



Arid Zone Journal of Basic and Applied Research
Faculty of Science, Borno State University
Maiduguri, Nigeria



Journal homepage: <https://www.azjournalbar.com>

Research Article

Haemoprevalence of Salmonellae Infections in Sheep in Maiduguri, Nigeria: A study Using Abattoir Samples

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ARTICLE INFO:

ABSTRACT

Keywords:

Haemoprevalence,
Salmonellae,
Sheep,
Abattoir,
Samples,
Maiduguri

A total of 329 comprising 192 of blood and 137 of faecal samples from sheep were examined for presence of salmonellae infections using abattoir samples. The prevalence of Salmonellae infections from both rams and ewes after screening blood samples were 2.0 (0.61%) and 5.0 (1.52%). Similarly screening of faecal samples from rams and ewes revealed the prevalence of 2.0 (0.61%) and 11.0 (3.34%) respectively. Antibiotic susceptibility testing revealed that all salmonellae were susceptible to Ciprofloxacin, Ofloxacin and Norfloxacin, and had intermediate sensitivity to Nitrofurantoin, Tetracyclines and Amoxicillin whereas the isolates were totally resistant to Gentamycin, Ampicillin, Chloramphenicol and Cefuroximes. Microbiological screening involved incubation in Selenite-F broth of blood sample and faecal samples at 37°C for 24 hours. A dense suspension of both emulsified blood and faecal samples was inoculated into brilliant green agar plates uniformly. The inoculum was plated out on the remainder of the plate surface area incubated at 37°C for 24 hours. Heavy inoculation of MacConkey agar plates yielded separate presumptive Salmonellae and *E-coli* colonies and the former was picked and streaked on to separate Mac Conkey agar plates and were incubated at 43°C for 24 hours. Biochemical tests for confirmation of Salmonellae followed incubation of presumptive Salmonellae colonies into kohns or Trippie Sugar Iron (TSI) agar. Agar diffusion method employed addition of broth culture on prepared MacConkey agar and impregnated antimicrobial disc were pressed down to achieve adequate contact and incubated for 48hours for zones of inhibition measured and interpreted as sensitive, intermediate or resistant. The studies affirmed that Salmonellae infections in sheep were common in Maiduguri although the prevalence rate was low. This might be attributed to the sample type screened. One of the constraints was lack of screening of equal sample sizes of blood and faeces. Observance of biosecurity measures with adequate provision of feeds and portable drinking water should be ensured

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INTRODUCTION

Salmonellae have been isolated from nearly all vertebrates, and infection has been associated with both animal and human diseases. Salmonellae infections in sheep have been recorded in most countries of the world. Human Salmonella infections in the United States have been estimated in millions annually. In some of these cases, foods of animal origin have been implicated as the source of the pathogen (APHIS, 2001). Although, Salmonellae infections are increasing worldwide but there are only few reports on Salmonella surveillance in African and other developing countries. This has made it difficult to estimate the actual burden of salmonellosis, especially in Africa (Saba *et al.*, 2013).

Many Salmonellae serovars have subsequently been associated with deaths and abortions in sheep in all parts of the world. The number of flocks affected annually is probably small, but within these flocks the losses may be high because many animals may be affected in any one outbreak. Other diseases may aggravate Salmonella infection in sheep. Vodas and Elitsina (1986) found that mixed infections with *S. abortus ovis* and *Chlamydia psittaci* were more severe than *S. abortus ovis* alone. Likewise, Linklater (1983) recorded the presence of *C. psittaci* during abortion outbreaks associated with *S. montevideo* and Sojka *et al.* (1983) found that *S. arizonae* (O61:k:1,5,7) was often associated with other disease conditions. Heavy dosing with zinc oxide as a prophylaxis against facial eczema has also precipitated Salmonella outbreaks in young sheep (Allworth *et al.*, 1985).

