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Investigation of Climatic and Non-climatic Risk Factors of *Fasciola gigantica* Infection in Slaughtered Cattle Based on a Cross Sectional Survey in Sokoto State, Nigeria

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Authors' contributions

This work was carried out in collaboration among all authors. Author IH designed the study, performed the statistical analysis, wrote the protocol, and wrote the first draft of the manuscript. Authors HB and JK managed the analyses of the study. All authors read and approved the final manuscript.

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ABSTRACT

Aim: This study presents the first effort at identifying the effects of both climatic and non-climatic factors on fascioliasis infection in slaughtered cattle at an abattoir in Sokoto state.
Study Design: Two questionnaires were administered to elicit relevant information regarding the parameters of each slaughtered cattle and the socio-demographic status of the owners of each slaughtered cattle. Faecal and bile samples were collected from each slaughtered cattle.
Place and Duration of Study: A cross-sectional survey applied to investigate risk determinants of 300 slaughtered cattle at abattoirs in the study area.

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Methodology: Binary logistic regression was used to determine risk determinants for infections.
Results: Results indicate that of 300 faecal samples from the slaughtered cattle in 10 provinces revealed that 92 (30.7%) were positive for the presence of *F. gigantica* parasite while 208 (69.3%) were unaffected. Age of cattle was found to be more likely to fascioliasis infection (or: 1.0498; 95% ci: 1.0305-1.0695) than the younger ones. The breed of cattle was associated with an increased likelihood of infection with *F. gigantica* (or: 1.5934; 95% ci: 1.0641-2.3860). Male cattle were 0.6 times less likely to be infected with *F. gigantica* (or: 0.6213; 95% ci: 0.3302-1.1688) than female cattle. similarly, cattle belonging to fulani were more likely to be infected with *F. gigantica* (or: 3.1229; 95% ci: 1.7959-5.4303) than those cattle that belonged to hausa/zabarma ethnic groups. In terms of climatic variables, elevation has an association with increased likelihood of infection with *F. gigantica* infections (or: 1.0004; 95% ci: 0.9796-1.0216).
Conclusion: This study demonstrated that sokoto state is endemic area for *Fasciola gigantica* infections and it recommends the need to formulate appropriate strategies to control the disease.

Keywords: Fascioliasis; sokoto; slaughtered cattle; abattoirs.

1. INTRODUCTION

Fasciola gigantica is a significant constraint on the health and wellbeing of 16 million cattle in Nigeria due to the increasing number of condemned livers in various abattoirs in all the geopolitical zones of the country [1,2,3]. Reported that there is a change in the economic status of low-income class into middle class across the world. In the Nigerian economy alone, the contribution of livestock specifically cattle according to the Central Bank of Nigeria, CBN [4] was about 12.7% of total agriculture gross domestic product (GDP). However, disease such as fascioliasis with a cosmopolitan distribution is affecting animal's productivity, and therefore the World Health Organisation has recommended the need to formulate appropriate strategies to control the disease [5,6-8]. Also, the economic losses due to fascioliasis have been estimated to be over US$800 million per annum in Africa's 200 million cattle population [9,10]. According to [11], *F. gigantica* being one of the species of trematodes has recently been enlisted as a significant disease by Food Technologist' Expert Panel on Food Safety and Nutrition.

It was highlighted by [12] that two major categories of factors have been affecting the geographical distribution of *F. gigantica* which include climatic and environmental factors on one hand and livestock characteristics as well as associated practices of grazing management factors on the other hand. That has been corroborated by [13] who reported that the risk of infection of fascioliasis could be 'influenced' by the population of animals and also a system of animal grazing that determines their accessibility to both contaminated water and pasture. This approach of study that focuses on practices of herd management as potential risk factors when complemented with climatic factors can assist significantly in recognising infection sources and most effective way of designing control programs [14,15]

In Nigeria, no known study focused on risk determinants based on herd management practices of slaughtered animals at abattoirs for *F. gigantica* infection. In northern Nigeria, a major producer of livestock to other parts of the country, the knowledge of risk factors for fascioliasis infection is scanty with only a few studies documenting risk factors at herd level and slaughtered cattle at abattoirs [2,16,17,18]. This study presents the first effort at identifying the effects of both biotic and abiotic factors on fascioliasis infection in slaughtered cattle at an abattoir in Sokoto State. The research would serve as a guide in designing effective control measures against fascioliasis infection prevalence.

