003 to July, 2011 (WHO, 2012). The virus is excreted in the droppings of infected birds and their respiratory secretions (Dinh *et al*., 2006). Transmission to humans could occur through contact with infected sick or dead poultry or their droppings, or contact with contaminated litter or surfaces (e.g egg crates) (Anonymous, 2004; ESFA, 2005). The possible routes of entry of the virus into humans are the mouth, nose, eyes and lungs (Dinh *et al*., 2006). The report that relatively high rates of H5 and H9 antibody seroprevalence was recorded among Hong Kong poultry workers have highlighted the potential for AI H5N1 viruses to transmit to unprotected humans, particularly those with occupational exposure (Dinh *et al*., 2006). Such transmission may increase the likelihood of reassortment between a currently circulating human virus and an avian virus and thus the possible creation of a strain with pandemic potential. It is pertinent to mention that all reported human cases have coincided with outbreaks of HPAI H5N1 in poultry (Mohan *et al*., 2008). The presence of water reservoirs which was observed to be higher in the AF farms may contribute to the occurrence of HPAI H5N1 outbreak. It has been reported that these water reservoirs are sometimes shared by domestic

ducks and generally ducks on backyard farms feed on nearby reservoirs of water, predominantly, ponds made by the poultry farmers for household purposes or for aquaculture (Biswas *et al*., 2009). The implication is that these water reservoirs might become contaminated with AI H5N1 viruses by virus-shedding ducks that congregate at these places to feed on vegetation, small fish and amphibians that may be found in the water (Desvaux *et al*., 2010). The presence of dense vegetation and tall trees could indirectly present the risk for the occurrence of AI H5N1 among the poultry farms in view of the fact that these aforementioned places could provide conducive homes and roosting places for rodents and wild birds. It has been reported that wild birds represent a reservoir for AI H5N1 viruses worldwide (Deogu *et al*., 2003; Hoye *et al*., 2010). This is a concern because many of the birds are migratory and travel over long distances across international borders (Hoye *et al*., 2010). Wild birds have been shown to introduce novel influenza gene segments into a population, that when reassorted with existing viruses can generate a dissimilar virus with different antigenic and other biological characteristics (Biswas *et al*., 2009). Looking at epidemiological data currently available, evidence is mounting that wild birds may play an important role in the AI H5N1 cycle and could be the initial source for some AI H5N1 viruses which may be passed on through contact with resident water fowl or poultry, particularly domestic ducks (Biswas *et al*., 2009). In the event of low pathogenic viruses, the virus can undergo mutation or re-assort with viruses in the domestic and possibly resident bird populations until HPAI occurs (Biswas *et al*., 2009). The role of these wild birds could be complicated by the fact that the control of HPAI H5N1 in wild bird populations may not be feasible from logistical, environmental and biodiversity points of view (Biswas *et al*., 2009). Epidemiological studies have suggested that wild birds can play a role in the transmission of AI H5N1 viruses to domestic poultry and vice versa (Deogu *et al*., 2003). There was evidence of a relationship between the risk of rodents and wild birds accessing poultry feed and the occurrence of AI H5N1 in poultry farms and this is consistent with previous reports (Power, 2005). Rodents might contaminate feed and litter with their excrement containing the AI H5N1 viruses (Cardona, 2007). They are particularly important to disease control, because they are frequently infected with disease-causing organisms and can perpetuate the organisms on a farm (Zander *et al*., 1997). The presence of free

range birds and water fowls (local chickens, domestic ducks, geese, pigeons) was found to be a significant risk factor and this was recognized previously as a risk factor for HPAI occurrence, possibly due to their potential role as a reservoir of infection (Webster *et al.,* 1997; Gilbert *et al*., 2006; Paul *et al*., 2010; Ferro *et al*., 2010). Infected domestic ducks may exhibit no clinical signs, yet can excrete high concentrations of AI H5N1 viruses that are pathogenic to other poultry species (Wakawa *et al*., 2008; Henning *et al*., 2010). It has been reported that the possible risk factors for AI H5N1 spread in Indonesia include duck movements, contacts between ducks and other poultry and inadequate handling of sick or dead ducks by flock owners (Henning *et al*, 2009; Henning *et al*., 2010). Similarly, scavenging ducks have been implicated as important contributors to HPAI H5N1 outbreaks in poultry flocks in South-east Asia (Thanawat *et al*., 2005). In similar studies, available evidence indicated that free-range domestic birds (chickens, ducks, guinea fowls and pigeons), played an important role in the spread of HPAI H5N1 in Vietnam and Thailand. In the case of pigeons, the risk factor of contact with pigeons included two categories: the owner's own domestic pigeons and neighbours' visiting pigeons. It is important to note that keeping pigeons alongside commercial poultry is a common practice among some poultry farmers in Kano State. The implication is pigeons' feeding and behaviour could probably allow them to come in close contact with the secretions of HPAI-infected or dead chickens or with fomites, enabling them to transmit the virus (Chalmers, 2005; Biswas *et al*., 2009). The practice of keeping birds of different ages was significant. The implication is that, multiple ages on the same premise may constitute a serious disease potential from both actively infected birds and recovered carriers, particularly if birds of differing ages are closely associated through management practices or proximity (Zander *et al*., 1997). The finding that allowing free access to poultry pens, non restriction of visitors and parking vehicles close to poultry pens might pose significant risk for the occurrence of AI H5N1 is consistent with previous reports (Cardona &

Kuney, 2002; Cardona, 2007; Cardona, 2008; Henning *et al*., 2010). Because of their mobility, duties, curiosity, ignorance, indifference, carelessness or total concentration on current profit margin, humans constitute one of the greatest potential causes of the introduction of disease (Power, 2005). Rarely is this because they become infected and shed the disease agent, but rather because they track infectious agents, use contaminated equipment, or manage their flocks in such a way that spread of disease is inevitable (Power, 2005). Poultry catchers and egg traders that were allowed to wear the same clothing between farms and also allowed to enter poultry farms were considered to be significant risks. The implication is that their contaminated clothes and shoes might mechanically spread the AI H5N1 viruses from infected to uninfected premises (EFSA, 2005; Power, 2005). The significant risk associated with the method of dead bird disposal by refuse dump in this study is also consistent with previous reports (Cardona & Kuney, 2002). The danger is, infected dead birds may be fed upon by wild birds, domestic free roaming birds, cats or dogs. It has been reported that the disposal in the environment of dead birds may raise an additional risk for AI H5N1 spread, particularly for farming systems characterized by free-roaming birds, given tendencies toward predation and/or cannibalism (FAO, 2006). The report that domestic cats and dogs can be infected if they feed on infected chickens has also fueled concerns about the risk that AI H5N1 virus poses to cats and dogs, and subsequently to humans who have direct contact with them (Richard, 2006; Pilaipan, 2010).

In conclusion, the risks for the occurrence of HPAI H5N1 are higher in AF than NAF farms. The AF farms have not improved in their biosecurity practices despite their previous experiences with outbreaks of HPAI H5N1 in the State and government's campaign against the disease. It is recommended that veterinary inspection to enforce and encourage best biosecurity practices for poultry farms should be introduced and sustained.

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