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RESEARCH ARTICLE

Assessment of Biosecurity Measures in Live Poultry Markets in N'Djamena, Chad

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Abstract

Background and Objective: Although, biosecurity is a primary means of disease prevention in livestock farming, implementing these measures remains challenging in live poultry supply chains. This study evaluated the implementation of biosecurity measures across four major commercial markets in N'Djamena, Chad: Al-Afia, Champs de Fil, Diguel and Dembé.

Methodology: Between July and August 2023, a cross-sectional survey was conducted among 120 permanent live poultry vendors. A structured questionnaire was used to assess vendors' awareness of avian pathogens, knowledge of biosecurity standards and implementation of sanitary practices.

Results: The results showed that 60.83% of vendors had low levels of biosecurity knowledge, 23.34% had moderate knowledge and 15.83% had good knowledge. Dembé market had the highest proportion of vendors with good biosecurity knowledge, with 6.67% of the total respondents classified in this category and a Mean±SD of 6.67±0.97%, significantly higher than the corresponding values for Al-Afia (2.50±0.31%) and Diguel (1.66±0.09%). Regarding compliance, 60% of vendors failed to implement biosecurity protocols, whereas only 5% adhered strictly to the recommended standards. Complete non-implementation was most prevalent at Diguel (17.50±4.28%) and Al-Afia (15.00±3.44%), compared with Champs de Fil (10.83±2.87%). These deficiencies were associated with a lack of formal training, inadequate market infrastructure and low perceived immediate health risks.

Conclusion: The findings indicate substantial gaps in biosecurity knowledge and compliance among live poultry vendors in N'Djamena. Given the potential role of live poultry markets in the transmission of avian influenza, Newcastle disease and other infectious diseases, targeted training programs, infrastructure improvements and strengthened regulatory frameworks are urgently needed.

INTRODUCTION

In sub-Saharan Africa, particularly in Sahelian countries such as Chad, where demand for animal protein is growing rapidly, small-scale and family poultry production plays a critical socioeconomic role. Local indigenous chickens have several advantages, including short reproductive cycles, low start-up costs and resilience to harsh environmental conditions. Despite their modest individual productivity, family poultry farms are a primary source of animal protein and an important source of household income, particularly for rural and peri-urban women[1,2]. Traditional extensive poultry

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systems predominate in rural areas of Chad, while semi-industrial and commercial live poultry trade networks have expanded significantly around peri-urban areas near major urban centers such as N'Djamena. However, the poultry sector faces systemic vulnerabilities, including limited veterinary extension support, inadequate financial investment and weak biosecurity measures along transport corridors, at farm gates and within urban live poultry markets (LBMs)[3,4].

The introduction of pathogens into poultry trade chains can cause substantial economic losses through mortality, reduced bird performance and compromised meat quality. Inadequate sanitary practices in holding cages and market stalls may create conditions conducive to the persistence and dissemination of viral and bacterial pathogens, particularly in the absence of systematic cleaning, disinfection and vector control protocols that conform to international sanitary and hygiene standards[5]. Biosecurity encompasses the full set of operational practices implemented to prevent the introduction and spread of infectious agents within livestock populations and commercial hubs[6]. In Chadian live poultry markets, infrastructure and facilities such as vehicle disinfection rollers, footbaths, running water and species-segregated holding stalls are virtually absent. Consequently, poultry vendors and traders may be highly exposed to cross-contamination by viral pathogens, particularly highly pathogenic avian influenza virus (HPAI H5N1) and Newcastle disease virus (NDV)[7,8].

N'Djamena's markets have a distinctive epidemiological vulnerability due to the continuous mixing of avian species of different ages and health statuses originating from different provincial supply zones. Recent regional studies across Central and West Africa emphasize that live poultry markets can act as epidemiological amplification centers when biosecurity standards are inadequate[8,9]. However, quantitative empirical assessments of biosecurity knowledge and practices among urban poultry vendors in Chad remain scarce. To address this knowledge gap, this study aimed to evaluate the biosecurity knowledge and operational compliance practices of live poultry vendors in four major commercial markets in N'Djamena, Chad.

