Sero-positivity and associated intrinsic and extrinsic drivers of Rift Valley fever occurrence in pastoral herds of Nigeria: A cross sectional survey

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Abstract

Background: Rift Valley fever (RVF) is a vector-borne emerging zoonotic disease of animals and humans characterized by major socioeconomic losses to livestock farmers, with potential global public health threat. The study assessed herders’ existing knowledge, sero-prevalence and factors influencing the occurrence of RVF in cattle herds.

Methods: A cross-sectional study using questionnaire and determination of IgM was conducted among pastoral herds. Frequencies and proportions were used for descriptive analysis. Categorical variables were presented as proportions and their associations determined by Chi-square tests. Associations were analyzed by univariable tests and multivariable logistic regressions analysis at 95% confidence level.

Results: All 403 pastoralists (50.5±15.5 years) participated in this study with the majority of respondents being male, married and had no formal education. The majority of the pastoralists reported low knowledge about zoonotic RVF infections. The within-herd seropositivity of RVF in Nigeria is 5.6% which was higher under nomadic (7.4%) than agro-pastoral (3.8%) settings. All animal demographic characteristics of age, sex and breeds were not significantly (p>0.05) associated with occurrence of RVF in pastoral cattle herds. However, all the socio-ecological factors significantly (p<0.05) influenced RVF occurrence in pastoral settlements. However, availability of mosquitoes in the pastoral environments (OR=7.81; 95% CI: 4.85, 12.37), presence of rivers and streams in grazing fields (OR=10.80; 95% CI: 6.77, 17.34), high rainfall (OR=4.30; 95% CI: 2.74, 6.59), irrigated rice fields (OR=5.14; 95% CI: 3.21, 7.79) and bushy vegetation and (OR=6.11; 95% CI: 3.96, 9.43), animal movement (OR=2.2; 95% CI: 1.45, 3.25) and seasonal variations (OR=2.34; 95% CI: 1.55, 3.51) were more likely to influence RVF occurrence in pastoral herds.

Conclusions: This study highlighted low levels of knowledge about RVF among surveyed
pastoralists as well as socio-ecological factors contributory to RVF occurrence. This study illustrates recent circulation of RVFV in Nigeria and needs urgent interventions. This challenging gap calls for health education of these vulnerable populations on the socio-economic and health threats of RVF in the remote rural areas of developing countries, especially Africa.

Background

Rift Valley fever (RVF) is a vector-borne emerging zoonotic disease of animals (cattle, small ruminants, camels, and wildlife) and humans, caused by Rift Valley fever virus (RVFV) of the family *Bunyaviridae* and genus *Phlebovirus* [1, 2, 3]. The disease causes significant morbidity and mortality of about 10% and 30%, respectively in animals [4]. Abortion is often the only obvious indication of the disease in cattle [5]. The virus is mainly transmitted among livestock through infected mosquito bites (mainly *Aedes* and *Culex*) and possibly by bites of other blood sucking insects, such as sand fly of *Phlebotomus* spp [6], and by direct contacts with infected animal tissues, bodily fluids and fomites [1, 3]. However, vertical transmission between animals has also been reported [7, 8]. RVFV is mostly transmitted to humans through bites of infected *Aedes* mosquitoes [9, 10], and by direct contacts with infected animals or inhalation of aerosols during the handling or slaughtering of infected ruminants [2, 5, 11]. The disease causes major socioeconomic losses to livestock farmers, with potential global public health threat [6, 12, 13].

