

RESEARCH

Open Access



Assessment of the knowledge, practice, and perception of anthrax among slaughterhouse workers in Nigeria

Oluwawemimo Oluseun Adebowale^{1*}, Oladapo Oyedeji Oludairo², Abimbola Adetokunbo Oloye³, Muhammad Mahuta Muawiyyah⁴, Umar Babangida Aliyu⁵, Ridwan Olamilekan Adesola⁶, Hezekiah Kehinde Adesokan⁷, Gladys Chinelo Ezech⁸, Joseph Ogugua Akwoba⁹, Arinola Bukola Richards², Afeez Babatunde Jimoh¹, Tayo Oluwabukola Oyawole¹, Michael Abolanle Akinbami¹, Taiwo Oluwole Jolaoso¹⁰, Adeniyi Olarenwaju Tade¹⁰ and Ifeoluwapo Omolola Akanbi¹¹

*Correspondence:
Oluwawemimo Oluseun
Adebowale
adebowaleoluwawemimo1@gmail.com

Full list of author information is
available at the end of the article

Abstract

Background Anthrax is a neglected and life-threatening infectious zoonotic disease occurring, especially in Africa. This study was conducted a week before the confirmation of the anthrax outbreak in Nigeria in July 2023. It assessed the knowledge, risk practice, and perception of anthrax among the high-risk working groups, such as meat processors, butchers, animal farmers, meat vendors, para-veterinarians, veterinarians, cleaners, administrative staff, and animal traders in slaughterhouses (SHs) in Nigeria. Also, the national preparedness towards an outbreak was evaluated.

Method A total of 627 participants were purposively selected from seven States and interviewed using a semi-structured questionnaire. Data was analysed using descriptive and logistic regression statistics.

Results Most (499; 81.4%) of the participants were males, with the mean age being 37.3 ± 12.0 years old, and the majority (471, 78.1%) had no tertiary education. One-third (207, 32.7%) of the participants self-reported being aware of anthrax, and 13.2% indicated that anthrax was a serious disease for both animals and humans. The knowledge median score was 0.0 (min 0, max 30), the general knowledge level was poor (16.8%), and 91.2% (527) of participants fell within this category. The practice median score was 6.0 (min 0, max 12) and categorised as generally poor (52.9%). Gaps observed in practices that could promote the risk of participants' exposure to anthrax included slaughtering sick animals for human consumption, splashing blood on inspected carcasses, carrying carcasses on heads or shoulders, and disposing of condemned animal tissues or organs in open dumps. One-third of participants (202, 32.2%) strongly perceived that efficiently implementing vaccination in livestock would reduce the outbreak in humans. Furthermore, participants with no tertiary qualifications and no veterinary background had increased odds (COR: 14.378, 95% CI; 4.923–41.991, $p=0.000$) and (COR: 9.157, 95% CI; 3.644–23.008, $p=0.000$) of having an inadequate knowledge level of anthrax, respectively. Participants who



were non-veterinarians/non-para veterinarians had increased odds (COR: 3.471, 95% CI: 1.629–7.392, $p=0.001$) of having a poorer practice level than veterinarian or para veterinarians. Conversely, participants less than 37 years old had lower odds (COR: 0.268, 95% CI: 0.148–0.486, $p=0.000$) of having a poor practice level than those above the age.

Conclusion The knowledge level of the high-risk working groups was poor, with observable critical risk practices. Promoting media publicity and awareness creation, vaccination, effective disease surveillance, on-farm biosecurity, and adequate border control are critical strategies to prevent anthrax outbreaks in Nigeria.

Keywords Anthrax, Knowledge, Risk Practice, Perception, Slaughterhouse, Public health, One Health

1 Background

Anthrax is an infectious zoonotic and neglected tropical disease of enormous economic and public health consequences. Anthrax was prioritised as the 5th most important “One Health” zoonosis after rabies, avian influenza, Ebola Virus Disease, and swine influenza in Nigeria in 2019 [1]. The disease is caused by a bacterium called *Bacillus anthracis*, which primarily affects herbivores such as goats, sheep and cattle, and other mammals, including humans. The pathogen can be transmitted to humans through the consumption of contaminated foods and products of animal origin and contact with infected animals. In addition, the bacterium can occur naturally in the environment, is highly resistant, and its persistence may become complicated due to the impact of global warming [2].

Recently, an outbreak of anthrax was reported in the neighbouring country, Ghana, in June 2023, with confirmed suspected anthrax infections and fatality among 11 individuals who consumed the carcass of dead cattle [3]. By July 13, 2023, the Federal Ministry of Agriculture and Rural Development (FMARD), Nigeria, officially confirmed and reported its first case of anthrax in a mixed livestock farm in Niger State, northern Nigeria (with a subsequent outbreak in an abattoir setting in Oko Oba, Lagos State, south-western Nigeria). The farm was reported to have experienced sudden deaths of livestock with eight mortalities. In addition, the animals that died were observed to have been bleeding from external orifices, with the blood failing to clot [3]. The disease can spread rapidly across borders due to its transboundary nature and capability, thus requiring a regional collaborative one-health approach among sub-Saharan nations to mitigate the disease and consequent burdens.

The report of the disease in Nigeria prompted early intervention measures by FMARD and the Nigeria Centre for Disease Control and Prevention (NCDC) to contain the spread. These interventions included the constitution of a “One Health” technical working team, stimulation of a National Incident Management System, appointment of an incident response manager, contact tracing of persons and livestock exposed to the index cases, and improvement of an Incident Action Plan (IAP) for confirmed cases in humans. Other measures were: the acquisition of medical countermeasures and consumables such as medications, personal protective equipment (PPEs), and laboratory consumables; activation of real-time laboratory testing; quarantine of affected and susceptible farms; vaccinations of animals, as well as sensitisation and risk communication initiatives [4].

Anthrax has been established to affect risk groups, especially people who are in close contact with animals and potentially contaminated animal products. These groups include veterinarians, abattoir and slaughterhouse workers, animal farmers, and producers. The disease has been estimated to cause about 2000 human and 85,235 animal deaths globally [1, 5, 6]. However, the case fatality rates in humans vary according to the pathway of exposure and infection, with the risk of death in intestinal and respiratory anthrax being between 25–75% and 5–80% respectively, even with treatment [5]. Though listed and documented as one of the priority one health zoonoses in Nigeria in 2019, anthrax is still a neglected disease, as little or no substantial strategic action plans for its intervention have been implemented. Aside from the challenge of real-time diagnostic capacities in animal and human health sectors, which hampers mitigation strategies, poor risk communication and public awareness, even among the high-risk population groups, and poor funding for animal health, especially vaccination, and multisectoral surveillance worsen the disease situation. Importantly, the disease has been associated with various perceptions, poor awareness, knowledge, and practices even among the high-risk agricultural communities [7, 8]. Studies [8–10] have shown that knowledge, risk practices, and perception of the disease are inadequate, especially among the public and livestock keepers, and such could play key roles in the persistence of the disease outbreaks. This study, therefore, assessed the knowledge, risk practices, and perception towards anthrax, especially among the high-risk working groups in Slaughterhouses (SHs) communities in Nigeria, considering the recent outbreaks in Nigeria and neighbouring Ghana. Also, the national preparedness towards an outbreak was evaluated. The study identified gaps that can promote evidence-based decisions for the review of action plans to mitigate further disease outbreaks in the country, and the development of targeted educational literacy programmes among farmers, animal health workers and handlers, and the general public using a “One Health” approach.

2 Methods

2.1 Study location and design

The Federal Republic of Nigeria is situated in West Africa between latitudes 4–14° N and longitudes 2–16° E and occupies a land area of 917,156 km² with over 230 million inhabitants [11]. It is bordered in the north by the Niger and Chad Republics, in the east by Cameroon, in the west by the Benin Republic, and in the south by the Gulf of Guinea and the Atlantic Ocean. Nigeria consists of 36 States categorised into six geopolitical zones—Southwest, Southeast, Southsouth, Northeast, Northwest, Northcentral, and the Federal Capital Territory (FCT) [12]. Four (4) geopolitical zones in Nigeria and at least one (1) State from the zones were conveniently selected for the study. The study was consequently conducted in seven (7) States from the Southeast (Enugu and Ebonyi States), North-central (Kwara State), Northwest (Zamfara and Kebbi States), and Southwest (Ogun and Oyo States) geopolitical zones of Nigeria (Fig. 1). A multistate cross-sectional study was conducted among SH workers who are considered to have a high risk of exposure to anthrax.

The level of knowledge, practice, and perception relating to the disease, and the national preparedness towards an outbreak were investigated. Central SHs within the capital cities of each State were covered. The survey was conducted from July (a week before an outbreak was confirmed in Nigeria) to September 2023.