MATERIALS AND METHODS

Ethical statement: The study protocol was reviewed and approved by the Institutional Ethics Committee of the Higher National Institute of Sciences and Techniques of Abéché (INSTA, Abéché, Chad; approval reference No. Eth-2023-INSTA-004). The study was conducted in accordance with internationally accepted ethical principles and guidelines for research involving human participants, including the principles of voluntary participation and informed consent.

Study area and market selection criteria: The study was conducted in N'Djamena, the capital city of Chad. The city is located in the Sahelian zone at approximately 12.8°N latitude and 15.2°E longitude, at the confluence of the Chari and Logone rivers10. N'Djamena experiences a semi-arid climate characterized by a short rainy season from July to September and an extended dry season.

Four major municipal markets were purposively selected based on three criteria: (1) A high daily volume of live poultry transactions, (2) Strategic geographical representation across major municipal districts and (3) Their role as primary wholesale and retail hubs receiving birds from major provincial supply routes, including Hadjer-Lamis, Chari-Baguirmi and Mayo-Kebbi.

The four selected markets were Al-Afia Market (4th District), Champ de Fil Market (5th District), Dembé Market (7th District) and Diguel Market (8th District) (Fig. 1).

Sampling strategy and vendor selection: In collaboration with representatives of market vendor unions, preliminary site mapping was conducted to identify all commercial poultry sales points within the four selected markets. Poultry traders were categorized into two operational groups: permanent vendors, who operated fixed stalls year-round and seasonal or transient vendors. The sample was restricted to permanent vendors because of their sustained presence, high daily poultry-handling volume and potential long-term influence on market sanitary conditions.

Of the 135 permanent vendors identified across the four markets, 120 met the inclusion criteria, which required a minimum operational tenure of six months and voluntary consent to participate. These vendors were surveyed, representing an overall coverage rate of 88.9%. The sample size distribution by market was as follows: Al-Afia (n = 32), Champ de Fil (n = 31), Diguel (n = 29) and Dembé (n = 28).

Data collection and questionnaire structure: A field survey was conducted from July to August 2023 using a structured, pre-tested questionnaire. Data were collected through face-to-face interviews conducted by trained veterinary technical personnel. Field data collection tools included a digital camera for documenting market conditions and a handheld GPS receiver (Garmin eTrex 22x) for recording the geographical coordinates of the market sites.

The questionnaire was developed in accordance with standard FAO guidelines for biosecurity assessments in live poultry markets[6] and was structured into four core domains (Table 1).

