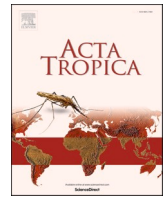




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# Risk assessment and preventive health behaviours toward COVID-19 amongst bushmeat handlers in Nigerian wildlife markets: Drivers and One Health challenge

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## ABSTRACT

Over 70% of emerging infectious diseases are zoonotic and 72% of them have wildlife reservoirs with consequent global health impacts. Both SARS-CoV-1 and SARS-CoV-2 emerged certainly through wildlife market routes. We assessed wildlife handlers' zoonotic risk perceptions and preventive health behaviour measures toward COVID-19 during pandemic waves, and its drivers at wildlife markets using Health Belief Model (HBM) constructs. A cross-sectional study was conducted at purposively selected wildlife markets in Nigeria between November 2020 and October 2021. Descriptive, univariate, and multivariable logistic regressions analyses were performed at 95% confidence interval. Of the 600 targeted handlers in 97 wildlife markets, 97.2% ( $n = 583$ ) participated. Consumers were the majority (65.3%), followed by hunters (18.4) and vendors (16.3%). Only 10.3% hunters, 24.3% vendors and 21.0% consumers associated COVID-19 with high zoonotic risk. Also, only few handlers practiced social/physical distancing at markets. Avoidance of handshaking or hugging and vaccination was significantly ( $p = 0.001$ ) practiced by few handlers as preventive health behaviours at the markets. All the socio-demographic variables were significantly ( $p < 0.05$ ) associated with their knowledge, risk perceptions, and practice of preventive health behaviours toward COVID-19 at univariate analysis. Poor markets sanitation, hygiene, and biosecurity (OR=3.35, 95% CI: 2.33, 4.82); and poor butchering practices and exchange of wildlife species between shops [(OR=1.87; 95% CI: 1.34, 2.60) and (OR=2.03; 95% CI: 1.43, 2.88), respectively] were more likely to significantly influence COVID-19 emergence and spread at the markets. To tackle the highlighted gaps, collaborations between the public health, anthropologists, and veterinary and wildlife authorities through the One Health approach are advocated to intensify awareness and health education programmes that will improve perceptions and behaviours toward the disease and other emerging diseases control and prevention.

## 1. Introduction

Emergence of the Severe Acute Respiratory Syndrome coronavirus 2 (SARS-CoV-2) with global health pandemic concern in early 2020 in China was perceived to be associated with wildlife trade, a predominant narrative that is yet to be confirmed with evidence, and was the second to emerge (Andersen et al., 2020; Xiao et al., 2020; Zhang et al., 2020). The first was the SARS-CoV-1 that emerged in China and was found to be associated with infections in masked palm civets (*Paguma larvata*) and

raccoon dogs (*Nyctereutes procyonoides*) in markets and restaurants (Cheng et al., 2007). However, SARS-CoV-2 was initially connected to a wet market in Wuhan, China where different wildlife species are traded (Haider et al., 2020; Sheath et al., 2020). This has led to some wildlife species like snakes, pangolins, and bats being singled out as possible sources or intermediate hosts of the virus (Xiao et al., 2021).

Links were made between COVID-19 emergence and the wildlife at the Huanan seafood wholesale market in Wuhan, Hubei Province, China (WHO, 2021a). The role of the wet market was suggested as a forum for

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either the spillover, amplification, or reservoir of SARS-CoV-2 because of SARS-CoV-2-positive environmental samples collected in the market (WHO, 2021b). Since then, the wildlife trade remains the centre of international discussions about COVID-19 emergence (Turcios-Casco and Cazzolla Gatti, 2020; MacLean et al., 2021). However, the source of SARS-CoV-2 still remains a contentious issue with the overall risk remaining a concern (WHO, 2021c).

A wildlife market (wildlife trade hotspot) is a place where wildlife fresh meats (also known as bushmeat) from both live and dead animals and their products are stored and sold, often in an open-air environment (Roe et al., 2020). Consumption of bushmeat provides a source of protein and income for human livelihoods as well as many benefits of socio-cultural significance such as international tourism (Ordaz-Németh et al., 2017; Kogan et al., 2019). It is a global phenomenon, commonly found in Asia and Africa, that allows the mixing of multiple species from many sources, and provides avenues for pathogen introduction, evolution, amplification, and divergent dissemination pathways of emerging infectious diseases of societal concern affecting humans (Webster, 2004).

An estimated 75% of human emerging infectious diseases are zoonotic (Jones et al., 2008), and 72% of them originated from wildlife (Taylor et al., 2001; Kock and Caceres-Escobar, 2022). It has been given that about 24% of all wild terrestrial vertebrate species are traded globally, and the legal international wildlife trade was estimated to be worth US\$107 billion, while the illegal wildlife trades was estimated at US\$7–\$23 billion annually in 2019 (IPBES, 2020). Also, around 421,000,000 threatened wild animals were traded between 226 nations or territories from 1998 to 2018 (Liew et al., 2021). The trade and consumption of wildlife and wildlife products (food, medicine, and fur) contribute to emerging diseases, a critical One Health challenge, having been implicated in zoonotic outbreaks, including SARS and COVID-19 (Lin et al., 2021).

Although the risk of infections from wild meat hunting and handling along the supply chain is not quantifiable at present, zoonotic diseases have nonetheless emerged and re-emerged from these practices, often with immense public health and socio-economic consequences, as in the cases of the deadliest epidemic viral diseases like Ebola virus in Central and West Africa, and SARS coronavirus in China (Leroy et al., 2004; Leendertz et al., 2016; Cui et al., 2019). Also, many international organizations like the World Health Organization (WHO), the World Organisation for Animal Health (OIE), and the United Nations Environment Programme (UNEP), have pointed to tropical wild meat hunting and trade as a key driver of emerging disease outbreaks and SARS-CoV-2 emergence that resulted in COVID-19 pandemic (OIE, WHO, UNEP, 2021; Wegner et al., 2022).