2. MATERIALS AND METHODS

2.1 Climate and Environmental Variables

This study used yearly averages of relevant climatic variables that affect the life cycle of fascioliasis and its intermediate host snails in binary regression techniques as independent variables while the binary response was presence and absence of *F. gigantica* infections. These variables include rainfall, temperature, NDVI, soil moisture and elevation obtained from various satellite platforms.

Rainfall (RFE2.0 is available athttp://earlywarning.usgs.gov/fews.) for the whole of Africa from 2000 to date with a spatial resolution of 8 kilometres at 10-day composites. This study used the data from 2005-2014. Likewise, land surface temperature MODIS LST (MOD11C1) within the same temporal range as rainfall was obtained from the National Aeronautic and Space Administration (NASA) Earth Observations website (http://neo.sci.gsfc.nasa.gov/). This research also used NDVI data set from 2005 to 2014 and is available on the National Aeronautic and Space Administration (NASA) website (http://neo.sci.gsfc.nasa.gov/).

The soil moisture used in this research utilised the Global Land Data Assimilation System (GLDAS-2) produced through the combined efforts of the National Aeronautics and Space Administration (NASA), the National Oceanic and Atmospheric Administration (NOAA), the Goddard Space Flight Centre (GSFC) and the National Centre for Environmental Prediction [NCEP]. Lastly, the elevation data applied in this study is a product of the global 1-arc second Shuttle Radar Topographic Mission (SRTM) via the United States Geological Survey's EarthExplorer website (http://earthexplorer.usgs.gov).

2.2 The Study Area

Sokoto State is situated between longitudes 4º 8′ E and 6º 54′ east of Greenwich meridian and latitudes 12º N and 13º 58′ north of the equator (Fig. 1). A cross-sectional survey was carried out in July to August to investigate the prevalence of *F. gigantica* infections and herd management practices risk factors in cattle in 10 provinces of Sokoto State, northwestern Nigeria. These provinces were drawn to represent the four agricultural zones of Sokoto State, which encompass the entire 23 local government areas. The agricultural zones include Sokoto, Isa, Gwadabawa and Tambuwal [19]. In Sokoto zone Rabah was selected, in Isa zone, Goronyo was selected, in Gwadabawa zone, Silame was selected, in Tambuwal zone both Dangeshuni and Shagari were selected.

A total of 300 slaughtered cattle (154 females and 146 males) were randomly sampled for *F. gigantica* infections. For each sampled cattle the owner of the herd from which it belongs was selected. *Sarkinfawa* (King of the abattoir) was very handy in tracing the owners of each of the sampled slaughtered cattle.