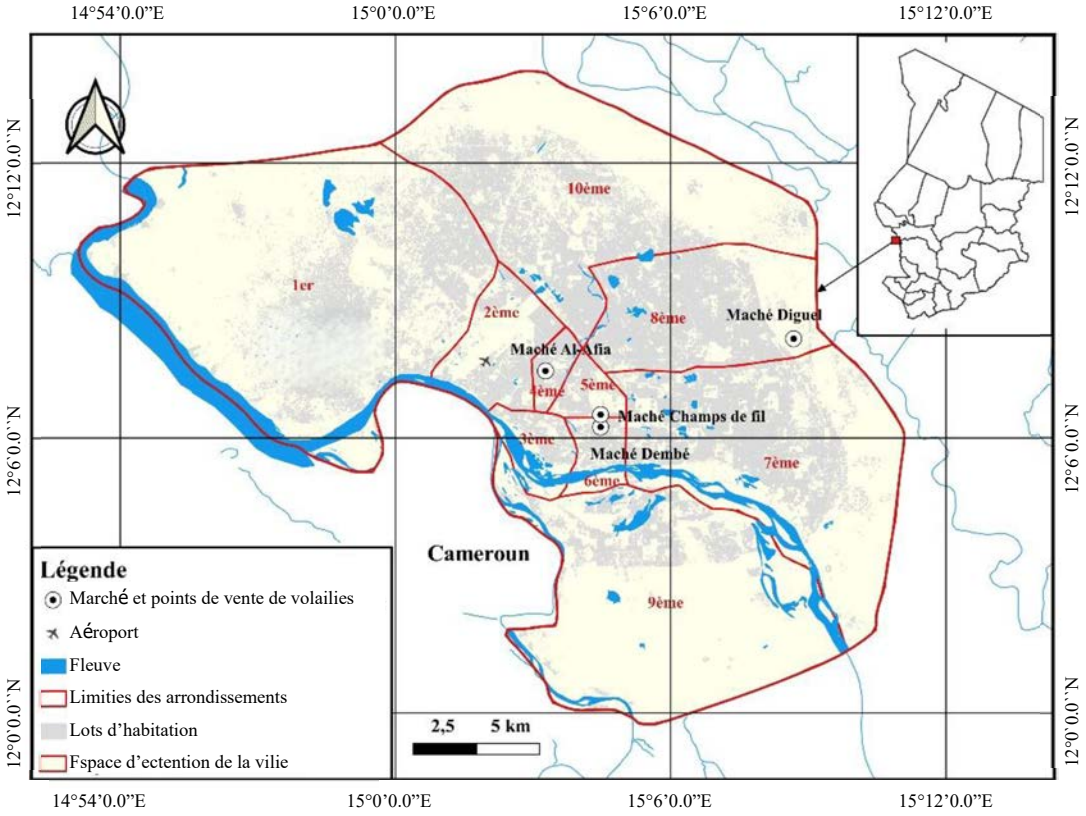


Fig. 1: The location of the city's poultry markets

Table 1: Structure of the questionnaire and biosecurity domains assessed

Domain	Evaluated variables	Scoring criteria/levels
Avian disease awareness	Knowledge of clinical symptoms (NDV, HPAI), transmission routes, mortality reporting	Low (<50%), Moderate (50-75%), Good (>75%)
Biosecurity knowledge	Understanding of quarantine, disinfection, species segregation, footbaths, personal hygiene	Low (<50%), Moderate (50-75%), Good (>75%)
Biosecurity Implementation	Routine stall cleaning, disinfectant use, dead bird disposal, sick bird isolation, PPE use	Poor (None/0-25%), Low (26-50%), Moderate (51-75%), Good (>75%)

HPAI: Highly pathogenic avian influenza, NDV: Newcastle disease virus, PPE: Personal protective equipment

Statistical analysis: The data were compiled and checked for missing entries using Microsoft Excel 2016. The dataset was subsequently transferred to XLSTAT software (version 2016, Addinsoft, Paris, France) for statistical analysis. Categorical variables, including knowledge levels and compliance categories, were analyzed using the chi-square test of independence to assess differences in the distribution of frequencies among markets. One-way analysis of variance (ANOVA) was used to compare continuous knowledge and implementation scores among markets, with results expressed as mean±standard deviation (SD). Standard Errors (SE) were calculated to quantify the precision of the estimated means. When significant differences were detected by ANOVA, post hoc pairwise comparisons were performed using Tukey's Honestly Significant Difference (HSD) test. The threshold for statistical significance was set at $p<0.05$.