As of 13 October 2020, out of 558,313 samples tested, 60,430 (10.8%) cases were confirmed throughout Nigeria. These include 7372 (1.3%) active cases, 51,943 (9.3%) discharged patients and 1115 (0.2%) deaths (NCDC, 2020). Furthermore, only about 6000,000 Nigerians have received initial dose of COVID-19 vaccine as at the end of the survey in November 2021, while only 3369,628 people have taken the second dose, bringing the unvaccinated population to more than 200 million (97.15%) of the entire population (NPHCDA, 2021). However, covid cases as of October 2021 were 211,887 active cases and 2896 deaths (case fatality rate of 1.4%) (<https://www.worldometers.info/coronavirus/country/nigeria/>).

Science-based information on measures to mitigate the emergence and prevent the spread of the COVID-19 pandemic at the wildlife markets during the waves in Nigeria is not readily available. Preventative health behaviours can drastically mitigate the transmission of emerging infectious diseases during outbreaks, and people's knowledge and perceptions of diseases have a significant impact on their willingness to adopt such behaviours (Dryhurst et al., 2020; Lee et al., 2020). Research into knowledge, risk perceptions, and preventive behaviour of the stakeholders on the COVID-19 pandemic in line with two constructs of the Health Belief Model (HBM) will be good indicators for assessing the

willingness to prevent and control current and future pandemics through the wildlife markets (Strecher and Rosenstock, 1997). The constructs posit that health-related decisions depend on the effects of one's susceptibility perceptions to a given condition and the severity of the condition, which together make up 'perceived threat; and perceptions of the benefits of engaging in specified health actions. Behavioural change is, nevertheless, modified by factors such as demographic variables and knowledge (Strecher and Rosenstock, 1997). Identifying risk factors for disease emergence and dissemination through wild animals to humans is one of the most important epidemiological challenges. The dynamic interface can act as conduit for humans' exposure to zoonotic pathogens in an environment with inadequate biosecurity infrastructure.

The objectives of this study were to quantitatively assess bushmeat handlers' knowledge, perceptions, and preventive health behaviours toward risks of COVID-19 pandemic, and dissemination risk pathways at bushmeat markets during the three waves in Nigeria in line with the two constructs of HBM. We also want to identify possible associations between the handlers' socio-demographic characteristics and their knowledge, perceptions, and preventive health behaviours toward COVID-19 in the wildlife markets. We hypothesized that the socio-cultural and economic factors cannot influence COVID-19 emergence and spread in the markets. The outcome of this research is to generate better understanding of the barriers and drivers that would inform risk communication and critical stakeholders' engagement in COVID-19 management in critically vulnerable groups.

## 2. Methods

### 2.1. Study area and study design

The study was conducted in three states (Niger, Kwara, Kogi) and the Federal Capital Territory Abuja geopolitically located in North-central Nigeria, and climatically situated in the Guinea savanna ecological zone of the country. This ecoregion lies within the humid tropical savanna zone with mean annual high temperatures ranging between 30 and 33 °C, and annual rainfall averages 1600–2000 mm with average duration of about 210 days. The savanna zone has a warm forest and woodland climate bridging between the hot north and cold south of Nigeria. Wildlife markets in the North-central geo-ecological zone of Nigeria were selected because of the favourable climatic condition.

The study design was a cross-sectional study conducted from November 2020 to October 2021 amongst eligible bushmeat handlers transacting socio-economic activities in wildlife hotspot markets.

### 2.2. Sample size and sampling procedure

The sample size was determined using the simple random method (Thrusfield, 2009). In mathematical notation,  $n = Z^2 p (1 - p) / d^2$ ; where  $n$  is the required sample size;  $Z^2$  is the standard deviation, 1.96;  $p$  is the expected response from the target populations; and  $d$  is the desired absolute precision. The Open Source Epidemiologic Statistics for Public Health (OpenEpi) version 2.3.1 software (Dean et al., 2013), with power set at 50% and 4% margin of error at 95% confidence level was used for computation. A sample size of 600 participants was obtained and enrolled in the study. As for the wet market settings, 18% degree of precision was used and 30 markets were obtained for the study.

A multi-stage sampling procedure was used to select the wildlife hotspot markets and the respondents. In the first stage, three states and the Federal Capital Territory (Abuja) were conveniently chosen from the study area based on the existing state structures. At least seven markets were purposively selected in each state in the second stage. In the third and final stage, at least 150 respondents were randomly selected in each state, with at least 18 from each market, proportionally allocated based on size of the market. Attendants who worked in the markets but do not directly engage in meat handling activities, such as the causal cleaners,

were excluded.

### 2.3. Data collection tools and procedure

A structured questionnaire was developed in hard copy by the researchers using experts' opinions. It was made up of descriptive, closed-ended questions to ease processing, and contained five parts. In the first part, socio-demographic characteristics of age, gender, marital status, socio-economic activities, and level of formal education of the respondents were reported. In the second part, questions on the knowledge of the participants about the COVID-19 pandemic were asked. The third part was on participants' perceptions of COVID-19 risks during bushmeat handling activities as well as risk pathways for transmission. In the fourth part, questions about factors that influence COVID-19 emergence and spread in the markets were asked. In the last part, questions were on the preventive health behaviours for the control and prevention of its emergence and dissemination during the pandemic waves.

The questionnaire was prepared in English and translated into Hausa (for easy communication amongst participants without formal education). It was then reviewed and assessed by subject experts for its content, design, simplicity, relevance, and understanding. For reliability, a pilot study was carried out to pre-test 5% of the study population who were excluded in the final analysis, and necessary changes were made accordingly. Six data collectors (animal health workers) were trained, assigned, and monitored on a regular basis by the investigators.