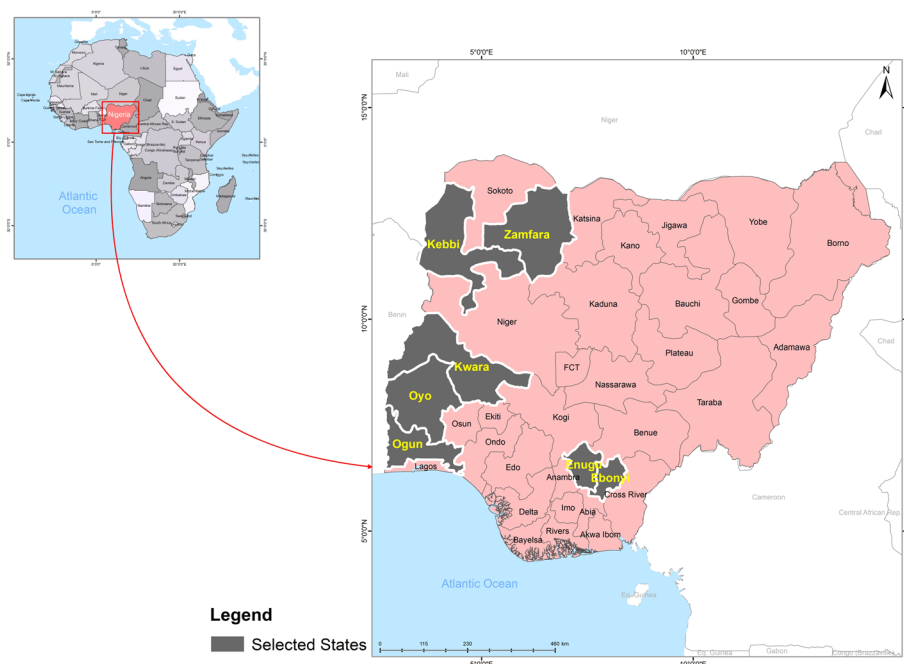


Fig. 1 Geospatial Representation of States in Nigeria that participated in the study

The SHs were visited for the recruitment of participants from the various high-risk groups. These included veterinarians, para-veterinarians, butchers, meat processors, meat vendors, animal farmers, SH administrative staff, and cleaners. The participants were at least 18 years old, actively working at the SH, and willingly consented to take part in the study.

2.2 Sample size calculation

The sample size was determined by the formula: $n = Z^2 P (1-P) / d^2$, where n = required sample size, Z = confidence level at 95% (standard value 1.96), P = the expected proportion (0.5) of participants to have a good level of knowledge, practice, and perception, and d = level of precision at 5%. A total of 384 participants were estimated, and a 10% non-response rate was added to give a total of $n = 423$. Using non-probability convenience sampling, responses were obtained from a total of 627 SH workers across the seven States in Nigeria.

2.3 Questionnaire design, pretest, and data collection

The self-reported SH worker questionnaire was designed after an extensive literature review of related studies conducted elsewhere in Africa and Asia [8, 9, 13–15] and information from the World Health Organisation (WHO) and European Centre for Disease Prevention and Control (ECDC) official websites [16–19]. The tool evaluated the levels of knowledge, risk practice, perception, and preparedness towards anthrax among SH workers in major cities of Enugu State (Nsukka), Ebonyi State (Abakaliki), Kwara State (Ilorin), Zamfara State (Gusau), Kebbi State (Birnin Kebbi), Ogun State (Abeokuta) and Oyo State (Ibadan). All questions were written in English and were administered by field enumerators who translated the questions from English to local dialects for uneducated participants.

The questionnaire began with a brief overview of the nature and purpose of the study (Questionnaire S 1). Then, it was divided into four sections (A to D) to assess the sociodemographic profiles of participants (section A), participants' awareness and knowledge about anthrax (B), risk practice, perception and prevention (C), and national preparedness towards an anthrax outbreak (D). Sections A to C were filled by all participants, while information regarding the country's preparedness for an anthrax outbreak (section D) was obtained from veterinarians and para-veterinarians only. Five questions were asked regarding age, gender, education, occupation, and religion in the demographic section. The second section evaluated the awareness and knowledge of participants about the disease by asking 15 questions with subcategories. The third section assessed risk practices and perception toward the prevention of disease (19 questions). Twelve of the questions for practice were tested as Yes, No, and I don't know. The perception questions (7) were tested by a 5-point Likert scale of "Not Sure", "strongly disagree", "disagree", "agree", and "strongly agree". The last section comprised nine questions to assess how prepared the government was in mitigating an outbreak, and responses based on the perception of veterinarians and para-veterinarians were collected for this section. One of the questions asked the veterinarians and para-veterinarians to rank anthrax on a scale of 1 to 10 among other zoonoses for government prioritisation and intervention. Also, we wanted to know if the disease should be considered a "One Health" Zoonosis and controlled using a "One Health" approach. Similarly, other questions were based on a 5-point Likert scale as previously described.

Face validation of the questionnaire was performed by four qualitative and quantitative experts in the subject area, and revisions were made based on their comments and recommendations to enhance relevance and clarity. Subsequently, it was pilot-tested among SH workers ($n = 20$) in a slaughterhouse, who were excluded from this study. The measure of reliability or internal consistency of the survey instrument was estimated using Cronbach's alpha coefficient. The reliability of questions used to assess the knowledge and risk practices was 0.98 and 0.88, respectively. Further necessary modifications were made based on the outcome of the pilot study.

2.4 Statistical analyses

Data generated were captured and filtered in Microsoft Excel, 2013 (Microsoft Corporation, Redmond, WA). Data analyses were conducted with Microsoft Excel (2013), GraphPad Prism 10.2.2, and IBM SPSS 25.0 for descriptive and inferential statistics. Descriptive statistics were conducted for all categorical variables and presented in the form of frequencies and proportions/percentages. The levels of measured outcomes for knowledge and practices were expressed as median (minimum and maximum). A numeric scoring system was used to determine the knowledge and practice of anthrax among the participants. Briefly, for knowledge scoring, each score was graded as "1" (correct) and "0" (where wrong answers/I don't know/no responses were provided), with the maximum score being 32 and ranging from 0 to 32. For practice, each score was graded as "1" for right practice and "0" for wrong practice/I don't know/no response. The maximum score for this part was 12 and ranged from 0 to 12. The scores for knowledge and practice were thereafter converted to percentages for level classifications. The study participants who scored $\geq 70\%$ were classified as having adequate knowledge and good practice, while $< 70\%$ as having inadequate knowledge and poor practice. These cut-off

points were set as it is expected that participants have high knowledge and demonstrate best practices that would reduce their risk of exposure [12].

The knowledge and practice scores across demographic categories were compared using Kruskal–Wallis and Mann–Whitney rank sum tests, depending on the normality check of datasets by the Shapiro–Wilk or Kolmogorov–Smirnov test. The correlations between knowledge and risk practice scores were assessed by using Spearman's correlation rank coefficient. Correlations greater than $|0.5|$ were considered strong correlations, whereas correlations between $|0.3|$ and $|0.5|$ were considered moderate correlations, and finally, correlations lower than $|0.3|$ as weak correlations. A value of $p \leq 0.05$ was set for all statistically significant variables.

Furthermore, binary logistic regression analysis (BLRA) was conducted to identify demographic predictors (age, gender, level of education, religion, and occupation) for the outcome variables (knowledge and practice). A value of $p \leq 0.05$ was set for all statistically significant variables, and Crude odds ratios (CORs) were computed to determine the strength of associations between variables at 95% confidence intervals (CIs). Missing data were handled using the SPSS pairwise deletion to enable the use of all available data for the regression analysis.

3 Results

3.1 Socio-demographic profiles of participants

A total of 627 SH workers participated in the study, giving a response rate of 163.3%. Out of the 627, a total of 499 (81.4%) were male, while 114 (18.6%) were female. The mean age of participants was 37.3 years (± 12.0). The majority (456, 73.5%) of the participants belonged to the Islamic faith, while 151 (24.4%) were Christians, and others were traditionalists or a combination of one or more of the faiths (2.1%). For the educational background, 87 (14.4%) and 45 (7.5%) of the participants had tertiary and diploma qualifications, respectively. The majority (218, 36.2%) had secondary school leaving certificates. The participants majorly belonged to specific working categories such as: meat processors (115, 18.7%), butchers (171, 27.8%), animal farmers (28, 4.6%), meat vendors (122, 19.8%), para-veterinarians (36, 5.9%), veterinarians (28, 4.6%), SH cleaners (19, 3.1%), the administrative staff (5, 0.8%), and animal trader (1, 0.2%). Table 1 further describes the socio-demographic characteristics of participants.

3.2 General awareness and knowledge about anthrax among the high-risk SH working groups in Nigeria

Only about one-third (32.7%) of the participants self-reported having heard about anthrax. The top three media channels from where participants received information about the disease were veterinary professionals (13.4%), radio (11.9%), and internet/social media (6.2%). Figure 2 describes the other media from which information about the disease was received. Thirty participants (4.8%) self-reported having once been infected with the disease. The majority (61.4% and 72.1%) did not know or respond to our question on the aetiology of the disease and whether the disease could be contracted from sick humans, respectively. A minority (14.2%) correctly indicated that bacteria were the cause of anthrax. Equally, a low percentage (13.2%) of the participants were aware that anthrax is a serious and severe disease in animals and humans, and that anthrax could be transmitted from only animals to humans (19.8%).