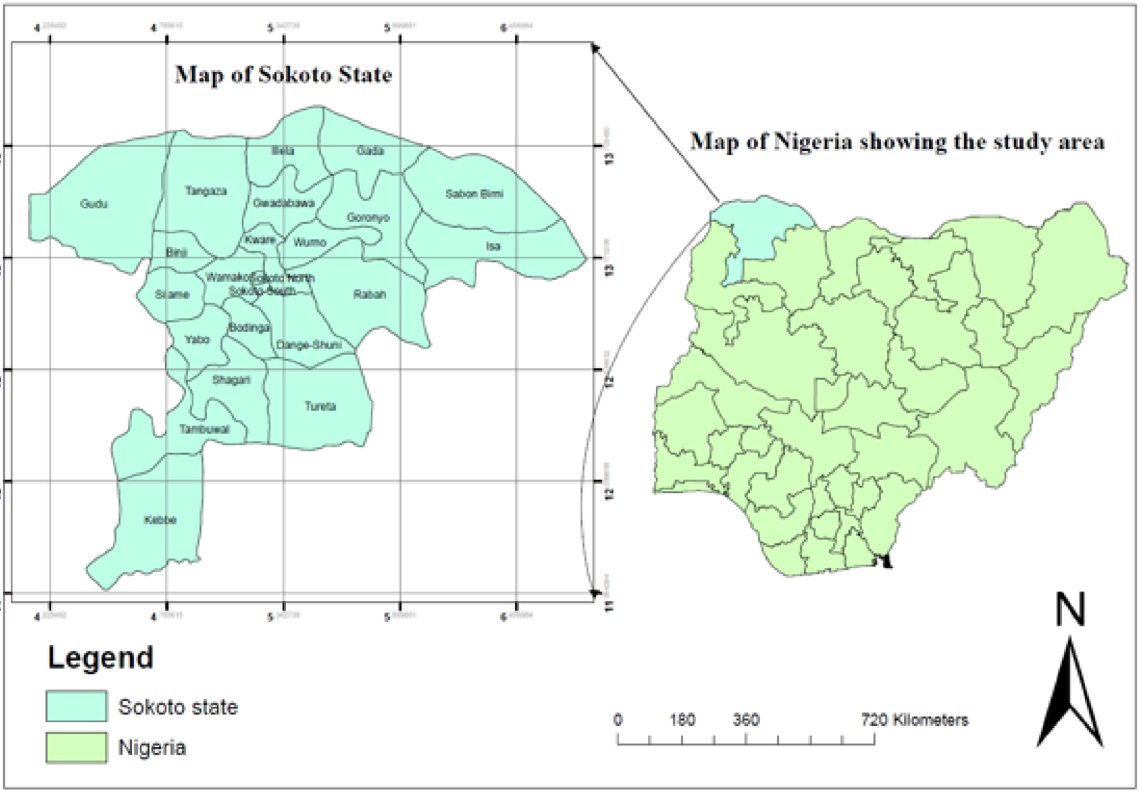

Fig. 1. The map of the study area

2.3 Data Collection

This study was carried out using two questionnaires to elicit relevant information regarding the biological characteristics of each slaughtered cattle and socio-demographic status of their owners. The biological characteristics of each slaughtered cattle include breed, its source, age, sex and age. In addition, cattle owners socio-demographic characteristics centred on herd management system and the knowledge of the disease among others. The disease fasciolosisis known in the study area by different names as butchers and herdsmen refer to it as “ciwon hanta” as well as “Fadama”. The latter name implies the association of the parasite with moisture due to its association with the marshy areas that are common along the river sides in the study area [20].

Faecal test: Faecal samples were collected from the rectum of each sampled slaughtered cattle with the aid of plastic gloves in line with Hansen and Perry [21] report. The plastic glove was carefully twisted inside out and taken under suitable conditions to Parasitology laboratory of Usmanu Danfodio Veterinary Teaching Hospital for analysis. Also, the bile from the gall bladder of each selected cattle was obtained along with the faeces.

Sedimentation technique was applied by this study as adopted by MAFF [22], Hansen and Perry, Bunza, Magajiet al., [23]. The following equipment were required: Beakers, tea strainer, measuring cylinder, means of shaking the mixtures, test tubes, cover slips, teaspoons as well as a microscope. A beaker is a cylinder container made up of glass commonly used in the laboratory. The tea strainer is a device used in the filtering of small solid particles from the liquid. A test tube is a tube-like device made of glass with only one opening that can contain a small number of substances for laboratory testing. The microscope is an optical device that can magnify an image of either animal or plant or animal cells for viewing.

In the laboratory, a quantity (3g) of faeces contained in a test tube was mixed with 40-50ml of tap water (distilled water). That would result in a solution with suspended particles of faeces. The tea strainer was used in filtering the suspension after blending with the aid of a fork and then poured into a test tube. In order to allow the suspension to settle properly the sediment was left for five minutes after adding 10% formalin. Then the suspended particles in the form of liquid substances referred to as supernatants were ejected (discarded) with utmost caution. The resulting sediment containing eggs of fascioliasis in the test tube was centrifuged at 2000rpm. These sediments were later mixed with the 5 ml of water and 1ml of diethyl-ether and then gradually allowed to settle for another five minutes. The supernatants were cautiously discarded as done previously. Microscopic examination was carried out on the sediments that were strained with a drop of methylene blue that was poured on to micro slide (clean micro glass slide) enclosed with a cover slip at a magnification of 10*10.