Data were collected by the interviewer-questionnaire administer process. Study objectives were explained to the participants prior to the survey. Informed verbal consent was obtained from each participant before the commencement of an exercise. Participation was made voluntary based on the individual's availability, willingness to be part of the study, and notification of the right to participate or withdraw at any stage of the survey (WMADH, 2013). The completed questionnaires were collected and checked for accuracy, and thereafter labelled and coded.

### 2.4. Data entering and analysis

The obtained data were transferred into Microsoft Excel 2016 spreadsheet (Microsoft Corporation, Redmond, WA, USA) for cleaning and processing. Descriptive statistics and frequency tables were generated to explore the distribution of data. Categorical variables were expressed using descriptive statistics of frequencies and proportions, and associations amongst the handlers were explored using the Pearson chi-square test or Fisher's exact test where necessary.

To assess the knowledge, perception, and preventive health behaviour levels of the handlers, a numeric scoring system was applied. The outcome variables from the respondents regarding their socio-demographic, as well as socio-cultural and economic predictive themes, were categorized as 'inadequate' versus 'adequate', and 'poor' versus 'satisfactory', respectively. The outcomes were computed as binary responses of 'No' for incorrect response during the questionnaire administering and scored '0'; and 'Yes' for correct response was scored '1'. The grading systems ranged from 1 to 20. All scores were summed up and cut-off points set thus: respondents that scored "1 to 10" were considered having scored below average or " $\leq 50\%$ " and were regarded as 'inadequate' responses. However, those that scored "11 to 20" were considered having scored above average or " $\geq 50\%$ " and considered 'adequate'. Same applied to 'poor' and 'satisfactory' responses for socio-cultural and economic predictive determinants (Alhaji et al., 2017, 2018). The higher the score, the higher the COVID-19 knowledge-perception-preventive health behaviour levels; and the socio-cultural and economic determinants.

A univariate analysis performed with the Chi-square test was used to identify variables associated with the probability of 'inadequate' and 'adequate' or 'poor' and 'satisfactory' responses. Unconditional

associations with  $p < 0.05$  were further subjected to a multivariate logistic regression model to control for confounders and effect modifiers. The multivariate regression model was fitted with a machine-led likelihood backward stepwise regression technique. The Hosmer–Lemeshow goodness-of-fit test was used to assess the predictive ability of the model (Hosmer et al., 1997) and was found to be adequate. The confidence intervals of logistic regression were exponentiated to express them as odds ratios. All statistical analyses were conducted using the software Stata 17 (Stata Corp, College Station, TX, USA) and tests were conducted at a 5% significance level.

### 2.5. Ethical consideration

The Research proposal approval was obtained from the Research Ethics Committee of Niger State Ministry of Livestock and Fisheries, Nigeria with Ref. No. NGS/MLF/723-20.

## 3. Results

### 3.1. Socio-demographic characteristics of the participants

Of the 600 targeted handlers in 30 wildlife hotspot markets, 97.2% ( $n = 583$ ) responded. The majority of the respondents belonged to the age group 48–57 years (23.8%,  $n = 139$ ) (Fig. 1). Consumers were the majority (65.3%), followed by the hunters (18.4), and then vendors (16.3%). Males were in the majority (85.8%,  $n = 401$ ) and 31.2% ( $n = 182$ ) were females. Married participants were in the majority (68.98%,  $n = 402$ ) and 31.1% ( $n = 181$ ) were singles. Approximately one-quarter of the participants (28.0%,  $n = 169$ ) had no formal education, while 20.9%, 25.2%, and 24.9% had primary, secondary, and tertiary education, respectively.

### 3.2. Knowledge about the COVID-19 pandemic amongst the bushmeat handlers

All responded handlers (100.0%) indicated to had heard about COVID-19 pandemic outbreaks in Nigeria and worldwide. They received index information from friends (10.3%), relations (10.8%), print/electronic/social media (45.1%), veterinary health officials (9.9%), and public health officials (23.9%).

The significant levels of knowledge themes from the handlers about the COVID-19 pandemic are shown in Table 1. Only one-third (32.7%) of the consumers reported knowing people that contracted COVID-19 in Nigeria. Few hunters (23.4%), vendors (35.8%), and very few consumers (2.6%) knew that COVID-19 virus can infect wildlife. Inversely, less than one-third (31.8%) of the hunters, and more than half of the vendors (54.7%), consumers (53.0%) knew that COVID-19 virus can infect humans at wildlife markets. Very few of the hunters (15.0%), vendors (18.9%), and consumers (21.5%) knew that COVID-19 virus is

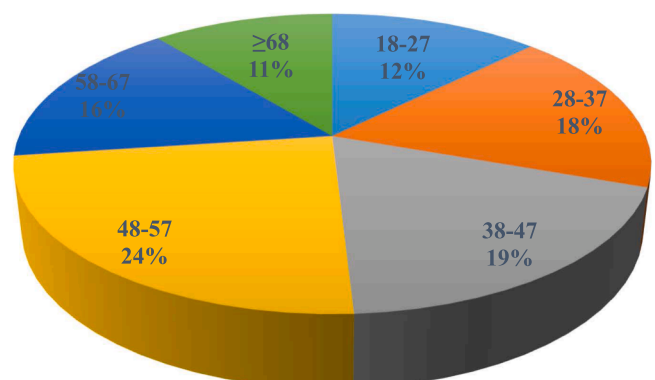


Fig. 1. Proportion of age range distribution of the participants.

**Table 1**  
Knowledge about COVID-19 pandemic amongst bushmeat handlers at the wildlife markets in North-central Nigeria: 2020 – 2021.