RVF is endemic in many African countries, the Arabian Peninsula, and some Indian Ocean Islands [14, 15, 16]. It is often encountered in endemic and epidemic forms in Africa and Middle East [5, 17, 18]. In West and Central Africa, its occurrence is associated with seasonal rainfall during non-epidemic periods [19]. For RVF occurrence, seasonal and
ecologically driven risk factors are related to vector habitat availability and vegetation dynamics [3]. Movement of infected vectors, persons and animals could lead to emergence of the disease in non-endemic areas [20]. A clinical epizootic of RVF and its spread in the Sahel was associated with nomadic cattle and seasonal migrations of herdsmen [21]. There is no official report of clinical RVF occurrence in Nigeria [22], but studies have indicated circulation of RVFV among ruminants and humans [23, 24, 25]. No attempt has been made to quantitatively investigate current RVFV circulation, seasonality and ecological determinants of the disease in pastoral herds of Nigeria, while this information is needed to better mimic the vegetation dynamics in relation to RVF emergence. Moreover, there is also a need to use extrinsic socio-ecological factors (other than climate), such as livestock and vector densities, in data-driven RVF epidemiology for surveillance and control programmes. Effective surveillance and early warning systems for timely response to RVF emergence in livestock require adequate knowledge about its epidemiology [26, 27]. The study objectives were to assess existing herders’ existing knowledge about RVF and estimate its within-herd sero-prevalence in pastoral herds. We hypothesized that intrinsic demographic characteristics of animals and extrinsic socio-ecological factors cannot influence occurrence of RVF in cattle herds.

Results

Demographic characteristics of participants

All the 403 selected pastoralists, with mean age of 50.5±15.5 years, participated in the study. Most of the participants (24.3%) were in age group 50–59 years. The majority of respondents were male (81.9%) and married (83.4%), while 13.9% and 3.7% were single and widows, respectively. Segregated by occupation, 50.1% (202/403) were nomadic pastoralists and 49.9% (201/403) were agro-pastoralists. The majority of participants
(62.8 %,) had no formal education and very few (7.4%) had tertiary education (Fig. 1).

**Existing knowledge about Rift Valley fever**

All the respondents reported to have heard about RVF, locally called *Gabi-gabi*. Common sources of information about the disease were: relatives (93.4%) and radio (6.6%). When asked about clinical manifestations of RVF in cattle, majority of agro-pastoralists (67.79%, 136/201) and nomadic pastoralists (92.6%, 187/202) mentioned high mortality in newborns. Also, 85.1% (171/201) agro-pastoralists and 94.6% (191/202) of nomadic respondents reported sudden onset of abortions in pregnant cows. However, few agro-pastoralists (27.9%, 56/201) and nomadic (38.1%, 77/202) mentioned high fever as sign in animals, and 43.8% (88/202) agro-pastoralists and 82.7% (167/202) nomadic indicated listlessness in newborns as clinical manifestation. Regarding mode of transmission of RVFV in cattle, most agro-pastoralists (57.7%, 116/201) and nomadic (72.3%, 146/202) reported mosquito bites, while 25.9% (52/201) agro-pastoralists and 40.1% ((81/202) nomadic respondents mentioned bites of other flies. On zoonotic nature of RVF, only 24.4% (49/201) agro-pastoralists and 11.4% (23/202) nomadic pastoralists indicated the disease to be zoonotic. Most responses from the two occupational groups on knowledge variables about the disease in cattle were significantly (p<0.05) associated (Table 1).

**RVFV sero-positivity**

A total of 107 sera samples were screened for RVFV-IgM antibodies and six were sero-positive. This finding represented within-herd anti-RVF IgM antibodies recent burden of 5.61% (6/107, 95% CI: 2.31, 11.30) in pastoral herds of Nigeria. A sero-prevalence of 7.7% (95% CI: 2.00, 19.52) was recorded in animals aged 1–3 years followed by those aged more than 3 years (4.4%, 95% CI: 1.13, 11.54). Under pastoral production systems, sero-prevalence was higher in nomadic production system (7.4%, 95% CI: 2.40, 16.91) than in
agro-pastoral system (3.8%, 95% CI: 0.64, 11.91). Details of breed, age sex and production system sero-positivity are presented in Table 2.