Table 1 Socio-demographics of abattoir and slaughterhouse workers who participated in the study from July to September 2023 in Nigeria

Variables	Categories	Frequency	Percentage	95% CI
Gender (613)	Male	499	81.4	78.1–84.3
	Female	114	18.6	15.7–21.9
Age Group (in years, n = 531)	18–22	51	9.7	7.4–12.4
	23–27	75	14.2	11.4–17.4
	28–32	85	16.0	13.1–19.4
	33–37	78	14.8	11.9–17.9
	38–42	72	13.5	10.9–16.7
	> 42	170	31.8	28.2–36.1
Educational Level (603)	No Formal	110	18.2	15.4–21.5
	Primary	143	23.7	20.5–27.2
	Secondary	218	36.2	32.4–40.1
	Diploma	45	7.5	5.6–9.9
	Tertiary	87	14.4	11.8–17.5
Religion (n = 620)	Islam	456	73.5	69.9–76.9
	Christianity	151	24.4	21.1–27.9
	Islam & Christianity	1	0.2	< 0.0–1.0
	Traditionalist	9	1.5	0.7–2.8
	All of the Above	3	0.5	0.09–1.5
Occupation (n = 615)	Meat processor	115	18.7	15.8–21.9
	Butcher	171	27.8	24.4–31.5
	Butcher & meat processor	78	12.7	10.3–15.5
	Butcher & farmer	4	0.7	0.19–1.7
	Butcher & meat processor & meat vendor	7	1.1	0.5–2.3
	Meat vendor	122	19.8	16.8–23.2
	Para-veterinarian	36	5.9	4.2–8.0
	Veterinarian	28	4.6	3.1–6.5
	Animal farmer	28	4.6	3.1–6.5
	SH cleaner	19	3.1	1.9–4.8
	Animal trader	1	0.2	< 0.0–1.0
	SH staff	5	0.8	0.3–1.9
Location (State)	Ebonyi	107	17.1	14.3–20.2
	Enugu	64	10.2	8.1–12.8
	Kwara	57	9.1	7.1–11.6
	Zamfara	49	7.8	5.9–10.2
	Kebbi	45	7.2	5.4–9.5
	Oyo	148	23.6	20.4–27.1
	Ogun	157	25.0	21.8–28.6

n = number of Response

Few participants self-reported that pathogens could be transmitted through; consumption of contaminated animal products such as meat and “ponmo” (hides, 24.1%), touching of such products (21.2%), especially during slaughtering (18.2%), processing of hides and skins (18.5%), handling of infected animals (19.1%), and contaminated soil (15.6%). Identification of symptoms of the infection in animals and humans by participants was low. Approximately one-third (33.0%) of the participants knew that the preventive measure for anthrax was vaccination. Table 2 provides responses relating to knowledge about anthrax.

About 25.5% of the participants self-reported having heard about the outbreak of anthrax in neighbouring countries such as Ghana during the period of the study, and

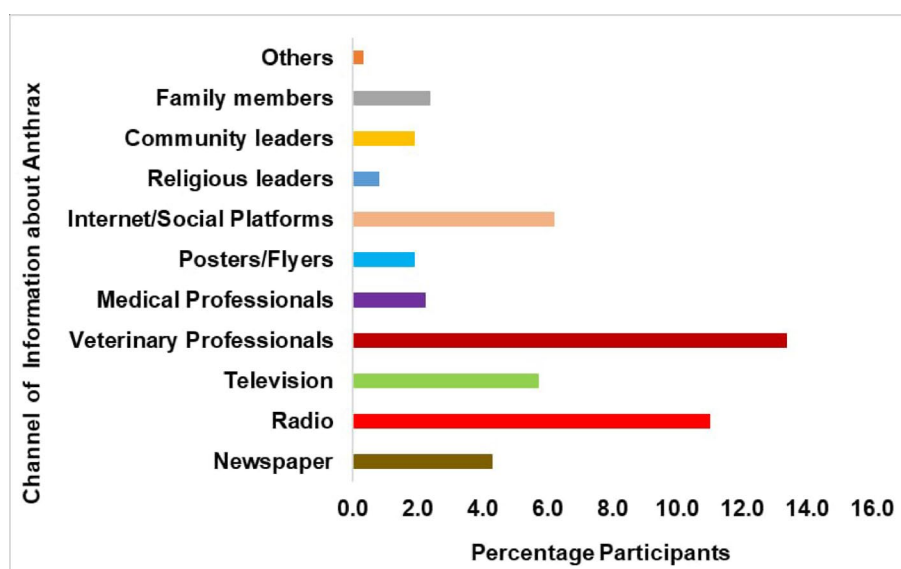


Fig. 2 Channels of information from where participants have heard about Anthrax

33.0% indicated that the disease in animals and humans is preventable by vaccinating animals.

The knowledge median score was 0.0 (min 0, max 30). The participants' knowledge level was categorised as inadequate, with most (91.2%, $n=527/627$) of them falling within this level.

Table 3 further describes the knowledge scores across the demographics of the respondents.

A significant variation in knowledge score was observed across age categories ($p=0.0035$), educational background ($p<0.0001$), religion ($p=0.0286$), occupational groups ($p<0.0001$), and States ($p<0.0001$), Table 3.

3.3 General practice regarding anthrax among high-risk SH workers in Nigeria

Practices that may likely expose SH workers to anthrax and aid the transmission of the disease were assessed. The median score for practice was 50.0 (min 0.0, max 100), and the practice level was categorised as being poor (52.9%). Most of the participants (421, 67.1%) fell within the poor practice level, while others (206, 32.9%) had good practice towards anthrax. From the study, a total of 105 (16.7%) self-reported being involved with meat inspection, 276 (44.4%) slaughtering of animals and washing of carcasses, 277 (46.6%) skinning, 265 (42.3%) hide ("ponmo") processing and cleaning of offal. Also, 254 (40.5%) of the participants' self-reported to carry carcass on head or shoulder, 224 (35.7%) splash blood from other animals on carcasses, 229 (36.7%) slaughter sick or moribund animals for human consumption, 89 (14.4%) slaughter and sell condemned animals for consumption, 256 (41.0%) dispose condemned animals openly or on open dumps, 256 (40.8%) bury condemned animals, and 415, (66.3%) claim to use personnel protective coverings. The practice scores across the various demographic variables are described in Table 4.

A significant difference in practice scores was observed among gender ($p=0.0010$), age groups ($p<0.0001$), educational background ($p=0.0002$), religion ($p=0.0108$), occupational groups ($p<0.0001$), and States ($p<0.0001$), Table 4.

Table 2 The knowledge of anthrax (cause, transmission, symptoms/clinical signs, control and prevention) among SH workers (n = 627)

Variables	Categories	Frequency	Percentage	95% CI
Aware of anthrax				
	Yes	205	32.7	29.1–36.4
	No/IDN/NR	422	67.3	63.5–70.8
The causative agent for anthrax				
	Correct	89	14.2	011.6–17.1
	Incorrect/IDN/NR	538	85.8	82.8–88.3
Is anthrax a serious disease in humans and animals?				
	Correct	83	13.2	10.8–16.1
	Incorrect/IDN/NR	544	86.8	83.8–89.2
Can anthrax be obtained from a sick person?				
	Correct	28	4.5	3.1–6.4
	Incorrect/IDN/NR	599	95.5	93.6–96.9
Anthrax can only be transmitted from animals to humans				
	Correct	121	19.8	16.4–22.5
	Incorrect/IDN/NR	503	80.2	76.9–83.2
Can get anthrax by eating infected meat and meat products e.g., ponmo (hides)?				
	Correct	151	24.1	20.9–27.6
	Incorrect/IDN/NR	476	75.9	72.4–79.1
Can get anthrax by touching infected meat and meat products e.g., ponmo (hides)?				
	Correct	133	21.2	18.2–24.6
	Incorrect/IDN/NR	494	78.8	75.4–81.8
Can get anthrax during the slaughtering of livestock?				
	Correct	114	18.2	15.3–21.4
	Incorrect/IDN/NR	513	81.8	78.6–84.6
Can get anthrax through the processing of hair, hides, skins, and bone?				
	Correct	116	18.5	15.6–21.7
	Incorrect/IDN/NR	511	81.5	78.2–84.3
Handling infected animals without protective covering?				
	Correct	120	19.1	16.25–22.4
	Incorrect/IDN/NR	507	80.9	77.5–83.7
Through contaminated soil?				
	Correct	98	15.6	12.9–0.18.6
	Incorrect/IDN/NR	529	84.4	81.3–87.0
Is sudden death a symptom of infection in animals?				
	Correct	131	20.9	17.89–24.2
	Incorrect/IDN/NR	496	79.1	75.7–82.1
Is un-clotted dark red blood a symptom of infection in animals?				
	Correct	129	20.6	17.5–23.9
	Incorrect/IDN/NR	498	79.4	76.1–82.4
Is bleeding from the natural orifices a symptom of infection in animals?				
	Correct	134	21.4	18.3–24.7
	Incorrect/IDN/NR	493	78.6	75.2–81.6
Is incomplete stiffening a symptom of anthrax in animals?				
	Correct	134	21.4	18.3–24.7
	Incorrect/IDN/NR	493	78.6	75.2–81.6
Is pain a symptom of anthrax in animals?				
	Correct	94	15.0	12.4–18.0
	Incorrect/IDN/NR	533	85.0	81.9–87.6
Is swelling a symptom of anthrax in animals?				
	Correct	99	15.8	13.1–18.8
	Incorrect/IDN/NR	528	84.2	81.1–86.8
Is fatigue a symptom of infection in animals?				