Variable	Bushmeat handlers	No n (%)	Yes n (%)	P-value
Knew about people that contracted COVID-19 in Nigeria	Hunters	96 (89.7)	11 (10.3)	<0.001*
	Vendors	88 (92.6)	7 (7.4)	
	Consumers	257 (62.3)	124 (32.7)	
COVID-19 virus can infect wildlife	Hunters	82 (76.6)	25 (23.4)	<0.001*
	Vendors	61 (64.2)	34 (35.8)	
	Consumers	371 (97.4)	10 (2.6)	
COVID-19 virus can be transmitted from humans to humans	Hunters	73 (68.2)	34 (31.8)	0.001*
	Vendors	43 (45.3)	52 (54.7)	
	Consumers	179 (47.0)	202 (53.0)	
COVID-19 virus can be transmitted from wildlife to humans (zoonosis)	Hunters	91 (85.0)	16 (15.0)	0.040*
	Vendors	77 (81.1)	18 (18.9)	
	Consumers	299 (78.5)	82 (21.5)	
COVID-19 virus can be transmitted from humans to wildlife (reverse zoonosis)	Hunters	101 (94.4)	6 (5.6)	0.193
	Vendors	86 (90.5)	9 (9.4)	
	Consumers	366 (96.1)	15 (3.9)	
COVID-19 virus can be transmitted from environment to humans	Hunters	74 (69.2)	33 (30.8)	0.001*
	Vendors	84 (88.4)	11 (11.6)	
	Consumers	253 (66.4)	128 (33.6)	
Socio-economic and psychological impacts was due to lock down and movement control	Hunters	10 (9.3)	97 (90.7)	<0.001*
	Vendors	7 (7.4)	88 (92.6)	
	Consumers	229 (60.1)	152 (92.6)	

Statistically significant at  $p < 0.05^*$ .

zoonotic, meaning that it can be transmitted from wildlife to humans in the markets. Furthermore, a small proportions of the hunters (5.6%), vendors (9.4%), and consumers (3.9%) agreed that COVID-19 virus has reverse zoonotic potential at wildlife markets. However, about one-third of the hunters (30.8%) and consumers (33.6%), and less than a quarter of the vendors (11.6%) mentioned that COVID-19 virus can be significantly transmitted from the markets' environments to humans. On the socio-economic and psychological impacts of the pandemic, majorities of the hunters (90.7%) and vendors (92.6%) as well as more than one-third (33.6%) of the consumers reported to have been significantly impacted at wildlife markets due to lockdown and movement control.

### 3.3. Perceptions about zoonotic risk of COVID-19 associated bushmeat handling activities

Variable proportions of the bushmeat handlers significantly perceived all the handling activities during the pandemic waves at the wildlife markets to be associated with zoonotic risks of COVID-19

**Table 2**  
Perceptions about zoonotic risks of COVID-19 associated with bushmeat handling activities at the wildlife markets in North-central Nigeria: 2020 – 2021.

Activities	Bushmeat handlers	Low risk n (%)	High risk n (%)	P-value
Eating raw or undercooked bushmeat	Hunters	96 (89.7)	11 (10.3)	0.020*
	Vendors	81 (75.7)	14 (24.3)	
	Consumers	301 (79.0)	80 (21.0)	
Handling body of live wildlife	Hunters	98 (91.6)	9 (8.4)	0.007*
	Vendors	87 (91.6)	8 (8.4)	
	Consumers	312 (81.9)	69 (18.1)	
Handling body of dead wildlife	Hunters	96 (88.4)	11 (11.6)	0.001*
	Vendors	86 (90.5)	9 (9.5)	
	Consumers	289 (75.9)	92 (24.1)	
Co-habiting with wildlife in same environment	Hunters	101 (94.4)	6 (5.6)	0.001*
	Vendors	61 (64.2)	34 (35.8)	
	Consumers	282 (74.0)	99 (26.0)	
Farming wildlife in peri-urban and rural areas	Hunters	95 (88.8)	12 (11.2)	<0.001*
	Vendors	50 (51.6)	45 (48.2)	
	Consumers	286 (75.1)	95 (24.9)	

Statistically significant at  $p < 0.05^*$ .

(Table 2). Very low proportions of the hunters (10.3%), vendors (24.3%), and consumers (21.0%) perceived eating raw or undercooked bushmeat to be of high zoonotic risk of COVID-19. Also, very low proportions of the hunters (8.4%), vendors (8.4%), and consumers (18.1%) perceived handling bodies of live wildlife to be of high zoonotic risk of COVID-19 at the markets. Also, handling of dead wildlife during the pandemic waves at the markets was perceived to be of high zoonotic risk by very few hunters (11.6%), vendors (9.5%), and consumers (24.1%).

On co-habiting with wildlife in the same environment, 5.6% of the hunters, 35.8% of vendors, and 26.0% of the consumers significantly perceived this activity during the waves to be of high zoonotic risk at the markets. Also, 11.2% of the hunters, 48.2% of vendors, and 24.9% of consumers significantly perceived farming of wildlife in peri-urban and rural areas during the waves to be of high zoonotic risk.

### 3.4. Risk pathways for the emergence and spread of COVID-19 at wildlife markets

More than two-thirds of the hunters (89.7%), vendors (75.7%), and consumers (79.0%) significantly ( $p = 0.020$ ) perceived consumption of bushmeat and products to be of low-risk routes for the emergence and spread of COVID-19 at wildlife markets. Also, contacts with wildlife and fomites were significantly ( $p = 0.007$ ) perceived by very few of the hunters (8.4%), vendors (8.4%), and consumers (18.1%) to be of high-risk pathways for the spread of COVID-19 at wildlife markets. In addition, very low proportions of the hunters (11.6%), vendors (9.5%), and consumers (24.1%) significantly ( $p = 0.001$ ) perceived environmental contaminations (exposures through surfaces and aerosols) to be of high-risk pathways for the dissemination of COVID-19 at wildlife markets (Table 3).