2.4 Statistical Analysis

This section presents the results of both the descriptive and the inferential statistics employed in the study.

3. RESULTS

3.1 Cattle Management and Slaughtered Cattle Data

The characteristics of the owners of the slaughtered cattle in the selected localities during the field survey are shown in Table 1. Males constitute 88.3% of the respondents while females were only 11.7 %. Likewise, the age group between 16-45 years were the majority (61.6%) while the group with the lowest number of respondents were those in the age category of 60 and above (mean age was 36.45, SD± 14.59, range 17-63 years). A more significant number of the respondents were married (71.7%) and without any formal education (73%). Most of the respondent acquired their cattle through inheritance (56.7%) while those whose cattle were given as a gift to them constitute only 14.3%. The slaughtered cattle were reared mostly by Fulani (54%) then the Hausa/Zabarma ethnic group (46%).

A total of 300 hundred cattle were slaughtered with a mean age (in months) of 44.1 (SD ±17.302, range 23-74 months). Female cattle were slaughtered more (51.3%) than male cattle (48.7%). Regarding the breed composition, Sokoto Gudale was the most dominant (52.7%) followed by Red Bororo with 28.7% while the white Fulani breed constitutes only 18.7% of the slaughtered cattle.

Table 1. Demographic characteristics of the owners of the slaughtered cattle in studied provinces in Sokoto State, Nigeria

Demographic characteristics	Frequency	Percentage
Sex		
Male	265	88.3
Female	35	11.7
Total	300	100
Age(years)		
16-45	185	61.6
46-60	90	30
Above 61	25	8.4
Total	300	100
Marital status		
Single	85	28.3
Married	215	71.7
Total	300	100
Education level (formal)		
Primary	80	43.3
Secondary/ Higher institution	10	3
None	220	53.7
Total	300	100
Source of cattle		
Purchase	87	29
Inherited	170	56.7
Gift	43	14.3
Total	300	100
Tribe		
Hausa/Zabarma	138	46
Fulani	162	54
Total	300	100

Table 2. Slaughtered cattle *F. gigantica* infections from the provinces studied in Sokoto State, Nigeria

Provinces	Slaughtered cattle	Sample size	Infected	Percent positive
Goronyo	223	30	09	30
Kebbe	119	30	13	43
Wurno	196	30	09	30
Gada	203	30	06	20
Sokoto N	535	30	12	40
Gudu	205	30	06	20
Silame	251	30	08	26
Shagari	121	30	12	40
Dangeshuni	108	30	08	26
Rabah	124	30	09	30
Total	2085	300	92	30.7%