Table 2 (continued)

Variables	Categories	Frequency	Percentage	95% CI
	Correct	103	16.4	13.73–19.5
	Incorrect/IDN/NR	524	83.6	80.4–86.3
Can identify symptoms in humans?				
	Yes	105	16.8	14.0–19.8
	No	522	83.2	80.1–85.9
Is fever a possible symptom of disease in humans?				
	Correct	103	16.5	13.7–19.5
	Incorrect/IDN/NR	524	83.5	80.4–86.2
Is chills a possible symptom of disease in humans?				
	Correct	91	14.5	0.11.9–017.5
	Incorrect/IDN/NR	536	85.5	0.82.50–0.9069–94.7–88.0
Is fatigue a possible symptom of disease in humans?				
	Correct	94	15.0	12.4–0.18.1
	Incorrect/IDN/NR	532	85.0	81.8–87.4
Are skin rashes a possible symptom of disease in humans?				
	Correct	49	7.8	5.95–10.2
	Incorrect/IDN/NR	578	92.2	89.8–94.0
Is lack of appetite a possible symptom of anthrax in humans?				
	Correct	85	13.6	11.1–16.4
	Incorrect/IDN/NR	542	86.4	83.5–88.9
Is coughing a possible symptom of anthrax in humans?				
	Correct	90	14.4	11.8–17.3
	Incorrect/IDN/NR	537	85.6	82.6–88.1
Is headache a possible symptom of anthrax in humans?				
	Correct	87	13.9	11.3–16.8
	Incorrect/IDN/NR	540	86.1	83.2–88.6
Is irritability a possible symptom of anthrax in humans?				
	Correct	44	7.0	5.2–9.3
	Incorrect/IDN/NR	583	93.0	90.6–94.7
Is diarrhea a possible symptom of anthrax in humans?				
	Correct	73	11.7	9.3–14.4
	Incorrect/IDN/NR	554	88.3	85.6–90.6
Is vomiting a possible symptom of anthrax in humans?				
	Correct	80	12.8	10.3–0.15.6
	Incorrect/IDN/NR	547	87.2	84.4–89.6
Is sweating a possible symptom of infection in humans?				
	Correct	80	12.8	10.3–15.6
	Incorrect/IDN/NR	547	87.2	84.4–89.6
Are you aware of anthrax outbreaks in neighboring countries?				
	Yes	160	74.5	22.2–29.1
	No/IDN/NR	467	25.5	70.9–77.7
Will the vaccination of animals prevent disease in animals and humans?				
	Correct	204	33.0	28.9–36.3
	Incorrect/IDN/NR	423	66.7	63.7–71.0

IDN = I Don't Know; NR = No Response; CI = Confidence Interval

3.4 The general perception of anthrax among high-risk SH workers in Nigeria

Two hundred and forty (38.3%) participants were uncertain about perceiving their job as a risk for exposure to disease, 278, (44.3%) reported that animals condemned for anthrax should not be slaughtered or consumed even if it was cooked well, 249 (39.7%) of the participants stated that vaccination of livestock would prevent the disease in humans, while 262 (41.8%) self-reported government was taking zoonoses control serious in Nigeria.

Table 3 Knowledge scores on anthrax among high-risk working groups across demographic variables

Variables	Categories	Frequency	Percentage	Knowledge Score	P= value
Gender (n=613)	Male	499	81.4	0.0 (min 0.0, max 30.0)	0.7039
	Female	114	18.6	0.5 (min 0.0, max 30.0)	
Age Group (n=531)	18–22	51	9.7	0.0 (min 0.0, max 26.0)	0.0035
	23–27	75	14.2	2.0 (min 0.0, max 28.0)	
	28–32	85	16.0	1.0 (min 0.0, max 30.0)	
	33–37	78	14.8	1.0 (min 0.0, max 30.0)	
	38–42	72	13.5	1.0 (min 0.0, max 29.0)	
	≥ 43	170	31.8	1.0 (min 0.0, max 29.0)	
Educational Level (n=603)	No Formal	110	18.2	0.0 (min 0.0, max 25.0)	< 0.0001
	Primary	143	23.7	0.0 (min 0.0, max 25.0)	
	Secondary	218	36.2	0.0 (min 0.0, max 29.0)	
	Diploma	45	7.5	15.0 (min 0.0, max 28.0)	
	Tertiary	87	14.4	17.0 (min 0.0, max 30.0)	
Religion (n=620)	Islam	456	74.0	0.0 (min 0.0, max 30.0)	0.0286
	Christianity	151	24.5	1.0 (min 0.0, max 30.0)	
	Traditionalist	9	1.5	1.0 (min 0.0, max 7.0)	
Occupation (n=615)	Meat processor	115	18.7	0.0 (min 0.0, max 22.0)	< 0.0001
	Butcher	171	27.8	0.0 (min 0.0, max 29.0)	
	Meat vendor	122	19.8	0.0 (min 0.0, max 30.0)	
	Veterinarian & Para-veterinarian	64	10.5	24.0 (min 7.0, max 30.0)	
	Animal farmer	28	4.6	0.0 (min 0.0, max 29.0)	
	SH cleaner	19	3.1	1.0 (min 0.0, max 16.0)	
	Animal trader	1	0.2	0.0 (0)	
	SH staff	5	0.8	15.0 (min 3.0, max 30.0)	
Location (State)	Ebonyi	107	17.1	1.0 (min 0.0, max 10.0)	< 0.0001
	Enugu	64	10.2	13.0 (min 0.0, max 29.0)	
	Kwara	57	9.1	13.0 (min 0.0, max 29.0)	
	Zamfara	49	7.8	3.0 (min 0.0, max 30.0)	
	Kebbi	45	7.2	6.0 (min 1.0, max 29.0)	
	Oyo	148	23.6	0.0 (min 0.0, max 28.0)	
	Ogun	157	25.0	0.0 (min 0.0, max 30.0)	

min = minimum; max = maximum, n = number of participants

However, a little over half of the participants (322, 51.4%) strongly disagreed that meat inspection was of no use in detecting and preventing anthrax spread. Also, 34.9% (219) strongly disagreed that animals condemned to anthrax should be slaughtered or consumed by humans if livestock owners were not compensated by the government. Similarly, 32.2% (202) of the participants strongly agreed that the efficient implementation of vaccination in livestock would reduce the outbreak in humans (Fig. 3).

3.5 Correlation between knowledge and practice scores

There was a significant but weak positive correlation between knowledge and practice scores ($r = 0.1870$, $n = 627$, $p < 0.0001$), with poor knowledge about anthrax associated with poor practice level.

3.6 Association between demographic factors of participants with knowledge and practice towards anthrax.

The associations between the participants' demographic characteristics and outcome variables (knowledge and practice levels) were evaluated using a BLRA (Table 5).