### 3.5. Practices of preventive health behaviours against COVID-19 pandemics at wildlife markets

All the preventive health behaviours were significantly practiced against COVID-19 during the three waves of the pandemic at the wildlife

**Table 3**  
Risk pathways for the emergence and spread of COVID-19 at the wildlife markets during the pandemic waves in North-central Nigeria: 2020 – 2021.

Variable	Bushmeat handlers	Low risk n (%)	High risk n (%)	P-value
Consumption of bushmeat and products	Hunters	96 (89.7)	11 (10.3)	0.020*
	Vendors	81 (75.7)	14 (24.3)	
	Consumers	301 (79.0)	80 (21.0)	
Contacts with wildlife and fomites	Hunters	98 (91.6)	9 (8.4)	0.007*
	Vendors	87 (91.6)	8 (8.4)	
	Consumers	312 (81.9)	69 (18.1)	
Environmental contaminations (exposures through surfaces and aerosols)	Hunters	96 (88.4)	11 (11.6)	0.001*
	Vendors	86 (90.5)	9 (9.5)	
	Consumers	289 (75.9)	92 (24.1)	

Statistically significant at  $p < 0.05^*$ .

markets (Table 4). Washing and sanitizing hands after touching wildlife was significantly ( $p = 0.001$ ) practiced by less than one-quarter of the hunters (4.7%) and vendors (22.1%), but by about one-quarter of the consumers (26.5%) as preventive measures against COVID-19 pandemic at the wildlife markets. Social/physical distancing of at least two metres at the market site was significantly ( $p = 0.001$ ) practiced by less than one-quarter of the hunters (6.5%), vendors (23.2%), and the consumers (24.1%) as preventive health behaviours against the disease at the markets; while very low proportions of the hunter (7.5%), vendors (15.8%), and the consumers (1.6%) significantly ( $p < 0.001$ ) practiced the use of personal protective equipment (gloves, face masks and apron) as a measure against the disease at the markets. Also, only over one-third of the hunters (44.9%), vendors (46.3%), and the consumers (34.4%) significantly ( $p < 0.030$ ) practiced the use of face masque at all times at the markets. Avoidance of handshaking or hugging was significantly practiced by less than one-quarter of the hunters (17.8%) and about one-quarter of the vendors (41.1%) and consumers (32.8%) as preventive health behaviours at the markets. Furthermore, only 11.2% of the hunters, 20.0% of vendors, and 6.3% of the consumers significantly ( $p = 0.001$ ) practiced vaccination as preventive health behaviour against COVID-19 virus infection at the markets.

**3.6. Socio-demographic characteristics associated with knowledge, risk perceptions, and preventive health behaviours towards COVID-19 pandemic at wildlife markets**

All the socio-demographic variables of the handlers were significantly ( $p < 0.05$ ) associated with their knowledge, risk perceptions, and practice of preventive health behaviours toward COVID-19 at univariate analysis. However, the multivariate logistic regression model results indicated that handlers in age groups 48–57, 58–67, and  $\geq 68$  were more likely [(OR=6.91; 95% CI: 3.36, 14.23), (OR=11.64; 95% CI: 5.38, 25.17), and (OR=8.37; 95% CI: 3.71, 18.85), respectively] to possess significant knowledge and perceptions, and practiced preventive health behaviours on COVID-19 pandemic during the waves at the wildlife markets than other age groups. Also, male handlers were more likely (OR=3.67; 95% CI: 2.46, 5.47) to have significant knowledge and perceptions, and practiced preventive health behaviours than the females. Married handlers were three times more likely (OR=2.81; 95% CI: 1.92, 4.11) to possess significant knowledge and practice preventive health behaviours on the disease, while vendors and consumers were two times

**Table 4**  
Practices of preventive health behaviours against COVID-19 pandemic at the wildlife markets in North-central Nigeria: 2020 – 2021.

Variable	Bushmeat handlers	No n (%)	Yes n (%)	P-value
Washing and sanitizing hands after touching wildlife	Hunters	102 (95.3)	5 (4.7)	0.001*
	Vendors	74 (77.9)	21 (22.1)	
	Consumers	280 (73.5)	101 (26.5)	
Washing hands with soap before and after eating bushmeat	Hunters	89 (83.2)	18 (16.8)	<0.001*
	Vendors	71 (74.7)	24 (25.3)	
	Consumers	210 (55.1)	171 (44.9)	
Sterilization of tools with boiling water after use	Hunters	96 (89.7)	11 (10.3)	0.001*
	Vendors	68 (71.6)	27 (28.4)	
	Consumers	328 (86.1)	53 (13.9)	
Adequate sanitation and hygiene of wet market site	Hunters	54 (50.5)	53 (49.5)	<0.001*
	Vendors	68 (71.6)	27 (28.4)	
	Consumers	305 (80.1)	76 (19.9)	
Social/physical distancing of at least two metres at wildlife market site	Hunters	100 (93.5)	7 (6.5)	0.001*
	Vendors	73 (76.8)	22 (23.2)	
	Consumers	289 (75.9)	92 (24.1)	
Use face masque at all times	Hunters	59 (55.1)	48 (44.9)	0.030*
	Vendors	51 (53.7)	44 (46.3)	
	Consumers	250 (65.6)	131 (34.4)	
Use personal protective equipment (PPE)	Hunters	99 (92.5)	8 (7.5)	<0.001*
	Vendors	80 (84.2)	15 (15.8)	
	Consumers	375 (98.4)	6 (1.6)	
Avoiding handshaking or hugging	Hunters	88 (82.2)	19 (17.8)	0.001*
	Vendors	56 (58.9)	39 (41.1)	
	Consumers	256 (67.2)	125 (32.8)	
Fumigation of market site	Hunters	98 (91.6)	9 (8.4)	0.030*
	Vendors	83 (87.4)	12 (12.6)	
	Consumers	361 (94.8)	20 (5.2)	
Vaccination against COVID-19	Hunters	95 (88.8)	12 (11.2)	0.001*
	Vendors	76 (80.0)	19 (20.0)	
	Consumers	357 (93.7)	24 (6.3)	