In range sheep, the commonest occurrence of salmonellosis is during times of drought, when the sheep are concentrated in small areas of grass, which become heavily contaminated by faeces. Linklater (1983) found that abortions caused by *S. montevideo* reached epidemic proportions during severe winter of 1982. This

necessitated supplementary feeding and subjected pregnant ewes to prolonged cold stress which also led to close congregation of sheep at high risk in early pregnancy. Radial spread probably took place by means of birds or other wild animals or by environmental contamination through watercourses. Hunter *et al.* (1976) found that *S. typhimurium* spread from infected sheep into nearby watercourses and infect animals drinking downstream.

The prevalence of food borne illnesses in developing countries is considerable and in most countries there is limited data through which the incidence of a particular diseases and trends can be assessed over time (Hentgest and Freter, 1961). In developing countries, Salmonellosis is an important food borne disease and accounts for the majority of all outbreaks of such disease cases, hospitalizations and deaths where the causative agents are identified. Emergency outbreaks that involve hundreds of cases can pose extremely difficult problems for public health authorities (John, 1987).

Contaminated raw meat is one of the main sources of food-borne illness (Bhandare *et al.*, 2007; Podpecan *et al.*, 2007). Cattle have been incriminated as reservoirs of Salmonella species. In meat animals (sheep, cattle and swine), Salmonella infection arises from intensive rearing practices and the use of contaminated feeds. Cross contamination of carcasses with Salmonella can also occur during slaughtering operations which may include harvest time such as transport, lairage, slaughter and dressing. Other sources of contamination may be at post-harvest time such as boning, processing, retail distribution, and preparation (Ejeta *et al.*, 2004). Angelachov (1964) considered that environmental factors, including poor feeding, appeared to be linked with the development of abortion caused by *S. abortus ovis*. Cooper (1967) has shown that starvation may activate latent infection and Baker *et al.* (1971)

commented that losses caused by *S. dublin* were reduced when the ewes were provided with extra feed prior to movement.

Transport can precipitate Salmonella infection in sheep and, in Australia, high mortality rates were associated with shipping sheep to the Middle East (Gardiner and Craig, 1970), although Higgs *et al.* (1993) concluded that inanition was probably the primary cause. A major concern is for people working with infected animals and there are many reports of shepherds and farmers becoming infected (Hunter *et al.*, 1976; Findlay, 1978; Spence and Westwood, 1978). It is also possible that meat, milk and milk products may be contaminated with Salmonella, but there have been no recent outbreaks in the UK associated with these vehicles.

Multidrug-resistant phenotypes have been increasingly described among Salmonella spp. worldwide (Gyels, 2008).

The prominent epidemiological factor is the common carrier status in animals, the absence of symptoms in the majority of infected animals and the technical difficulties in detecting such carriers before or during meat inspection which make them a continuing source of contamination of the environment and hence of animal products. A great number of mammals, birds and reptiles are responsible for the maintenance of the chains of infections (Hirsh *et al.*, 2004).

A rapidly growing industry of intensive animal production is accompanying the process of urbanization with all its environmental and behavioural changes. A proper assessment should be made of hazards due to Salmonellae infections under such conditions (Urlings, 1992). In rural area, the role of animals in the spread of Salmonellosis to man through food is perhaps less significant. However, animals live in close proximity or even together with man and could contaminate drinking water and the environment (Jones, 1992). In previous studies, D'Aoust in New York (1989) indicated that prevalence of

Salmonella ranges between 2% and 51.5% in sheep. Woldemariam *et al.* (2005) in Ethiopia reported prevalence of 2.8% in apparently healthy slaughtered sheep and Wassie (2004) found higher prevalence of Salmonella in sheep in Addis Ababa as 11.5%. Studies conducted in northern India revealed the prevalence of Salmonellosis in sheep meat as 5% (Yadav *et al.*, 2006).

A study was carried out for the isolation of Salmonellae infectious in and around Bangladesh Agriculture University campus by Karim and Gani from sheep during the period of November 2006 to May 2007. A total number of 63 rectal swabs were collected and out of these samples, 9 were identified as positive for Salmonellae. The present study therefore sought to determine the prevalence of Salmonellae infections in sheep in Maiduguri using abattoir samples. It was also part of the objectives to determine the most effective antibiotics that ought to be used for the treatment of salmonellae infections in sheep in Maiduguri and environs.