RESULTS

Level of awareness regarding avian diseases: An overall assessment of disease awareness revealed that 60.84% of poultry vendors in N'Djamena had a low level of knowledge regarding major avian infectious pathogens, whereas 39.16% exhibited a moderate level of disease awareness (Table 2). Across the individual markets, the proportion of respondents with low disease awareness ranged from 14.17% in Champ de

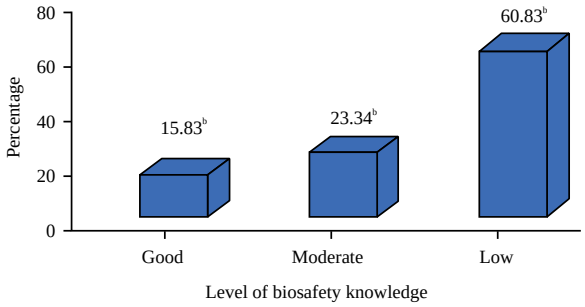


Fig. 2: Biosecurity knowledge levels among live poultry vendors in N'Djamena markets

Table 2: Awareness of avian diseases among live poultry vendors in the surveyed markets of N'Djamena

	Awareness of avian diseases		
Markets surveyed	Low (%)	Moderate (%)	p-value
Al-Afia	15.00	11.66	p = 0.032
Champ de fil	14.17	9.17	p = 0.041
Diguél	17.5	6.67	p = 0.011
Dembé	14.17	11.66	p = 0.028
Total	60.84	39.16	p = 0.028

Table 3: Biosecurity knowledge levels among live poultry vendors across surveyed markets

	Poultry markets				
Level of biosecurity implementation	Al-Afia (n = 32)	Champ de fil (n = 31)	Diguél (n=29)	Dembé (n = 28)	p-value
Good level (%)	2.50±0.31^{b}	5.00±0.81^{a}	1.66±0.09^{b}	6.67±0.97^{a}	p = 0.024
Moderate level (%)	8.33±1.03^{a}	5.01±0.75^{b}	1.67±0.12^{c}	8.33±1.86^{a}	p = 0.018
Low level (%)	15.83±1.49^{b}	13.33±1.52^{bc}	20.83±2.78^{a}	10.83±1.9^{c}	p<0.001

$^{a-c}$Within the same row, values sharing the same superscript letter do not differ significantly (p > 0.05) and n: number of merchants

Fil and Dembé to 17.50% in Diguel. Differences in disease awareness scores among the markets were statistically significant (p<0.05).

Level of biosecurity knowledge

Knowledge of biosecurity measures among poultry vendors in N'Djamena: Figure 2 illustrates the level of knowledge of biosecurity measures among poultry vendors in N'Djamena. The results show that 60.83% of poultry vendors in the main markets of N'Djamena had a low level of knowledge regarding these measures. This proportion was significantly higher than the corresponding proportions of vendors with moderate (23.34%) and good (15.83%) levels of knowledge (p<0.05).

Biosecurity knowledge levels among live poultry vendors by market: Table 3 presents the level of biosecurity knowledge among poultry vendors in N'Djamena. Only 6.67% of vendors at Dembé Market had a good level of knowledge of these measures, followed by 5.00% at Champ de Fil Market. These proportions were significantly higher than those recorded at Al-Afia (2.50%) and Diguel (1.66%) markets (p<0.05). In addition, 8.33% of vendors at Al-Afia and Dembé markets had a moderate level of knowledge of biosecurity measures, compared with 5.01% at Champ de Fil and 1.67% at Diguel. These differences were statistically significant (p<0.05).

A low level of knowledge of biosecurity measures was significantly more prevalent among poultry vendors at Diguel Market (20.83%), followed by those at Al-Afia Market (15.83%) and Champ de Fil Market (13.33%). However, no significant difference was observed between the proportions of vendors with low biosecurity knowledge at Dembé (10.83%) and Champ de Fil (13.33%) markets (p>0.05). Nevertheless, the proportion recorded at Champ de Fil was significantly higher than those observed at Al-Afia and Diguel markets (p<0.05).