Statistically significant at  $p < 0.05^*$ .

more likely [(OR=1.84; 95% CI: 1.03, 3.28) and (OR=1.63; 95% CI: 1.02, 2.58), respectively] to possess significant knowledge and practiced preventive health behaviours on COVID-19. Furthermore, handlers with tertiary education were fifteen times more likely (OR=14.72; 95% CI: 8.49, 25.52) to possess significant knowledge and perceptions, and practiced preventive health behaviours on the disease than those without formal education (Table 5).

**Table 5**

Handlers' socio-demographic characteristics associated with their knowledge, risk perceptions, and preventive health behaviours on COVID-19 pandemic at the wildlife markets in North-central Nigeria: 2020 – 2021.

Characteristics	Inadequate response n (%)	Adequate response n (%)	Odds ratio	95% CI	P-value
Age					
18–27	63 (85.1)	11 (14.9)	1.00		
28–37	78 (75.7)	25 (24.3)	1.84	0.84, 4.02	0.129
38–47	81 (74.3)	28 (25.7)	1.98	0.92, 4.28	0.080*
48–57	63 (45.3)	76 (54.7)	6.91	3.36, 14.23	<0.001*
58–67	31 (33.0)	63 (67.0)	11.64	5.38, 25.17	<0.001*
≥68	26 (40.6)	38 (59.4)	8.37	3.71, 18.85	<0.001*
Gender					
Female	141 (77.5)	41 (22.5)	1.00		
Male	194 (48.4)	207 (51.6)	3.67	2.46, 5.47	<0.001*
Marital status					
Single	132 (72.9)	49 (27.1)	1.00		
Married	197 (49.0)	205 (51.0)	2.81	1.92, 4.11	<0.001*
Bushmeat handling					
Hunter	75 (70.0)	32 (30.0)	1.00		
Vendor	52 (54.7)	43 (45.3)	1.84	1.03, 3.28	0.040*
Consumer	220 (57.7)	161 (42.3)	1.63	1.02, 2.58	0.030*
Formal education					
None	137 (81.1)	32 (18.9)	1.00		
Primary	78 (63.9)	44 (36.1)	2.42	1.42, 4.12	0.001*
Secondary	40 (27.2)	107 (72.8)	11.45	6.75, 19.44	<0.001*
Tertiary	32 (22.1)	113 (77.9)	14.72	8.49, 25.52	<0.001*

Statistically significant at  $p < 0.05^*$ ; CI – Confidence interval.

**3.7. Socio-cultural and economic factors influencing emergence and spread of COVID-19 pandemic at wildlife markets**

All the significant socio-cultural and economic factors perceived by the participants to influence the emergence and spread of COVID-19 pandemic at wildlife markets are presented in Table 6. After controlling for confounders and effect modifiers, aggregation of different wildlife species during capturing or hunting (OR=4.03, 95% CI: 2.79, 5.81); aggregations of different wildlife species during transportation (OR=2.33, 95% CI: 1.64, 3.31); aggregations of different wildlife species in the markets (OR=2.14, 95% CI: 1.67, 3.48); and poor markets sanitation, hygiene, and biosecurity (OR=3.35, 95% CI: 2.33, 4.82) were all more likely to significantly influence the emergence and spread of COVID-19 pandemic at wildlife markets. Also, poor butchering practices and exchange of wildlife species between shops in the markets, were two times more likely [(OR=1.87; 95% CI: 1.34, 2.60) and (OR=2.03; 95% CI: 1.43, 2.88), respectively] to significantly influence the emergence and spread of COVID-19 at the markets during the pandemic waves (Table 6).

**4. Discussion**

The emergence of COVID-19 pandemic in Nigeria not only pose a grave public health challenge to the government and the citizens but also has taken a toll on the economy, particularly the bushmeat industry. The traded wildlife species we observed in the market included

**Table 6**

Socio-cultural and economic factors influencing emergence and spread of COVID-19 pandemic at the wildlife markets in North-central Nigeria: 2020 – 2021.

Factors	Poor influence n (%)	Satisfactory influence n (%)	Odds ratio	95% CI	P-value
Aggregation of different wildlife species during capturing or hunting					
No	235 (62.3)	142 (37.7)	1.00		
Yes	60 (29.2)	146 (70.8)	4.03	2.79, 5.81	<0.001*
Aggregations of different wildlife species during transportation					
No	222 (58.1)	160 (41.9)	1.00		
Yes	75 (37.3)	126 (62.75)	2.33	1.64, 3.31	0.001*
Aggregations of different wildlife species in the markets					
No	215 (53.6)	186 (46.4)	1.00		
Yes	59 (32.4)	123 (67.6)	2.14	1.67, 3.48	0.001*
Aggregations of different species at same wildlife farms					
No	108 (54.3)	91 (45.7)	1.00		
Yes	188 (49.0)	196 (51.0)	1.23	0.88, 1.74	0.220
Poor markets sanitation, hygiene, and biosecurity					
No	112 (61.2)	71 (38.2)	1.00		
Yes	128 (32.0)	272 (68.0)	3.35	2.33, 4.82	<0.001*
Poor butchering practices					
No	171 (26.3)	148 (23.7)	1.00		
Yes	101 (24.8)	163 (35.2)	1.87	1.34, 2.60	0.001*
Exchange of wildlife species between shops in the markets					
No	247 (76.3)	144 (23.7)	1.00		
Yes	88 (24.8)	104 (35.2)	2.03	1.43, 2.88	0.001*