Table 4 Practice scores on anthrax among high-risk working groups across demographic variables

Variables	Categories	Frequency	Percentage	Practice Score	P= value
Gender (n=613)	Male	499	81.4	6.0 (min 0.0, max 12.0)	0.0010
	Female	114	18.6	7.0 (min 0.0, max 12.0)	
Age groups (in years, n=531)	18–22	51	9.7	4.0 (min 0.0, max 11.0)	< 0.0001
	23–27	75	14.2	6.0 (min 0.0, max 12.0)	
	28–32	85	16.0	6.0 (min 0.0, max 12.0)	
	33–37	78	14.8	6.5 (min 0.0, max 12.0)	
	38–42	72	13.5	7.0 (min 0.0, max 12.0)	
	≥ 43	170	31.8	8.0 (min 0.0, max 12.0)	
Educational Level (n=603)	No Formal	110	18.2	0.0 (min 5.5, max 12.0)	0.0002
	Primary	143	23.7	0.0 (min 5.0, max 12.0)	
	Secondary	218	36.2	6.0 (min 0.0, max 12.0)	
	Diploma	45	7.5	7.0 (min 0.0, max 12.0)	
	Tertiary	87	14.4	8.0 (min 0.0, max 11.0)	
Religion (n=616)	Islam	456	74.0	6.0 (min 0.0, max 12.0)	0.0108
	Christianity	151	24.5	7.0 (min 0.0, max 12.0)	
	Traditionalist	9	1.5	4.0 (min 0.0, max 7.0)	
Occupation (n=615)	Meat processor	115	18.7	4.0 (min 0.0, max 12.0)	< 0.0001
	Butcher	171	27.8	4.0 (min 0.0, max 11.0)	
	Meat vendor	122	19.8	8.0 (min 0.0, max 11.0)	
	Veterinarian & Para-veterinarian	64	10.5	9.0 (min 2.0, max 12.0)	
	Animal farmer	28	4.6	9.0 (min 3.0, max 12.0)	
	SH cleaner	19	3.1	9.0 (min 8.0, max 12.0)	
	Animal trader	1	0.2	0.0 (0)	
	SH staff	5	0.8	11.0 (min 0.0, max 12.0)	
Location (State)	Ebonyi	107	17.1	6.0 (min 0.0, max 12.0)	< 0.0001
	Enugu	64	10.2	5.0 (min 3.0, max 11.0)	
	Kwara	57	9.1	9.0 (min 0.0, max 12.0)	
	Zamfara	49	7.8	6.0 (min 0.0, max 11.0)	
	Kebbi	45	7.2	8.0 (min 0.0, max 11.0)	
	Oyo	148	23.6	8.0 (min 0.0, max 12.0)	
	Ogun	157	25.0	4.0 (min 2.0, max 11.0)	

min = minimum; max = maximum, n = number of participants

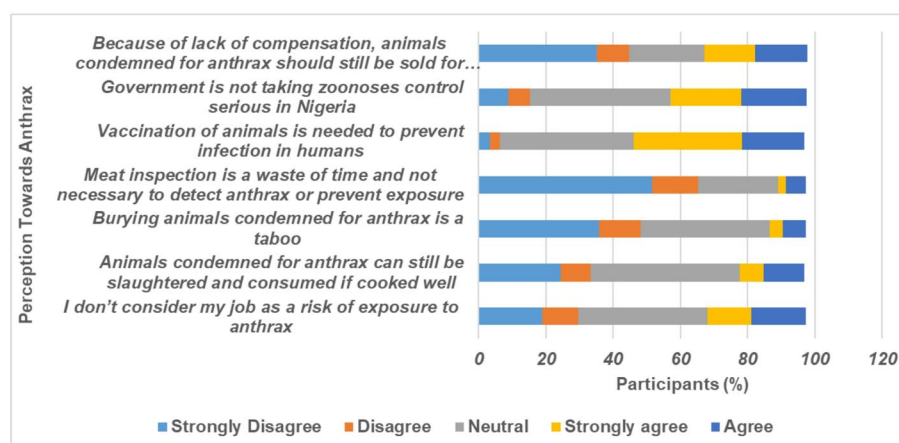
**Fig. 3** The perception of anthrax among high-risk SH workers who participated in the study:

Table 5 Association between demographic variables of participants with knowledge and practice of SH workers who participated in the study from July to September 2023

Variable	Knowledge level		Practice level	
	P= value	COR (95% CI)	P-value	COR (95% CI)
Age (years)				
< 37	0.068	0.175 (0.027–1.135)	0.000*	0.268 (0.148–0.486)
≥ 37	–	1	–	1
Gender				
Male	0.131	0.440 (0.152–1.276)	0.721	1.097 (0.658–1.829)
Female	–	1	–	1
Education				
No Tertiary	0.000*	14.378 (4.923–41.991)	0.699	1.120 (0.630–1.992)
Tertiary	–	1	–	1
Occupation				
Non-veterinary	0.000*	9.157 (3.644–23.008)	0.001*	3.471 (1.629–7.392)
Veterinary/Para veterinarians	–	1	–	1
Religion				
Muslim	0.099	2.068 (0.872–4.900)	0.508	1.173 (0.732–1.879)
Christian	–	1	–	1

* = Significant with *p* value less than 0.05; COR = Crudes Odds Ratio; CI = Confidence Interval

Participants with non-tertiary education qualifications (No formal, primary, or secondary) had increased odds (COR:14.378, 95% CI: 4.923–41.991, *p* = 0.000) of having inadequate knowledge level about anthrax than those with a tertiary education qualification. Similarly, participants who had no veterinary background (meat vendors, processors, cleaners, administrative staff, animal farmers, etc.) had increased odds (COR: 9.157, 95% CI: 3.644–23.008, *p* = 0.000) of having an inadequate knowledge level about the disease than veterinarians and para-veterinarians. Meanwhile, participants who were less than 37 years old had lower odds (COR: 0.175, 95% CI: 0.027–1.135, *p* = 0.068) of having an inadequate knowledge level than those above 37 years of age, though statistically marginal. Furthermore, participants who were non-veterinarians/non-para veterinarians had increased odds (COR: 3.471, 95% CI: 1.629–7.392, *p* = 0.001) of poor practice towards anthrax than veterinarians and para vets. Conversely, participants aged less than 37 years old had lower odds (COR: 0.268, 95% CI: 0.148–0.486, *p* = 0.000) of a poor practice than those above 37 years of age.

3.7 Relationship between participants' knowledge and practice levels to sources of information about Anthrax.

Understanding how the various media sources of information dissemination about the disease influence participants' knowledge and practice levels, and identifying the most appropriate channels, are crucial. Various channels of information captured in this study had significant associations with knowledge and practice levels, highlighting the importance of awareness creation. Only the use of religious leaders as an information channel was insignificantly associated with participants' practice (*p* = 0.194; Table 6).

3.8 Evaluation of national preparedness to prevent anthrax outbreak among veterinarians and para-veterinarians

A total of 50 out of 60 (83.3%) participants indicated anthrax as a "One Health" zoonosis and required control through a one health approach. A little over half (55.0%) showed believed that the animal health sector was well prepared to prevent anthrax outbreak

Table 6 Association between participants' knowledge and practice with the various channels of information about Anthrax

Channel of Information	Knowledge		P value	Practice		P value
	Poor n (%)	Good n (%)		Poor n (%)	Good n (%)	
Newspapers						
No/NR	558 (93.0)	42 (7.0)	0.000*	414 (69.0)	186 (31.0)	0.000*
Yes	14 (51.9)	13 (48.1)		7 (25.9)	20 (74.1)	
Radio						
No/NR	40 (7.2)	54 (78.3)	0.000*	385 (69.0)	173 (31.0)	0.005*
Yes	518 (92.8)	15 (21.7)		36 (52.2)	33 (47.8)	
TV						
No/NR	551 (93.2)	40 (6.8)	0.000*	404 (68.4)	187 (31.6)	0.009*
Yes	21 (58.3)	15 (41.7)		17 (47.2)	19 (52.8)	
Veterinary officers						
No/NR	521 (95.9)	22 (4.1)	0.000*	383 (70.5)	160 (29.5)	0.000*
Yes	51 (60.7)	33 (39.3)		38 (45.2)	46 (54.8)	
Internet/Social media						
No/NR	404 (68.7)	184 (31.3)	0.001*	552 (93.9)	36 (6.1)	0.000*
Yes	17 (43.6)	22 (56.4)		20 (51.3)	19 (48.7)	
Posters/flyers						
No/NR	568 (92.4)	47 (7.6)	0.000*	419 (68.1)	196 (31.9)	0.000*
Yes	4 (33.3)	8 (66.7)		2 (16.7)	10 (83.3)	
Medical officers						
No/NR	565 (92.2)	48 (7.8)	0.000*	416 (67.9)	197 (32.1)	0.011*
Yes	7 (50.0)	7 (50.0)		53 (5.7)	96 (4.3)	
Religious leaders						
No/NR	570 (91.6)	52 (8.4)	0.000*	419 (67.4)	203 (32.6)	0.194
Yes	2 (40.0)	3 (60.0)		2 (40.0)	3 (60.0)	
Community leaders						
No/NR	565 (91.9)	50 (8.1)	0.000*	418 (68.0)	197 (32.0)	0.002*
Yes	7 (58.3)	5 (41.7)		3 (25.0)	9 (75.0)	
Family friends						
No/NR	561 (91.7)	51 (8.3)	0.013*	415 (67.8)	197 (32.2)	0.023*
Yes	117 (3.3)	42 (6.7)		6 (40.0)	9 (60.0)	

* = significant with *p* value less than 0.05

from occurring, and similarly, 55.0% reported that there has been efficient national media publicity and awareness programmes on anthrax and preventive measures since the outbreaks in neighboring countries, while 40% disagreed. Concerning the country having a national contingency plan for disease control, 35.0% and 21.7% agreed and strongly agreed respectively, while 13.3% were unsure or did not respond to the question. In addition, a low percentage of the participants (40.0%) indicated that Nigeria has the technological and surveillance capacities to detect and contain anthrax outbreak, while the same number (41.7%) disagreed. The majority of the participants disagreed with the country having artificial intelligence capacity and response for supporting informed outbreak management in the country (43.3%). The main strategies needed to prevent an infection outbreak in Nigeria as suggested by veterinarians and para veterinarians included media publicity and awareness creation, enforcement of vaccination policy for infection prevention in animals, implementation of effective surveillance systems for early detection and management, development, and execution of literacy programmes for SH workers and communities, reformation of SH, improved biosecurity on farms, and effective implementation of border control policies.