**Cattle demographic characteristics associated with Rift Valley fever occurrence in herds**

At univariable analysis, all animal demographic characteristics of age, sex and breeds were not significantly (p>0.05) associated with occurrence of RVF in pastoral cattle herds. No statistical association ($\chi^2$: 0.403, $p = 0.810$) was observed among the local breeds. Among the age groups, there was no significant association in the sero-prevalence ($\chi^2$:0.504, $p = 0.470$). Also, there was no significant association in sero-prevalence between bulls and cows as well as between agro-pastoral cattle and nomadic pastoral cattle [($\chi^2$: 0.434, $p = 0.510$) and ($\chi^2$: 0.667, $p = 0.410$), respectively] as shown in Table 3.

**Socio-ecological drivers for Rift Valley fever occurrence in settlements**

At univariable analysis, all the socio-ecological factors significantly (p<0.05) influenced RVF occurrence in pastoral settlements. However, with multivariable logistic regressions, availability of mosquitoes in the pastoral environments was eight times more likely to influence RVF occurrence (OR = 7.81; 95% CI: 4.85, 12.37), while presence of rivers and streams in grazing fields was eleven times more likely to influence RVF occurrence (OR = 10.80; 95% CI: 6.77, 17.34). Also, high rainfall was more likely to influence RVF occurrence in pastoral settlements (OR = 4.30; 95% CI: 2.74, 6.59), and irrigated rice fields and bushy vegetation were more likely to influence emergence of the disease in the settlements [(OR = 5.14; 95% CI: 3.21, 7.79) and (OR = 6.11; 95% CI: 3.96, 9.43), respectively]. Furthermore, animal movement and seasonal variations were twice more likely to influence occurrence of the disease in pastoral settlements [(OR = 2.2; 95% CI: 95% CI: 0.64, 11.91).
Discussions

It is worth noting that the use of indigenous knowledge of local communities is a viable undertaking in epidemiology. This is because of its potential to support disease surveillance, early warning systems and preventive measures, thereby substantially mitigating risks of infectious diseases [34]. This study found common sources of information about RVF to be relations and radio. Radio programmes are crucial in the dissemination of epidemiological information on diseases among pastoralists, because they largely depend on radio to get information about livestock diseases. The use of radio as an efficient media for dissemination of information to educate livestock keepers on RVF has been substantiated [35, 36].

Although respondents have heard about RVF, low positive responses on its epidemiology were observed, indicating low level of knowledge. Except for anorexia in animals, high mortality in newborns and sudden onset of abortions in cows that had high positive responses, other RVF clinical manifestations and symptoms in animals were characterized by low proportional levels of knowledge. Also, there were few pastoralists with good knowledge of modes of transmission of RVFV in animals, except for bites of infected mosquitoes that had high positive responses. These findings are consistent with results of a study that reported low knowledge about vectors spreading RVF, signs and symptoms in animals among the livestock keepers in Sudan [27]. Studies have also associated pastoralists in Kenya and Tanzania with limited knowledge levels on symptoms and modes of RVF transmission [37]. Low knowledge levels observed in this study could be attributed to absence of educational programmes targeted at livestock farmers on emerging infectious diseases in Nigeria.

This study found 62.8% of participants without formal education. Possession of formal
education is very important as it creates opportunities for exchange of ideas on diseases through seminars and workshops. Low knowledge on RVF could be attributable to low formal education levels among pastoralists, which can predispose to low understanding about its zoonotic nature [38].