Statistically significant at  $p < 0.05^*$ ; CI – Confidence interval.

antelopes, grass cutters, porcupines, crocodiles, birds, snakes, wild turtles, monkeys, pangolins, amongst others. Many of these animals were displayed alive and few dead or slaughtered, mostly fresh and the markets can be described as wet wildlife markets. The lessons from these markets are the possibility of interspecies intermingling and sharing pathogens, as ascribed to the current observations on the emergence of SARS-CoV-2 in Wuhan, China (Lu et al., 2020). Although there has not been any reported outbreak of COVID-19 in the wildlife markets in Nigeria, the markets and associated handling activities therein have been reported to be the primary centre of target for SARS-CoV-2 spillover to humans and anthroponosis (WHO, 2020). This study forms part of the evolution that identifies and reaches vulnerable populations at risk of the pandemic. The outcomes highlight key knowledge, perception, and practice gaps and provide perspective on the intervention and capacity building needed to reduce the risks of COVID-19 and other emerging zoonoses and reverse zoonoses globally.

This survey applies the Health Belief model constructs of perceptions

of susceptibility and benefits of engaging in specified health actions. The model was adequate in predicting the COVID-19 preventive behaviour and can be used to guide behaviour change interventions amongst bushmeat handlers in the study area (Cohen, 1992). The results of the study indicate that adherence to preventive behaviours against COVID-19 was at a desirably low level, which could be due to poor sensitization of the group. This is in contrast with a result of an investigation that used the HBM in the early stages of COVID-19 in Hong Kong and found people with higher perceived susceptibility and severity of COVID-19 to be at low risk for COVID-19 because adequate preventive measures were taken (Kwok et al., 2020).

All the respondents in this study indicated to have heard about COVID-19 outbreaks in Nigeria, but very few of them know it to infects wildlife. This study also found very low proportions of the hunters, vendors, and consumers with knowledge and risk perceptions about COVID-19 at wildlife markets, particularly on the reverse zoonotic potential of the virus. Interestingly in a related survey, only 24% of bushmeat hunters and traders had knowledge about spillover threats of zoonoses from bushmeat to humans (Subramanian, 2012). On the socio-economic and psychological impacts of the pandemic, we found majorities of the handlers indicated that the disease has a significant impact due to lockdown and movement control, which can also predispose to poverty and other diseases. Although poverty subconsciously serves as a preventive measure, it is also the starting point and ultimate outcome of neglected diseases in humans (Troncoso, 2015). The findings on a generally low knowledge level were probably due to lack of target sensitization of vulnerable groups in Nigeria. Measures to bridge the knowledge gaps amongst these groups should be intensified using an educational programme with multiple outlets such as pamphlets, radio, and television focusing on the epidemiology of SARS-CoV-2 with special health messages on the mode of transmission, and control and prevention.

In this study, we observed very low proportions of handlers with significant perceptions about high zoonotic risks of COVID-19 during bushmeat handling activities. This contrast a report that found high proportions of people readily perceiving high zoonotic risks during bushmeat handling activities (Wilkie, 2006). Co-habitation with wildlife in same environment and farming of wildlife near the wildlife markets in peri-urban and rural areas during pandemic waves were perceived by majorities of the handlers to be low-risk activities. Noteworthy, we found very high proportions of the handlers significantly perceiving the consumption of raw or undercooked bushmeat and products; and contacts with wildlife and fomites to be low-risk routes for the spread of COVID-19 in such markets. To prevent zoonoses from wildlife, avoidance of eating uncooked bushmeat or non-biltong meat (a dried-meat delicacy) has been advocated (Alhaji et al., 2017). Human infection with SARS-CoV-2 occurs mainly through close contact with respiratory droplets, direct contact with infected persons, and contact with contaminated objects and surfaces (Liu et al., 2020). Also, few handlers significantly perceived environmental contaminations (exposures through surfaces and aerosols) to be of high-risk pathways at the markets. Inhalation of aerosols from infected individuals has been reported to be COVID-19 transmission route from person to person (Li et al., 2020). In overall, this study observed very low proportions of the handlers significantly perceiving high risk pathways for the COVID-19 emergence and spread at wildlife markets.

This study found that 4.7% of the hunters, 22.1% of vendors, and 26.5% of the consumers engaged in handwashing and sanitizing after touching wildlife as preventive health behaviour. Also, social/physical distancing at the market site; use of personal protective equipment (gloves, face masque, and apron); avoidance of handshakes or hugging; and vaccination against COVID-19 were significantly adopted by very few handlers as preventive health behaviours. The use of personal protective covers has been reported to be effective preventive health behaviour against zoonoses from wildlife meat in some Nigerian hunting communities (Friant et al., 2015). However, we observed over one-third

of the handlers significantly practicing the use of face masque at all times in the markets during the waves. The use of face masks, maintaining of minimum physical distance of at least two metres, avoidance of large crowds gathering, and avoidance of eating wild animal meat have been recommended (Hong et al., 2020; WHO, 2020). Such practices can mitigate and prevent the risk of COVID-19 emergence and spread (Yildirim et al., 2021). On vaccination, only 11.2% of the hunters, 20.0% of vendors, and 6.3% of the consumers were found to have received at least a shot of COVID-19 vaccine as a preventive measure at the markets. In Nigeria, myths and beliefs have been found to adversely influence the perceptions of most Nigerians thereby challenging the uptake of COVID-19 vaccine (Adedeji-Adenola et al., 2022). Inadequate knowledge and perceptions have been reported to influence poor vaccine uptake against COVID-19 during the waves in Bangladesh (Bari et al., 2021).