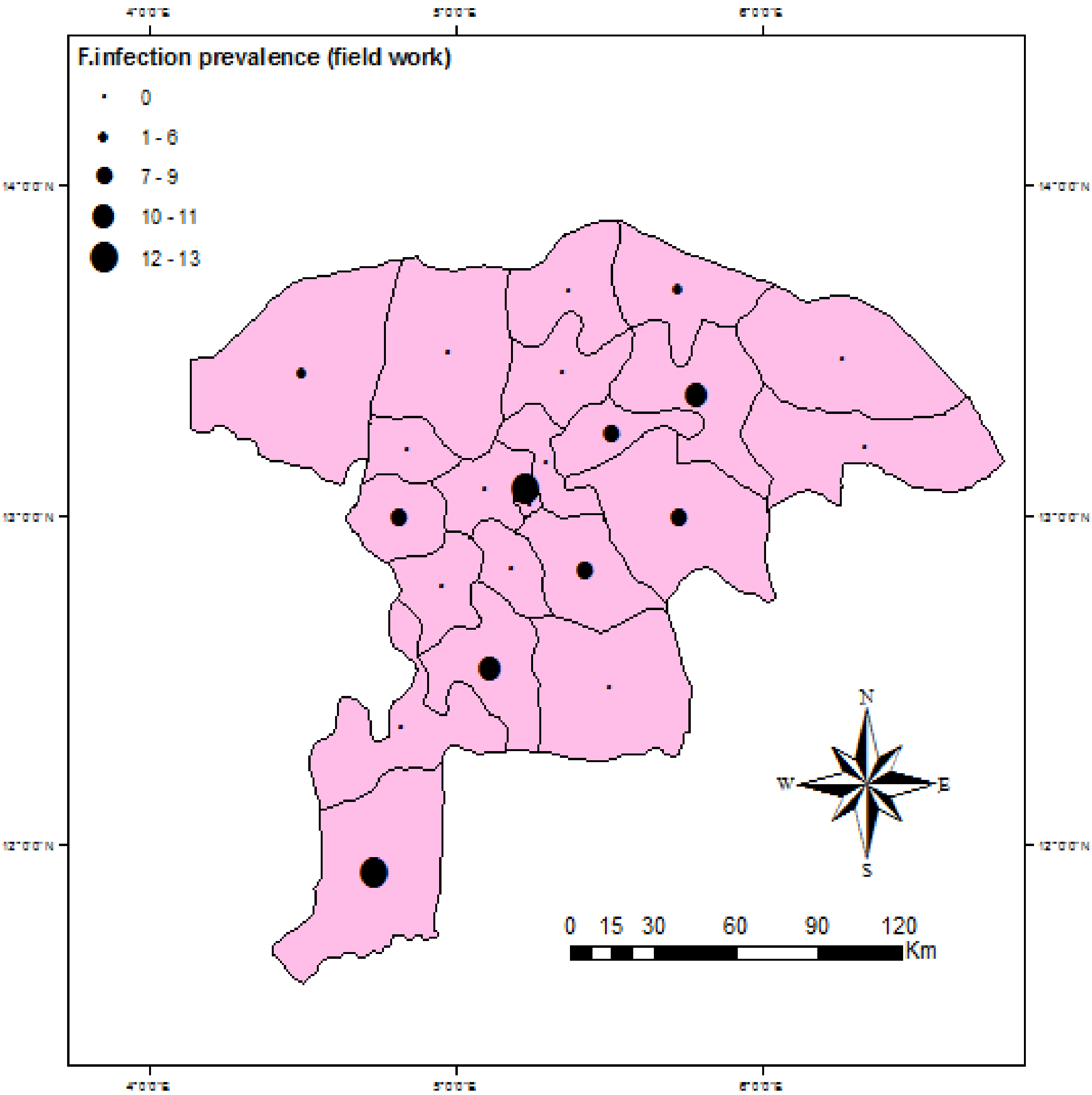

Fig. 2. Prevalence of fascioliasis infection across the 10 provinces studied in Sokoto State. The different dots indicate varying prevalence rates as recorded during the analyses of the faecal samples of the slaughtered cattle while dot that represents zero value shows areas that were not surveyed

3.2 Faecal Test Data

A faecal test analysis of 300 samples from the slaughtered cattle in 10 provinces revealed that 92 (30.7%) were positive for the presence of *F.gigantica* parasite while 208 (69.3%) were unaffected. The spread of infections was found across all the surveyed localities ranging from 26% to 43% (Table 2). The highest *F.gigantica* infectionswere documented in Kebbe (43%), Sokoto North (40%) and Shagari (40)while Gada and Gudu had the lowest *F.gigantica* infection (20%) (Fig. 2).

3.3 Associations between risk Factors and *F. gigantica* infections

The analysis revealed that there is a significant association between the characteristics of the slaughtered cattle that bordered on the source of cattle (from either local or exotic), age and breed and *F. gigantica* infection. However, the relationship between gender of the slaughtered cattle and fascioliasis infection was not significant (P>0.05) as shown in Table 3.