Although there has been no documented report of RVF outbreak in Nigeria, this study found evidence of silent RVFV circulation in all breeds, ages and sex of pastoral cattle, with overall within-herd serological RVFV IgM prevalence of 5.6%. This may indicate a recent natural exposure to the virus in the study area. Thus, absence of clinical signs in animals cannot exclude silent circulation of the virus in them and can be interpreted as a possible recent infection in these animals. Previous studies have shown that anti-RVFV IgM antibodies were lost in 50% of animals by 45 days after infection [2]. The silent circulation of active RVFV has previously been reported in slaughtered ruminants in Nigeria [39], and among apparently healthy animals in Somalia [40], and Democratic Republic of the Congo [41]. The observed high prevalence in nomadic pastoral cattle (7.4%) than in agro-pastoral animals (3.8%) could be due to long-distance movements and exposures. Animal movements, trade and changes in weather conditions are risk factors for RVF (re)occurring in West Africa and spreading to unaffected areas (FAO, 2017).

We found no significant influence of intrinsic factors (breed, age, sex, and production system) on RVF occurrence in the cattle herds. Contrary, previous studies reported natural correlation between RVFV sero-positivity and age of animals [42, 43]. However, in agreement with our findings, some studies have also reported no significant difference on sero-positivity between male and female animals [44, 45]. No significance statistically could due to the small sample of animals in this study, derived from some limitations. There was significant influence of seasons and ecological factors on RVF occurrence in pastoral cattle herds. Indeed, ecological factors of climate and landscape features can
predispose to mosquito density and population dynamics, with consequent influence on RVF emergence [46, 47, 48]. Significant factors observed include: high mosquito density, high cattle density, high rainfall, presence of ‘dambos’ and irrigated rice fields, availability of bushy vegetations, presence of rivers and streams, animal movement, and seasonal variables. High cattle density has previously been reported as risk factor for RVF transmission [41]. Ecological factors of climate, water bodies and other landscape features (such as forest, shrub, and agricultural areas) influence density and population dynamics of vectors of RVF [47, 49, 50]. The presence of temporary water bodies and floodplains, and forested or shrubby areas, artificial water bodies (such as dam and irrigated rice fields) are known to be predisposing factors for RVF occurrence in western and eastern Africa [47, 51, 52].

Results of this study have shown that pastoralists possessed low knowledge about RVF as a zoonotic disease. Educating pastoralists on its public health impact is needed and interventions that will enable pastoralists live in separate locations from animals are also required. Acting to address challenges caused by RVF in humans is essential because true incidence of the disease remains uncertain due to absence of routine surveillance data in Nigeria. On the basis of available estimates and likely geographical distribution associated with the risk factors, the number of people and animals with RVF may largely exceeds the number affected by other zoonotic health challenges, such as brucellosis, bovine tuberculosis, antimicrobial residues and resistance, that have received greater attention, funding, and resources.

Although there was sero-positive IgM against RVFV, major limitation was the relatively small sample size of animals, which might have undermined significant effects of independent variables on outcome variables during the univariable analysis of intrinsic determinants. A longitudinal cohort study involving large number of animals is advocated.
to clarify the epidemiology of the disease, with particular consideration for intrinsic factors in this study area. The lack of full adjustments for pastoral herds clustering in the designed random sampling was a limitation. However, the used of central tendency measures would be valuable enough to tolerate the likely imperfections in the confidence intervals. Furthermore, questionnaire was also used for data collection, but pre-tested prior to actual data collection to improve accuracy, quality control and ensured that no information was lost in the process.

Conclusions

This study highlighted low levels of knowledge about RVF among surveyed pastoralists. This challenging gap calls for health education of these vulnerable populations on the socio-economic and health threats of RVF in the remote rural areas of developing countries, especially Africa. This study illustrates recent circulation of RVFV in Nigeria and needs urgent interventions. For better understanding of RVF epidemiology, more investigations on the vector dynamics and livestock movements within Nigeria and across its borders are needed. To achieve food safety, food security, and public and environmental health, the identified burden and driving factors will require cross-disciplinary collaboration for surveillance and control of the disease.