In this study, handlers in age groups 48–57, 58–67, and  $\geq 68$  possess significant knowledge, risk perceptions, and practice preventive health behaviours toward COVID-19 pandemic than other age groups during the waves at the wildlife markets. Also, male handlers have more knowledge and perceptions as well as practice preventive measures than the females. This could be due to long-time experiences older handlers acquired in the field and the fact that males participate more in bushmeat handling activities, especially in hunting and consumption than the females due to culture. Greater risk perception and health preventative health behaviours for COVID-19, such as social/physical distancing and masque-wearing have been associated with an increase in knowledge about the disease (Dryhurst et al., 2020). Vendors and consumers possess significant knowledge about COVID-19 than the hunters. It is also noteworthy to mention that handlers with tertiary education fifteen times significantly possess more knowledge and perceptions, and practice preventive health behaviours on the disease than those without formal education. This could be because those with tertiary education have more opportunities to be better educated about COVID-19 and other emerging diseases through seminars, conferences, workshops, Internet, to mention a few. However, formal education has been reported not to have a significant influence on knowledge about zoonotic infection risks amongst bushmeat handlers (Subramanian, 2012). Knowledge and risk perceptions about zoonoses vary with demographic characteristics such as gender, married, and tertiary education, and have been associated with adequate knowledge and risk perceptions about COVID-19 and adoption of preventative health behaviours (Zhong et al., 2020). Therefore, understanding the impact of demographic factors on knowledge and perceptions of zoonoses is crucial to the improvement of health literacy and intervention in identified target groups.

We observed that participants perceived aggregation of different wildlife species during capturing or hunting; aggregations of different wildlife species during transportation; and poor markets sanitation, hygiene, and biosecurity to be significant drivers of the emergence and spread of COVID-19 pandemic at wildlife markets. Contamination of wildlife in trade, stress from the aggregations of live wildlife during hunting; in transport and storage; breeding farms and markets where they are sold are causal factors that promote the zoonotic disease emergence (Pruvot et al., 2019; Huong et al., 2020). The dynamic interfaces amongst different wildlife species and with humans can act as conduits by which humans are exposed to zoonotic pathogens in an environment (Gottdenker et al., 2014; Santiago-Alarcon and MacGregor-Fors, 2020). Also, poor butchering practices in the markets; and the exchange of wildlife species between shops were found to significantly influence the spread of COVID-19 in markets during the pandemic waves. Although improvements in market hygiene and butchering practices could diminish the risk to some extent, only wildlife trade chain regulations offer substantial risk mitigation (Petrikova et al., 2020). There is substantial evidence that COVID-19 transmission is closely related to a person's socio-economic activities (Kaur et al., 2020; Wise et al., 2020).



The emergence of COVID-19 pandemic drives negative impacts on people and nations and would require engagement and education of the stakeholders on zoonoses, pandemics, spillover, human-animal-environmental health interface challenges, and solutions. This will require working across disciplines focusing on a One Health approach, which is the collaboration between multiple disciplines working at local, national, and global levels to achieve optimal human, animal, and environmental health (Deem et al., 2018). This will assure control of the current pandemic threat and prevention of future ones (El Zowalaty and Järhult, 2020). This collaboration will require an understanding of cultural, societal, and economic realities coming from the COVID-19 pandemic as well as the comprehension of the potential critical control points of dissemination from forest to dinner table (Huong et al., 2020). All future strategies for mitigation and prevention of emerging and re-emerging infectious diseases associated with wildlife trade should be based on collaborations, and risk assessments, and encompass wildlife ecosystem, public and animal health (Booth et al., 2020; Di Marco et al., 2020; Eskew and Carlson, 2020; Roe et al., 2020). The use of One Health approach will lower the potential of future zoonotic outbreaks and be more sustainable as compared with other strict approaches such as markets closure.

A major limitation in this study was the non-reflection of causal relationship amongst the bushmeat handler groups because data were collected from a cross-sectional survey, but does shown an association. The use of central tendency measure on associations was, however, valuable enough to cover the likely imperfection from lack of confidence intervals adjustments for the groups during the random sampling. The strength of this study, on the other hand, centres on the fact that it focuses on research area with paucity of information about COVID-19 associated with trade of wildlife and their products in many developing countries. This study adds to the existing evidence on the critical knowledge and perceptions gaps on high-risk behaviour amongst wildlife traders in Nigeria.

## 5. Conclusion

From this study, we found most handlers not to be concerned or were minimally concerned about the zoonotic or reverse zoonotic risks of SARS-CoV-2 during bushmeat handlings. Only a few of them have significant knowledge and risk perceptions, and as well practice preventive health behaviours on COVID-19, the challenging critical gaps. Furthermore, some challenging influencing factors were identified. To tackle the highlighted gaps, collaborations between the public health, anthropologists, and veterinary and wildlife authorities through the One Health approach are advocated to intensify awareness and health education programmes that will improve perceptions and behaviours toward disease mitigation. By applying the Health Belief model constructs, the study further presents the most important cognitive determinants, which in turn would be a valuable addition in designing the disease preventive behavioural change strategies.

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## CRediT authorship contribution statement

**Nma Bida Alhaji:** Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Writing – original draft. **Ismail Ayoade Odetokun:** Formal analysis, Investigation, Methodology, Project administration, Writing – original draft. **Mohammed Kabiru Lawan:** Methodology, Supervision, Writing – review & editing. **Abdulrahman Musa Adeiza:** Supervision, Writing – review & editing. **Wesley Daniel Nafarnda:** Supervision, Writing – review & editing. **Mohammed Jibrin Salihu:** Supervision, Writing –

review & editing.

## Declaration of Competing Interest

The authors declare that they have no competing interests.

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