4 Discussion

Anthrax remains a neglected tropical disease that seldom receives attention from the government and researchers in Africa, including Nigeria. The re-emergence of the disease in 2023 has re-emphasised the need for the country to scale up integrated surveillance and monitoring frameworks and systems for transboundary animal infectious diseases and zoonoses occurring at the animal-human–environment interface. Having robust, well-structured, and efficient surveillance and reporting systems enhances early detection and management of potential outbreaks [20]. In addition, improved One Health implementation, diagnostic capabilities, resources (infrastructure, personnel, and funding), literacy advocacy, and border control policies or legislation are crucial for prompt disease intervention. The present study investigated potential gaps in knowledge, practice, and perception about anthrax among the high-risk working groups in ABs and SHs in Nigeria.

The demographics from this study showed that the majority of SH workers with the highest risk of exposure to anthrax were males and those with primary school and no formal education. These findings are consistent with previous studies conducted in Nigeria [21–24], Ethiopia [25–27], Bangladesh [9], and Malaysia [28]. Animal handling and slaughtering are demanding activities, and maybe the reason there were more male than female workers at the ABs and SHs. Also, with the poor level of education, it is not surprising to observe a low awareness level about anthrax among the study participants, except in categories with diplomas or tertiary education. Education plays a key role in how people access, process, and comprehend information, including health messages [14].

Adequate knowledge, practice, and perception of SH workers about anthrax are crucial to their overall health and safety as well as the general consumers of meat and meat products. It is known that disease transmission including anthrax is influenced by societal human behaviour, which correlates with the level of knowledge, attitudes, and practices of the public [8, 9]. With the present outbreaks of anthrax in West Africa, it is critical to generate scientific data to explain the knowledge, practice, and perception levels of SH workers to promote a framework for policy decisions and behavioural shifts through literacy programmes to prevent and control their exposure to the disease.

In general, the knowledge about anthrax among the participants was inadequate as less than one-third indicated the knowledge of the disease, its causative agent, clinical signs/symptoms in animals and humans, transmission pathways (such as consumption, processing, touching, or handling of infected animals or animal products e.g. cow skin (“ponmo”), and vaccination of animals as a preventive measure against infection in humans. The finding revealed that there may have been a lack of targeted sensitisation or health education response to create awareness to lower the risk of exposure and protect workers’ health despite the outbreaks within neighbouring countries. In selected agricultural settings in Uganda, inadequate knowledge about anthrax, especially the clinical manifestation and modes of transmission in humans and animals, and preventive measures (vaccination in animals) was documented [8]. Although a study in Bangladesh reported more livestock farmers being aware of anthrax, and correctly describing one or more symptoms of animal and human anthrax, farmers had limited knowledge of the mode of transmission of anthrax and the preventive method, which is vaccination. Furthermore, in Kenya, household communities had insufficient information about the

disease with approximately half of the respondents reported needing more literacy about the disease [15]. However, the majority of the study population had heard of anthrax and identified it as a zoonosis, knew the transmission sources, and knew that bleeding from body orifices is one of the clinical signs in animals [15]. Another similar study conducted among household communities in Ethiopia showed that a higher proportion of respondents stated that they knew the disease, but most of them could not identify the causative agent and clinical signs/symptoms in animals and humans [14]. It is critical to emphasize that targeted literacy programmes regarding this disease are essential for workers at ABs and SHs to support early detection, notification, and prevention of disease outbreaks in animals and humans. Expanding health knowledge about the disease among these categories of individuals, especially using the top preferred channels (veterinary professionals, radio, and internet/social media) is desirable to promote understanding and the adoption of rapid health responses to prevent and control exposures. These recommendations are strongly supported by a previous study among pastoral communities in Ethiopia [29] and the present study findings, which highlighted possessing a high level of education and being in veterinary-related professions as significant factors for increased knowledge about anthrax.

Similarly, the levels of risk practices related to anthrax among the participants were high. For instance, the majority of the non-veterinary working categories, such as butchers, meat processors, vendors, etc. still practised carrying carcasses on their heads or shoulders, splashing blood on carcasses, slaughtering sick and dying animals for human consumption, and poor waste and carcass disposal. Several of these risky and unsanitary practices are common practices in many Nigerian ABs and SHs [30, 31]. These practices not only serve as potential sources of transmission and exposure to zoonotic diseases, including anthrax, but may also adversely impact food safety and meat consumers. From the present study, more participants disagreed or strongly disagreed that buying meat condemned to anthrax is forbidden ("taboo"). This suggests that there is a possible gap in the level of perception and awareness of the health risk associated with the consumption of dead animals, including anthrax-contaminated meat. The practice and attitude of purchasing, consuming, and selling carcasses of animals that died from unknown causes, have been reported by other studies in Ghana and Zambia [32, 33]. Such meat is seen as serving as a source of inexpensive meat and an attractive option for the community [32]. Kamboyi and co-authors in a cross-sectional study of risk mapping and eco-anthropogenic assessment of anthrax in Zambia documented that 92.0% of participants self-reported within the questionnaire survey that the major method of disposal of anthrax carcasses was by consumption [34]. Furthermore, participants with no professional training in veterinary medicine (i.e. butchers, meat processors, meat vendors, cleaners, etc.) had high risk practices; thus, demonstrating poor preventive practices toward anthrax. This finding supports the fact that when people have adequate health knowledge, they execute good preventive practices and have the right perception toward health emergencies and responses to control and prevent an outbreak [35]. Health knowledge is a theoretical construct that includes providing detailed and specific information about etiology, prevalence, risk factors, prevention, transmission, symptomatology, and disease treatment, as well as on health services [35, 36]. Positive effects of appropriate levels of health knowledge have been shown to improve health behaviors and attitudes, which increase health promotion and disease prevention in a community.

Besides, health knowledge promotes the acquisition of health practices and perceptions and reflects the efforts made by the health system, the government, and the community to combat the negative impact of zoonoses [35]. Improving targeted health knowledge about anthrax is therefore critical among the high-risk working groups in abattoirs and slaughterhouses for public health safety. To support this further, it was observed that positive knowledge increases positive practice, thus emphasizing the need for veterinary intervention, good extension services, and literacy programmes for ABs and SHs workers in Nigeria. Moreover, veterinary and para veterinarians who participated in this study underscored intensifying media publicity and awareness creation about anthrax. Other mitigation strategies including enforcement of vaccination policy for infection prevention in animals, implementation of effective surveillance systems for early detection and management, development, and execution of literacy programmes for SH workers and communities, reformation of SH, improved biosecurity on farms, and effective implementation of border control policies were recommended.

Adopting a combination of approaches to effectively improve knowledge, learning, good practices among abattoir and slaughterhouse workers can be prioritised. In the Nigerian context, this could include targeted, practical and interactive or participatory training sessions, with incentives and training certificates provided to encourage participation. Such training should be conducted periodically as part of continuous workers' education to sustain knowledge and reinforce safe practices against exposure to anthrax and other abattoir related zoonoses. Also, the use of visual educational tools such as pictorial charts, signage, and posters presented in local languages can strategically be displayed at critical operation points within the slaughter facilities to serve as constant notices of risks of exposure to zoonoses, and the need to comply with good hygiene and safety practices. Community engagement and outreaches are powerful tools of awareness creation and behavioural modifications. This can be conducted regularly to promote positive behavioral changes, correct misconceptions about zoonoses, and strengthen efforts towards disease prevention, and abattoir workplace health and safety.

To promote animal disease prevention and control, Nigeria has recently released the updated Animal Diseases (Control) Act, 2022, which provides a comprehensive legal framework for the surveillance, prevention, detection, control, and eradication of infectious, contagious, transboundary, and zoonotic animal diseases across the country including those relating to the ABs and SHs. The Act outlines provisions for ensuring disease identification (at ante- and post-mortem inspection) and safe meat inspection, disease reporting, safe carcass disposal, and food safety operations. Therefore, strengthening and prioritising the implementation, enforcement, and compliance mechanisms of this Act would help achieve sustainable control of animal disease, especially zoonoses such as anthrax among high-risk occupational groups such as abattoir and slaughterhouse workers.