Level of biosecurity implementation and compliance:

Level of biosecurity implementation and compliance among poultry vendors in N'Djamena: Figure 3 illustrates the extent to which biosecurity measures were implemented by poultry vendors in N'Djamena's main markets. The results show that 60% of poultry vendors did not implement biosecurity measures. This proportion was significantly higher than the corresponding proportions of vendors with low (22.5%),

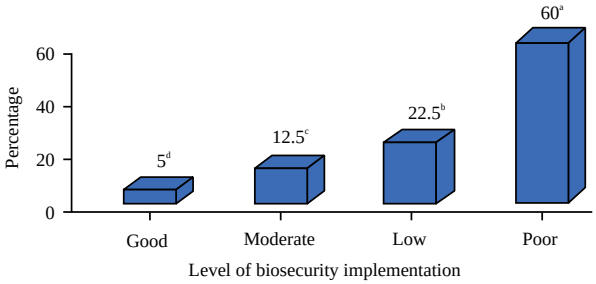


Fig. 3. Implementation of biosecurity measures in poultry markets in the city of N'Djamena

Table 4: Implementation of biosecurity measures across surveyed poultry markets

Level of biosecurity implementation	Poultry markets				p-value
	Al-Afia (n = 32)	Champ de fil (n = 31)	Diguél (n = 29)	Dembé (n = 28)	
Good (%)	1.67±0.07^{b}	1.67±0.08^{b}	0.83±0.01^{c}	2.50±0.76^{a}	p = 0.031
Moderate (%)	4.17±0.58^{a}	3.33±0.51^{b}	0.83±0.02^{c}	4.17±0.61^{a}	p = 0.022
Low (%)	5.83±0.93^{b}	7.50±1.01^{a}	5.00±0.89^{b}	4.17±0.98^{bc}	p = 0.004
Poor (%)	15.00±3.44^{a}	10.83±2.87^{b}	17.50±4.28^{a}	15.00±4.10^{a}	p = 0.015

$^{a-c}$Within the same row, values sharing the same superscript letter do not differ significantly (p > 0.05)

moderate (12.5%) and good (5%) levels of implementation (p<0.05). Overall, a significant difference was observed among the different levels of biosecurity implementation (p<0.05).

Level of biosecurity implementation and compliance by poultry market: Table 4 summarizes the level of implementation of biosecurity measures among poultry vendors across the markets of N'Djamena. As shown in the table, most poultry vendors in the main markets of N'Djamena did not implement biosecurity measures. The level of noncompliance was similar among Al-Afia, Diguel and Dembé markets but was notably higher than that observed at Champ de Fil Market.

Among vendors exhibiting a low level of biosecurity implementation, the highest proportion was recorded at Champ de Fil (7.50%), followed by Al-Afia (5.83%), Diguel (5.00%) and Dembé (4.17%) markets. Furthermore, 4.17% of vendors at both Al-Afia and Dembé markets exhibited a moderate level of biosecurity implementation. This proportion was significantly higher (p<0.05) than those observed at Champ de Fil (3.33%) and Diguel (0.83%) markets. Additionally, 2.50% of vendors at Dembé Market correctly implemented the recommended biosecurity measures and this proportion was significantly higher than those observed at the other markets.

DISCUSSION

This investigation revealed substantial deficits in biosecurity knowledge and practical compliance among live poultry vendors in major commercial markets in N'Djamena. Only 15.83% of the surveyed vendors demonstrated an good level of biosecurity knowledge, whereas 60.83% had low level of knowledge. These findings are consistent with those reported by Abbo *et al.*[4] in poultry farms in the N'Djamena area and the border zones of Hadjer-Lamis and Chari-Baguirmi, where more than 88% of farms exhibited low to moderate levels of biosecurity compliance. Taken together, these findings suggest that biosecurity deficiencies represent a systemic vulnerability across the Chadian poultry value chain rather than isolated shortcomings confined to individual markets.

A major contributor to this knowledge gap is the apparent absence of formal, structured veterinary biosecurity training among market vendors. Most vendors rely on informal peer-to-peer communication or general mass media, such as radio and television, to obtain information. Consequently, critical technical concepts, including vector control, appropriate disinfectant contact times, all-in/all-out management and pathogen exclusion, may remain poorly understood. As Amass and Clark [11] and Sanderson *et al.*[12] have highlighted, limited technical understanding can impair risk perception and reduce vendors' motivation to adopt preventive sanitary measures.