Methods

Ecological setting of study area

The study was conducted in Niger State in the Southern Guinea Savannah zone of Nigeria, between latitudes 8° 20′ N and 11° 30′ N, and longitudes 3° 30′ E and 7° 20′ E. The state serves as transit routes for pastoral herds on seasonal transhumance movements between northern and southern parts of Nigeria. It has three designated Agro-ecological zones: southern, eastern and northern zones, with variable climatic conditions. These zones are
characterized by many rivers, streams and ponds, fadamas for rice farming and four hydroelectric dams. There are also Kainji National Game Reserve and many transnational stock routes.

The state experiences two distinct seasons: rainy season (April to October) and dry season (November to March), with mean annual rainfall of about 150 cm spanning for a period of approximately 180 days. It has average annual temperature range of 22°C to 39°C and relative humidity of about 58.6%. These ecological variables predispose the state to annual flooding and consequently provide suitable breeding environments for vectors of vector-borne diseases, such as RVF, in water-filled topographic depressions, the ‘dambos’. The state has an estimated cattle population of 2.5 million, which are mostly in the custody of pastoralists [28].

Study design and target population

A cross-sectional study was conducted in pastoral settlements herding local breeds of cattle in two production systems between October 2017 and September 2018. Both serological and questionnaires tools were used for sample collection. For serological burden investigation, average nomadic and agro pastoral herd sizes were 50 and 25 heads of cattle, respectively of both sex, aged at least one year to exclude the effect of colostral antibodies and no vaccination history. Accessibility of herds was also considered, with insecure areas being excluded. Using questionnaire tool, age eligibility for pastoral household heads that participated was 20 years or above. They were expected at these ages to possess existing veterinary knowledge on livestock health management and diseases risk factors [29].

For the purpose of this research, a nomadic production system was defined as management that kept mainly cattle and took part in year-round movements of herds over large ranges for grazing without a permanent homestead. An agro-pastoral production
system was a semi-settled herd with small number of cattle, cultivating few crops and having limited movements on low range grazing within their environments.

**Sample size and sampling procedure**

For within herd sero-prevalence, same size was determine using random sampling for finite population, with power set at 11.3% [30], 6% desired absolute precision at 95% confidence level. A sample size of 107 heads of cattle was obtained. Sample size of households for questionnaire administration was determined using the same approach, with power set at 50% frequency of response; margin of error was 5% at 95% confidence level. A sample size of 384 households was obtained. To take care of non-response, a 5% contingency was added. Thus, 403 household heads were targeted for data collection.

A multi-stage sampling method was carried out. For questionnaire administration, three Agro-ecological zones were purposively considered in the first stage. In the second stage, 15 settlements were selected for each production system (30 pastoral settlements in all) across the study area, with five from either nomadic or agro pastoral herds in each Agro-zone. In the final stage, 134 pastoral households (67 from either group) were randomly selected in each zone. A total sample of 403 respondents, made up of 202 nomadic and 201 agro-pastoralists, were selected. For the sero-positivity, 10 herds (5 nomadic and 5 agro-pastorals) were purposively selected in each zone. Also, a minimum of 3 cattle were randomly selected proportionately from each herd.

**Data collection: serum samples and serological analysis**

Sampled cattle were classified according to age: 1–3 years and >3 years. Blood samples (5mls) were collected in dry vacutainer tubes from the jugular vein of each animal. Each vacutainer tube was labeled and individual animal information recorded. The collected blood samples were kept at room temperature for 12 hours in cool box at 4°C to allow
blood clot, centrifuged at 3,000 g for 10 minutes for erythrocytes sedimentation and serum formation. The sera were transferred into new vials and labeled before being stored at -20°C until further processing.

Serological analysis using capture IgM ELISA was conducted. To detect recent infection (IgM), all samples were tested using ID Screen RVF IgM ELISA (ID-Vet Innovative Diagnostics, Grabels, France) according to the manufacturer’s instructions. The test was considered valid when the mean value of the positive control OD (ODPC) was greater than 0.35 and the ratio of mean values of the positive and negative control ODs (ODPC and ODNC) was greater than 3. The sample was considered positive when the competition percentage was greater than or equal to 50%, doubtful when between 40% and 50%, and negative when ≤40%. All doubtful samples were considered as negative in this study.