The association between the practices of cattle management with *F. gigantica* infection was

Table 3. Association between the slaughtered cattle characteristics and *F. gigantica* infection in selected abattoirs and slaughter slabs in Sokoto State

Risk factors	Chi-Square	Df	*P*-Value
Animal source	10.05	1	< 0.001***
Age	28.96	1	< 0.001***
Breed	5.40	1	<0.05***
Gender	2.16	1	>0.05

*****= significant test*

Table 4. Association between practices of herd management and *F. gigantica* infection in selected abattoirs and slaughter slabs in Sokoto State

Risk factors	Chi-Square	df	*P*-Value
Cattle/herd acquisition	14.40	1	< 0.001***
Grazing areas	0.25	1	>0.05
Water source	8.69	1	<0.05***
Tribe	17.41	1	<0.05***

Table 5. Association between Climatic factors and *F. gigantica* infection in selected abattoirs and slaughter slabs in Sokoto State

Risk factors	Chi-Square	Df	*P*-Value
Temperature	1.50	1	> 0.05
NDVI	0.52	1	> 0.05
Rainfall	0.05	1	> 0.05
Soil moisture	0.03	1	> 0.05
Elevation	0.00	1	> 0.05

investigated in Table 3. The respondent's responses regarding how they acquired the slaughtered cattle, the source of drinking water for their cattle as well as the tribes of the cattle holders were significantly associated with the *F. gigantica* infection. This study further confirmed that the type of pastures where the slaughtered cattle of the respondents grazed was not significantly associated with fascioliasis infection.

The climatic variables such as temperature, NDVI, rainfall, soil moisture and elevation were found to be associated with *F. gigantica* but not significantly as shown in Table 5.

3.4 Effects of Risk Factors on Fascioliasis Infection

The result of the binomial logistic regression is shown (in Table 6) explains the effects of risk factors on *F. gigantica* infection. All these factors were statistically significant ($P<0.05$) except gender ($P>0.05$). The Hosmer-Lemeshow test indicated that the model fitted the data well ($P=0.716$). Moreover, the analysis showed that the source of animals that is weather exotic or local was not related to an increased likelihood of *F. gigantica* infections (OR: 0.2734; 95% confidence interval CI: 0.1137-0.6570). Age of cattle more significant than 24 months was found to be more likely to fascioliasis infection (OR: 1.0498; 95% CI: 1.0305-1.0695) than the younger ones. The breed of cattle of being either white Fulani, Red Bororo and Sokoto Gudalewas associated with an increased likelihood of infection with *F. gigantica* (OR: 1.5934; 95% CI: 1.0641-2.3860). Male cattle were 0.6 times less likely to be infected with *F. gigantica* (OR: 0.6213; 95% CI: 0.3302-1.1688) than female cattle.

The likelihoods for *F. gigantica* infection due to the practices of cattle management were shownin Table 7. The ways the cattle were acquired either through inheritance, been purchased from the market or received as a gift was found to be related to increased probability of fascioliasis infection (OR: 1.9700; 95% CI: 1.3612-2.8510). Similarly, cattle belonging to Fulani were more likely to be infected with *F. gigantica* (OR: 3.1229; 95% CI: 1.7959-5.4303) than those cattle that belonged to Hausa/Zabarma ethnic groups. However, grazing areas and source of drinking water for cattle were found to be associated with decreased likelihood of infection with

Table 6. Slaughtered cattle characteristics and the likelihood of *F. gigantica* infection using binary logistic regression

Risk factors	Odds Ratio	95% Confidence Interval
Animal source	0.2734	(0.1137-0.6570)
Age	1.0498	(1.0305-1.0695)
Breed	1.5934	(1.0641-2.3860)
Gender	0.6213	(0.3302-1.1688) NS

Table 7. Practices of herd management and the likelihood of *F. gigantica* infection using binary logistic regression

Risk factors	Odds Ratio	95% Confidence Interval
Cattle/herd acquisition	1.9700	(1.3612-2.8510)
Grazing areas	0.8980	(0.5895-1.3679)
Water source	0.3539	(0.1696-0.7381)
Tribe	3.1229	(1.7959-5.4303)