Regarding operational compliance, 60% of vendors failed to implement basic biosecurity measures and only 5% achieved satisfactory compliance. The substantial discrepancy between knowledge (15.83% satisfactory) and practice (5.00% satisfactory) illustrates a significant gap between awareness and implementation. Similar discrepancies between biosecurity awareness and actual practices have been

documented extensively in West Africa[7,9]. Structural constraints in N'Djamena's markets, including limited access to potable water, the lack of washable, non-porous cage materials and dedicated quarantine holding areas and economic pressures to maximize transaction speed, may substantially hinder compliance, even among vendors who understand basic biosecurity principles.

Significant differences were observed among markets, with Dembé exhibiting higher knowledge and implementation scores than Diguel and Al-Afia. These differences may be associated with variations in vendors' sociodemographic characteristics and market turnover. Dembé, a major commercial hub in N'Djamena, may attract experienced vendors who have more frequent interactions with veterinary or public health inspectors. Racicot *et al.*[13] demonstrated that educational attainment, trading experience and professional accountability are significantly associated with biosecurity adherence. Furthermore, Dorea *et al.*[14] and Racicot *et al.*[1] showed that heightened perceptions of immediate epidemic risk can improve short-term compliance. However, if vendors perceive the risk of an epidemic to be low, potentially because of limited awareness of recent outbreaks or insufficient dissemination of outbreak-related information, their motivation to invest in routine sanitation measures may be reduced. This potential explanation warrants further investigation, as the relationship between outbreak awareness and compliance was not necessarily established by the present findings.

Comparison of our findings with regional studies from West and Central Africa reveals shared epidemiological concerns. Studies conducted in neighboring countries, including Cameroon[5], Nigeria[16] and Niger[7], have identified live poultry markets as important interfaces for the circulation and transmission of Newcastle disease virus and the zoonotic Highly Pathogenic Avian Influenza (HPAI) H5N1 virus. These markets bring together avian species from diverse sources, including indigenous chickens, waterfowl and guinea fowl, often under high-density and stressful conditions. Such conditions can facilitate pathogen transmission between birds and increase opportunities for contact among infected and susceptible populations. In the case of influenza A viruses, co-infection with different viral strains may also create opportunities for genetic reassortment. Consequently, insufficiently monitored poultry trade and inadequate biosecurity practices in N'Djamena may pose risks to regional poultry production and veterinary public health, highlighting the need for targeted interventions to strengthen biosecurity throughout the poultry value chain.

CONCLUSION AND RECOMMENDATIONS

This study revealed substantial deficiencies in biosecurity knowledge and practical implementation among live poultry vendors in N'Djamena's major markets. Most vendors demonstrated inadequate biosecurity knowledge and poor implementation of biosecurity measures. The Dembé market exhibited better performance than Diguel and Al-Afia. The main factors potentially contributing to these deficiencies include the absence of structured vendor training programs, inadequate market infrastructure and low perceived disease risk.

To mitigate epidemic and zoonotic risks, the following priority actions are recommended:

- **Capacity building:** Establish mandatory, modular training programs for all registered market vendors, covering avian hygiene, biosecurity practices and disease recognition. These programs should be delivered by veterinary extension services
- **Infrastructure modernization:** Equip municipal markets with washable metal cages, reliable access to running water, standardized footbaths and dedicated isolation cages for sick birds to facilitate effective sanitation and reduce the risk of pathogen transmission
- **Regulatory enforcement and surveillance:** Implement routine sanitary inspections by municipal veterinary authorities, alongside active epidemiological surveillance for Newcastle disease virus and highly pathogenic avian influenza
- **Public-private governance:** Strengthen vendor cooperative associations to promote peer-led biosecurity compliance, collective responsibility and self-regulation within commercial markets

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