Data collection: questionnaire administration

We developed a structured questionnaire with mostly categorical questions to ease data processing and improve precision of responses. It was interviewer-administered by eight trained animal health technicians and supervised by the authors. The questionnaire consisted of four sections: demographic characteristics of respondents (6 questions); existing knowledge about RVF (9 questions); herd biodata (4 questions); and socio-ecological drivers of RVFV occurrence in herds (9 questions). The questionnaire was originally designed in English and verbally translated to local Hausa language during administration for respondents without formal education.

Questionnaire was pre-tested on 15 pastoral cattle herds’ settlements before final administration, and identified problems were eliminated and final high quality data collected. To achieve maximum response, advocacy visit was made to the leader (Dikkos) of each pastoral settlement a week prior to data collection and permission obtained.
Respondents were assured of voluntary participation, confidentiality of responses and the opportunity to withdraw at any time without prejudice in line with the World Medical Association Declaration of Helsinki [31]. Informed consent was obtained either by signatures (for literates) or thumb-printings (for illiterates) on a sheet before questionnaire administration and none declined to participate.

Data management and statistical analysis

Data from the field and laboratory were summarized into Microsoft Excel 7 (Microsoft Corporation, Redmond, WA, USA) spreadsheets and stored. Descriptive and analytical statistics were used. Frequencies and proportions were used for descriptive analysis. Categorical variables were presented as proportions and their associations determined by bivariate analysis using Chi-square tests. Associations were analyzed by univariable tests and multivariable logistic regressions analysis.

RVFV sero-positivity in animals was measured as the proportion of animals presenting antibodies against RVFV to the total number of animals in the target population. To assess associations, demographic characteristics of animals and socio-ecological factors were the independent (explanatory) variables. Identified sero-positivity and sero-negativity as well as pastoralists’ categorical responses to questions in questionnaire formed the dependent (outcome) variables. All explanatory and outcome variables were initially screened by univariable analysis using Chi-square tests [32] or Fisher’s exact test, where appropriate. Likelihood stepwise backward multivariable logistic regressions model was built by adding variables in a backward selection process in order to start with those with significant p-value from the univariable analysis. This was to control for confounding and test for effect modification. Variables with a p-value more than 0.05 on the univariable analysis were not included in the final model. The EpiInfo 3.4.3 (CDC, Atlanta, GA, USA) and OpenEpi version 2.3.1 [33] statistical packages were used for statistical analyses. A p<0.05 was considered
statistically significant in all analyses.

Declarations

Ethics approval and consent to participate

This study involved the use of questionnaire on household heads and cattle herds owned by the pastoralists. Samples for serology were collected from cattle in accordance with best practice guidelines to minimise contamination after verbal approval by the herders during advocacy visits, since majority of them do not possess formal education and was approved by the ethics committee. The committee also approved informed consent of participants either by signatures (for literates) or thumb-printing. This project proposal had ethical approval from the Niger State Ministry of Livestock and Fisheries Internal Research Ethics Review Committee (Ref No: NGS/MLF/RC–694).

Consent to publish

Not applicable

Availability of data and materials

The data analyzed during this study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they do not have any competing interests.

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Authors’ contributions

NBA and JA designed the study and supervised the data collection. NBA and IAO carried out data analysis and interpretation of results. NBA wrote the first draft. MKL and IGM assisted in manuscript write-up. OOB and IAO supervised the work. All authors read and approved the final draft.

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Abbreviations

CI: Confidence interval; ELISA: Enzyme-linked immunosorbent assay; OR: Odds ratio; RVF: Rift Valley Fever; RVFV: Rift Valley fever virus; $X^2$: Chi-square.

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Figures

![Figure 1](image-url)

Pastoralists’ formal educational levels in pastoral settlements in Nigeria