Table 8. Climatic factors and the likelihood of *F. gigantica* infection using binary logistic regression

Risk factors	Odds Ratio	95% Confidence Interval
Temperature	0.7904	(0.5422-1.1520) NS
NDVI	0.1753	(0.0016-19.7182) NS
Rainfall	0.9993	(0.9929-1.0057) NS
Soil moisture	0.9963	(0.9531-1.0414) NS
Elevation	1.0004	(0.9796-1.0216) NS

F. gigantica (OR: 0.8980; 95% CI: 0.5895-1.3679) and (OR: 0.3539; 95% CI: 0.1696-0.7381) respectively. The model that used practices of cattle management associations with the likelihood of infections with *F. gigantic* was well fitted according to the Hosmer-Lemeshow test (P=0.644).

Climatic factors and their associations with the probability of infection with *F. gigantica*is shown in Table 8. Although the associations of all the variables in the model were not statistically significant (P>0.05), the data fitted the model as revealed by the Hosmer-Lemeshow test (P=0.984). Elevation has an association with increased likelihood of infection with *F. gigantica* infections (OR: 1.0004; 95% CI: 0.9796-1.0216). NDVI (at 95% confidence interval) indicated an increased likelihood of infection with fascioliasis ((OR: 0.1753; 95% CI: 0.0016-19.7182).

3.5 Discussion

This study presents the first efforts towards determining the prevalence and possible risk factors associated with the slaughtered cattle in Sokoto State, Nigeria. Not long ago, it has been reported by [24] and [25] that the conventional method of using drugs for the treatment of *F. gigantica* infection is no longer beneficial. This situation, therefore, demands to investigate risk determinants associated with the slaughtered cattle in order to design a more accurate way of decreasing the infection and for the improvement of meat quality.

The sedimentation technique employed by this study to test for the presence of *F. gigantica* parasite revealed 30.7% infection. This percentage is higher than 27.6% reported by [26] which was based on only one abattoir in Sokoto metropolis. The prevalence rates recorded by [18] in Adamawa was 21.8% and also in south eastern Nigeria [27] reported 26% which were all lower than the prevalence rate reported in this study. In Bauchi, north central Nigeria [28] reported 76.9 % and also [2] recorded 74.9% in Kwara state north-central Nigeria. These variations in prevalence may be due to environmental factors and animal density between the areas of study. Also, separate cattle management systems employed by different localities may have accounted for such differences [29]. The *F. gigantica* prevalence rate recorded in this research is higher than 26% obtained in the Sahelian area of Kenya by [30] but lower than 36.5% obtained in Uganda based on the study by [31] but almost similar to 31.7% reported by [32] in Zimbabwe.

Regarding age, the prevalence of *F. gigantica* infection was significantly more associated with older cattle then younger ones [33-37]. This finding may be due to a decrease in immunity to fascioliasis infection in respect of the older cattle and comparatively higher in younger ones. This view was supported by [38] and [39]. Also, studies by [17] and [40] reported that older cattle were more susceptible to *F.gigantica* infection due to prolonged exposure at regular grazing sites. Similar to this study, older cattle were found by [18] had higher *F. gigantica* infection rate than the younger slaughtered cattle in Adamawa state, north-eastern Nigeria. This type of findings was also reflected in Tanzania by [41] and Botswana by [42].

This study reveals that there is a statistically significant relationship between breeds of cattle and infection of *F. gigantica* in Sokoto State. Sokoto Gudale and Red Bororo were the most predominant breeds with higher prevalence rate. The variations in infection rate across different breeds may be attributed to physiology, immunology and genetics of each breed which according to [43] and [44] can influence 'resistance and resilience to *F. gigantica* infections'. Similar to the findings in this study Sokoto Gudale breed was having higher prevalence rates as reported by [26] in the abattoir of Sokoto metropolis. Contrary to our findings, Red Bororo had more infections then the other breeds in Adamawa by [18]. In Botswana, also various breeds of cattle indicated differences in fascioliasis infection tolerance as reported by Mochankana and Robertson [42].