Furthermore, annual and effective routine vaccination of animals especially, ruminants is the primary tool for mitigating animal anthrax [37] and should be prioritized in disease endemic African countries. It is not surprising to know that the majority of the participants were uncertain or disagreed that vaccination was required in animals to protect public health due to the poor health knowledge of the disease except those with veterinary backgrounds. The current vaccination status in animals in Nigeria is uncertain, though there may be an existing anthrax vaccination policy in the country.

Internationally, the *Bacillus anthracis* attenuated Sterne-strain vaccine is used in animals [38]. In Nigeria, the National Veterinary Research Institute (NVRI) is saddled with the mandate to produce animal vaccines for animal health and welfare. During the outbreak in July 2023 in Nigeria, the National Veterinary Research Institute laboratory provided real-time laboratory testing and vaccines for ring vaccination of farms with suspected cases. However, there may be a need for the government and the animal sector to be more proactive than reactive to ensure that the anthrax vaccination policy, vaccine production, and campaign programmes are efficiently implemented and adequately funded to eliminate the persistence of the disease in Nigeria.

In addition, the anthrax outbreak highlights again the 'One Health' perception that human health is interconnected with animal and plant health and their shared environment [3]. To prevent further outbreaks in Nigeria, as well as other African countries, government efforts and advocacy by the one health sectors for the vaccination of animals are crucial to help prevent and reduce the likelihood of the spread of the disease to humans and individuals at the high-risk [3]. The establishment of government-integrated zoonotic disease (including anthrax) surveillance systems and programmes for early detection, early response to future outbreaks, and long-term active and passive monitoring of diseases to facilitate informed policy decisions and implementations should be spotlighted. Ensuring an integrated platform for multidisciplinary, multisectoral, and interdisciplinary collaboration among physicians, veterinarians, other human and animal health workers, environmental health professionals, social workers, and the media in mitigating the anthrax outbreak in Nigerian communities is highlighted. The One Health concept should be implemented in addressing the core sources of zoonotic spillovers at the human-animal interface. This approach will be more effective than individual sectors continuing to operate in silos, thereby impacting unending cycles of outbreaks [39, 40].

Notwithstanding the findings above, this study had some limitations. One, assessment of risk practices was limited to a questionnaire survey; on-the-spot assessment would have provided better insights into the participants' level of risk of exposure to anthrax. Two, only seven of the 36 states, including the Federal Capital Territory, Abuja, were conveniently sampled and included in the study; a larger sample size from a higher number of states would have been representative and provided more robust and generalisable data on the knowledge, risk practices and perception of abattoir and slaughterhouse workers in Nigeria. Despite these limitations, the present findings have provided critical baseline data required for informed control programmes and policy regarding anthrax in Nigeria.

5 Conclusions

The study revealed inadequate knowledge, preventive practices, and perception regarding anthrax among slaughterhouse SH workers, despite their position as a population group at high risk of exposure. Enhancing health knowledge remains a vital strategy to improve workers' preventive practices, attitudes, and perceptions toward exposure, prevention, and control of anthrax.

There is an urgent need for comprehensive public health literacy programmes, risk communication, stakeholder engagement, One Health initiatives, and advocacy efforts

to provide adequate knowledge that will safeguard SH workers against anthrax and ultimately prevent spillover into the human population.

Such programmes should include information on the aetiology, transmission pathways, clinical signs and symptoms in animals and humans, as well as the risk factors, treatment options, preventive measures, and rapid response strategies for containing infection outbreaks. In addition, there is a need to strengthen integrated surveillance system to enhance early detection and proactive response to anthrax in both animal and human populations.

Abbreviations

AB	Abattoir
BLRA	Binary Logistic Regression Analysis
CI	Confidence Interval
COR	Crudes Odds Ratio
FMARD	Federal Ministry of Agriculture and Rural Development
IAP	Incident Action Plan
NCDC	Nigeria Centre for Disease Control and Prevention
SH	Slaughterhouse
WHO	World Health Organization

Supplementary Information

The online version contains supplementary material available at <https://doi.org/10.1186/s12982-026-01374-7>.

Supplementary Material 1

Author contributions

AOO conceptualized the study, AOO managed, analyzed, and interpreted the data. OOO, OAA, MMM, ABU, ROA, AHK, EGC, RAB, AJO, JAB, OTO, AMA, JTO, TAO, and IOA participated in the data collection. AOO drafted the manuscript. AHK, OOO, and AJO critically reviewed and edited the manuscript. All authors did an overall review and editing and gave final approval of the submitted version for publication.

Funding

Not Applicable.

Data availability

The survey instrument is available as supplementary data. The raw datasets generated and/or analysed during the current study are available in the Mendeley Data Repository at <https://doi.org/10.17632/dzvd2ssy9h.1>

Declarations

Ethics approval and consent to participate

The College of Veterinary Medicine Research Ethics Committee, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria reviewed the research protocols and provided the ethical clearance for this study (Reference Number; FUNACOLVET/CREC/2023/07/03). After providing a detailed description of the study, informed consent was verbally obtained from each participant before the questionnaire was administered. Participation in the survey was voluntary and without any penalty attached for refusal. Also, personal identifiers were excluded and pseudonymized. Participants were assured that the information provided would be strictly confidential and used only for the study. The data were stored on a password-protected computer. Every participant was notified of his/her right to discontinue at any stage of the study as specified by the World Medical Association Declaration of Helsinki Ethical Principles (WMA, 2015).

Consent for publication

Not applicable.

Use of AI tools

The authors declare they have not used Artificial Intelligence (AI) tools in the creation of this article.

Competing interests

The authors declare that they have no competing interests.

Author details

¹Department of Veterinary Public Health and Preventive Medicine, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

²Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Ilorin, Ilorin, Kwara State, Nigeria

³Department of Veterinary Surgery and Theriogenology, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

⁴Department of Theriogenology, College of Veterinary Medicine, Federal University of Agriculture, Zuru, Kebbi State, Nigeria

⁵Ministry of Agriculture and Natural Resources, Zamfara, Zamfara State, Nigeria

⁶Department of Veterinary Medicine, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Oyo State, Nigeria

⁷Department of Veterinary Public Health and Preventive Medicine, University of Ibadan, Ibadan, Oyo State, Nigeria

⁸Department of Agriculture, Alex-Ekwueme Federal University, Ndufu Alike, Ebonyi State, Nigeria

⁹Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Nigeria, Nsukka, Enugu State, Nigeria

¹⁰Department of Veterinary Services, Ministry of Agriculture, Abeokuta, Ogun State, Nigeria

¹¹Federal College of Animal Health and Production Technology, Moor Plantation, Ibadan, Oyo State, Nigeria