Regarding the gender of the animals, in this study female cattle had a higher burden of *F. gigantica* infection (51.3%) than males (the bulls) (48.7%). Some reports in Nigeria by [44] and [45] were in agreement with our studies. [46] also recorded a higher prevalence of *F. gigantica* in cows than bulls in Egypt. This imbalance in infection rate among the female cattle was due to reproductive processes that tend to undermine their immunity to *F.gigantica* infection. This observation got support from [47] and [48]. In contrast to our findings in some abattoirs in Gwagwalada and Jalingo in northern Nigeria [49] and [50]respectively reported bulls were more susceptible to fascioliasis infection than the female cows.

Analysis of modes of acquiring the ownership of cattle as a risk factor has indicated inheritance as a most crucial predictor of *F. gigantica* in the study area. That is because the act of keeping cattle in Sokoto State is a traditional farming practice that has been passed on from successive generations using the same methods of management. Hence, exposure of cattle to the risk of infection would increase owing to the high illiteracy rate among the cattle owners as confirmed by this study (Table 1). A study in support of this observation was carried out by [51] who reported that the significant custodians of cattle in Nigeria have inadequate knowledge of risk determinants associated with animal diseases including *F. gigantica*. Similarly, tribe or ethnic background of the respondents proved to be a significant factor that has a high likelihood of increasing the risk of *F. gigantica* infections in Sokoto State. That is because Fulani ethnic group had the largest population of cattle not only in Sokoto State but the whole of Nigeria [52]. They are described as pastoralist [51] that are constantly on the move in search of water and grass for their animals. Even sedentary Fulani's (those that area settled permanently at one place) in the study area inhabit settlements where the primary sources of water for their livestock are ponds, streams, lakes and irrigation sites. These sites present appropriate conditions for gathering of animals in search of pasture and for drinking which eventually aids the transmission of fascioliasis. This situation has already been captured in a study by [53] and [54].

The fitness of the regression model used in this study has not only been limited to determinants of risk such as cattle characteristics, herd management and cattle holders' status in increasing the likelihood of cattle infection with *F.gigantica* but also climatic factors. The binomial regression model identified these climatic variables as important determinants of *F.gigantica* risks in the study area. Although these factors were statistically non-significant, the result reflects the advantage of biological characteristics as a more critical determinant of *F.gigantica* risk at individual cattle slaughtered at the abattoir. That is because some studies have demonstrated the significant roles of climatic and environmental conditions in influencing fascioliasis infection risks at different spatial units-local, regional and continental levels [55, 56-58]. Thus, the main conclusion of this study is that botic factors were more significantly affecting fascioliasis infections at individual slaughtered cattle at the abatoirs than abiotic factors. Similar to this study, [59] reported that there was a non significant relationship between climatic risk factors and fascioliasis infection among sheep and goats using the binary regression model in Thessaly, Greece.

4. CONCLUSION

This study has indicated the prevalence of *F. gigantica* infections in slaughtered cattle in Sokoto State using coprological analysis. However, other techniques of testing for the presence of fascioliasis include a haematological and seropositive analysis which were very useful indicators but outside the scope of our study. Other studies have applied these approaches [2, 59]. Regression techniques are an essential tool in species distribution modelling [60]. In that light, [61] and [62] added that new development in the study of diseases is to apply regression model to a specific area of study and then extrapolate the modelling predictions to a different area (s).

Given that, extrapolation of the result of this study should be done cautiously as even within the north-west ecological zone of Nigeria variations may exist regarding risk factors examined in the present study. Nigeria is a large country with diverse ecological conditions. Hence, there is a need for another study from the southern part in order to investigate potential risk factors affecting *F. gigantica* infections. Moreover, research on the influence of seasons on fascioliasis are limited [63,23] future studies should incorporate such significant directions. Nevertheless, the effects of the risk factors that were investigated using regression model in this study can be precious in designing effective control methods for *F. gigantica* prevention in slaughtered cattle in Nigeria.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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