Received: 4 October 2025 / Accepted: 9 January 2026

Published online: 26 January 2026

References

1. Ihekweazu C, Michael CA, Nguku PM, Waziri NE, Habib AG, Muturi M, et al. Prioritization of zoonotic diseases of public health significance in Nigeria using the one-health approach. *One Health*. 2021;13:10025. <https://doi.org/10.1016/j.onehlt.2021.100257>.
2. Ogunleye SC, Olorunshola MM, Fasina KA, Aborode AT, Akinsulie OC, Amoo A, et al. Anthrax outbreak: exploring its biological agents and public health implications. *Front Trop Dis*. 2024. <https://doi.org/10.3389/ftd.2023.1297896>.
3. Oduoye MO, Scott GY, Dave T, Bolanle AH, Mwinbong AD, Modupeoluwa OO. One health approach to mitigate anthrax in Ghana. *Health Sci Rep*. 2024. <https://doi.org/10.1002/hsr2.1807>.
4. Nigeria Centre for Disease Control and Prevention. Confirmation of Anthrax Outbreak in Nigeria. 2023. <https://ncdc.gov.ng/news/491/confirmation-of-anthrax-outbreak-in-nigeria>. Accessed 15 September 2024.
5. Ashinze P, Lawal L, Buhari AO, Adeoti SG, Mogaji AB, Lawal AO, et al. The sporadic resurgence of anthrax in sub-Saharan Africa: intricacies and challenges to controlling a potentially fatal zoonotic disease. *Int J Surg Global Health*. 2023. <https://doi.org/10.1097/GH9.0000000000000335>.
6. Al-Mustapha AI, Oyewo M, Abubakar AT, Bamidele F, Ibrahim H. The re-emergence of anthrax in Nigeria. *IJID One Health*. 2023;1:100010. <https://doi.org/10.1016/j.ijidoh.2023.100010>.
7. Traxler RM, Napetvaridze T, Asanishvili Z, Geleishvili M, Rukhadze K, Maghlakelidze G, et al. Knowledge, attitudes, and practices related to anthrax and animal care: a case-control study in Georgia. *PLoS ONE*. 2019;14(10):e0224176. <https://doi.org/10.1371/journal.pone.0224176>.
8. Kungu JM, Nsamba P, Wejuli A, Kabasa JD, Bazeyo W. Perceptions and practices towards anthrax in selected agricultural communities in Arua District, Uganda. *J Trop Med*. 2020;2020:9083615. <https://doi.org/10.1155/2020/9083615>.
9. Dutta PK, Biswas H, Ahmed JU, Shakif-Ul-Azam M, Ahammed BMJ, Dey AR. Knowledge, attitude and practices (KAP) towards anthrax among livestock farmers in selected rural areas of Bangladesh. *Vet Med Sci*. 2021;7(5):1648–55. <https://doi.org/10.1002/vms3.561>.
10. Rumide TS, Samuel E, Oni O. Anthrax Outbreak in Nigeria: An Issue for Concern? *J Infect Dis Epidemiol*. 2023;9:310. <https://doi.org/10.23937/2474-3658/1510310>.
11. Afolabi KO, Amoo OS, Onuigbo TI, Oraegbu JI, Awoseyi AA, Fasina FO, et al. Regional Cross-Sectional Based Study and Associated Risk Factors of Porcine Circovirus 2 in Nigerian Pigs. *Transbound Emerg Dis*. 2023;2023:1–15. <https://doi.org/10.23937/2474-3658/1510310>.
12. Adebowale OO, Adenubi OT, Adesokan HK, Oloye AA, Bankole NO, Fadipe OE, et al. SARS-CoV-2 (COVID-19 pandemic) in Nigeria: multi-institutional survey of knowledge, practices and perception amongst undergraduate veterinary medical students. *PLoS ONE*. 2021;16:e0248189. <https://doi.org/10.1371/journal.pone.0248189>.
13. Chacha I. Knowledge, Attitudes and Practices Regarding Anthrax among Community Members, Health and Veterinary Workers in Maragua, Kenya. University of Nairobi; 2017. p. 1–77.
14. Romha G, Girmay W. Knowledge, attitude and practice towards anthrax in northern Ethiopia: a mixed approach study. *BMC Infect Dis*. 2020;20(1):814. <https://doi.org/10.1186/s12879-020-05544-z>.
15. Mbai JM, Omolo JO, Wamamba D, Maritim D, Gura Z, Obonyo M. Assessment of knowledge, attitudes and practices towards anthrax in Narok County, Southern Kenya. *Pan Afr Med J*. 2021;38:120. <https://doi.org/10.11604/pamj.2021.38.120.19439>.
16. WHO, 2020. Anthrax Information Sheet. <https://www.who.int/publications/m/item/anthrax-information-sheet> Accessed 15 September 2023.
17. WHO, 2016. Anthrax. <https://www.who.int/europe/news-room/questions-and-answers/item/anthrax>. Accessed 15 September 2023.
18. WHO, 2008. Anthrax in human and animal guidelines. <https://www.who.int/publications/i/item/9789241547536>. Accessed 11 September 2023.
19. European Centre for Disease Prevention and Control. Anthrax. 2016. <https://www.ecdc.europa.eu/en/publications-data/anthrax-annual-epidemiological-report-2016-2014-data>. Accessed 15 January 2024.
20. Sharan M, Vijay D, Yadav JP, Bedi JS, Dhaka P. Surveillance and response strategies for zoonotic diseases: a comprehensive review. *Sci One Health*. 2023;2:100050. <https://doi.org/10.1016/j.soh.2023.100050>.
21. Adesokan HK, Raji AOQ. Safe meat-handling knowledge, attitudes and practices of private and government meat processing plants' workers: implications for future policy. *J Prev Med Hyg*. 2014;55:10–6.
22. Okpala COR, Nwobi OC, Korzeniowska M. Assessing Nigerian butchers' knowledge and perception of good hygiene and storage practices: a cattle slaughterhouse case analysis. *Foods*. 2021;10(6):1165. <https://doi.org/10.3390/foods10061165>.
23. Pearl Agu A, Kenan Onah C, David Umeokonkwo C, Chukwuka Nnabu R, Friday Igwe Una A. Hygiene practices in abattoir and slaughter slab, determinants and assessment of abattoir and slaughter slab facilities in Abakaliki, Ebonyi State South-East Nigeria. *Afr Health Sci*. 2021;21:1914–23. <https://doi.org/10.4314/ahs.v21i4.50>.
24. Alhaji NB, Aliyu MB, Adamu AM, Adeiza AM, Nafarnda WD, Usman AH, et al. Assessment of Abattoir Workers' Knowledge, Perceptions and Preventive Preparedness during COVID-19 Pandemic in North-central Nigeria: the Health Belief Model. *Sahel J of Vet Sci*. 2023;20:13–21.

25. Tegegne HA, Phyto HWW. Food safety knowledge, attitude and practices of meat handler in abattoir and retail meat shops of Jigjiga Town, Ethiopia. *J Prev Med Hyg.* 2017;30(4):E320–7. <https://doi.org/10.15167/2421-4248/jpmh2017.58.4.737>.
26. Tolera ST, Alemu FK, Mengistu DA. Knowledge, attitude, and practice of abattoir workers toward abattoirs waste management in Eastern Ethiopia. *Environ Health Insights.* 2022;16:11786302221075450. <https://doi.org/10.1177/11786302221075450>.
27. Gebeyehu DT, Tsegaye H. Food safety knowledge and practice of abattoir and butcher shop workers: a health risk management perspective. *One Health Outlook.* 2022;4:14. <https://doi.org/10.1186/s42522-022-00070-1>.
28. Abdullahi A, Hassan A, Kadarman N, Saleh A, Shu'aibu YB, Lua PL. Food safety knowledge, attitude, and practice toward compliance with abattoir laws among the abattoir workers in Malaysia. *Int J Gen Med.* 2016;9:79–87. <https://doi.org/10.2147/IJGM.S98436>.
29. Tschopp R, Kidanu AG. Knowledge-attitude and practice of anthrax and brucellosis: implications for zoonotic disease surveillance and control in pastoral communities of Afar and Somali region, Ethiopia. *PLoS Negl Trop Dis.* 2024;18(4):e0012067. <https://doi.org/10.1371/journal.pntd.0012067>.
30. Adebowale OO, Akinkuotu OO, Kehinde OO, Adebowale O. Public health implication of unwholesome practices at a municipal abattoir in South-Western Nigeria. *J of Nat Sc, Eng and Tech.* 2012;11(1):36–143.
31. Bakari NA, Umoh JU, Kabir J, Otolorin GR, Ehizibolo PO, Jibril YJ, et al. A case study of Yola Modern Abattoir, Adamawa State, Nigeria. *J Vet Adv.* 2015;5:995.
32. Opare C, Nsiire A, Awumbilla B, Akanmori BD. Human behavioural factors implicated in outbreaks of human anthrax in the Tamale municipality of northern Ghana. *Acta Trop.* 2000;76:49–52. [https://doi.org/10.1016/S0001-706X\(00\)00089-9](https://doi.org/10.1016/S0001-706X(00)00089-9).
33. Munang'andu HM, Banda F, Siamudaala VM, Munyeme M, Kasanga CJ, Hamududu B. The effect of seasonal variation on anthrax epidemiology in the upper Zambezi floodplain of western Zambia. *J Vet Sci.* 2012;13:293. <https://doi.org/10.4142/jvs.2012.13.3.293>.
34. Kamboyi HK, de Garine-Wichatitsky M, Hang'ombe MB, Munyeme M. Risk mapping and eco-anthropogenic assessment of anthrax in the upper Zambezi basin. *Vet Med Sci.* 2019;5(3):419–27. <https://doi.org/10.1002/vms3.168>.
35. Rincón Uribe FA, Godinho RCS, Machado MAS, et al. Health knowledge, health behaviors and attitudes during pandemic emergencies: a systematic review. *PLoS ONE.* 2021;16(9):e0256731. <https://doi.org/10.1371/journal.pone.0256731>.
36. Trevethan R. Deconstructing and assessing knowledge and awareness in public health research. *Front Public Health.* 2017;5:194. <https://doi.org/10.3389/fpubh.2017.00194>.
37. Sarker MSA, El Zowalaty ME, Shahid MAH, Sarker MA, Rahman MB, Järhult JD, et al. Maximization of livestock anthrax vaccination coverage in Bangladesh: an alternative approach. *Vaccines.* 2020;8(3):435. <https://doi.org/10.3390/vaccines8030435>.
38. Hugh-Jones M. Global anthrax report. *J Appl Microbiol.* 2015;87:189–91. <https://doi.org/10.1046/j.1365-2672.1999.00867.x>.
39. Wilcox BA, Steele JA. One health and emerging zoonotic diseases. In: Kickbusch I, Ganten D, Moeti M (eds) *Handbook of global health.* Springer, Cham; 2021. p. 1–49. https://doi.org/10.1007/978-3-030-05325-3_88-2.
40. Adesola RO, Okeke VC, Hamzat A, Onawola DA, Arthur JF. Unraveling the binational outbreak of anthrax in Ghana and Nigeria: an in-depth investigation of epidemiology, clinical presentations, diagnosis, and plausible recommendations toward its eradication in Africa. *Bull Natl Res Cent.* 2024;48(1):45. <https://doi.org/10.1186/s42269-024-01203-4>.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.