MATERIALS AND METHODS

Study Area

The study was carried out in Maiduguri which is also called Yerwa by its locals and is the capital of Borno State, Nigeria. Maiduguri lies between latitude 10.2⁰N and 13.4⁰ N and the longitude of 9.8⁰E and 14.4⁰E. Maiduguri is popularly called "Home of Peace" and the city sits along the seasonal Ngadda River which disappears into the Firki swamps in the areas around Lake Chad. Maiduguri was founded in 1907 as a military outpost by the British and has since grown rapidly with a population exceeding 1 million by 2007 (NPC 2009). Maiduguri harbours diverse tribes including Kanuri, Shuwa, Bura, and Fulani ethnic groups among others (Anonymous, 2007). The state covers an area of 69,436sq km and is the second largest state in the federation of Nigeria in terms of land mass. It is located in the Northern-eastern region of the country and occupies the greatest part of Lake Chad basin. It

shares border with republic of Niger to the North, Lake chad (Republic of Chad) to the North-east and Cameroon to the East. In the south and west it borders the Nigerian states of Adamawa Gombe and Yobe. The climate of the area is characterized by dry and wet seasons. The dry season lasts from October-April. The average annual temperature is about 28°C with

maximum of 45°C in March and minimum of 15°C during the dry harmattan season. The annual rainfall ranges from 750-1000mm (NiMET, 2022). Agriculture is the major occupation of the people and about 70% to 80% of the people engage in farming activities which is predominantly subsistence (NiMET, 2022).



Figure 1: Map of Borno State, Nigeria showing the location of the study area (Maiduguri Abattoir)

Sample Collection

Blood and faecal samples were collected before slaughter of sheep at the Maiduguri abattoir. The blood samples were collected in EDTA bottles and then placed into an ice pack to maintain viability during transportation and faecal samples were aseptically collected into sterile polythene bags. Both samples were carefully labeled and transported to the Veterinary Medicine laboratory in the University of Maiduguri for screening and analysis.

MATERIALS

The materials used for the study included: An autoclave that was used for sterilization of instruments employed for screening of salmonellae organisms. Hot air oven was used for media sterilization. Incubator was used during sample culture to provide the optimal temperature for salmonellae growth. Refrigerator was used for cool preservation of samples and reagents. Sensitive weighing

balance was used for measurement of reagents and solutes. Conical flask was used for preparation of various media and liquid reagents. Pasteur pipette was used for dispensing solutions and reagents. Measuring cylinder was also used for measurement of solutions and diluents. Disposable petri dishes were used as containers for various media preparations. Universal bottles were used as containers for media and broth preparations. Test tubes were also used for measurement of lower volumes of solutions and reagents. Aluminum foil was used as top cover for test tubes and conical flasks to guard against contaminations. Sterile hand gloves were used for protecting hands against corrosive substances and to avoid sample contamination. Masking tape was used for proper labeling of conical flasks, test tubes, universal bottles and sample bottles. Inoculating wire loop was used for streaking of samples for different culture media. Cotton wool was employed for sanitizing the

bench and for covering conical flask during incubation of samples. Distilled water was used as diluent and as universal solvent. Ethanol was used as disinfectant. Washing sponge was used for scrubbing during washing. Spirit lamp was used for sample screening. Antibiotic sensitivity disc was used for antibiotic sensitivity testing and sterile forceps were used for holding test tubes and equipment during sample processing.

Media Preparation

Selenite F broth

Selenite F broths was used as an enrichment media before inoculation of the sample onto a primary media. The constitution factor is 19g/L of water. Appropriate volume was prepared in a clean glass flask and sterilized under a pressure of 15mmHg and at temperature of 121 °C for 30 minutes. This was allowed to cool to a temperature of 40 - 45°C. It was then dispensed carefully into sterilized Bijou sample bottle (OIE, 2012).

MacConkey Agar (MCA)

Mac-Conkey Agar was used as a primary media. It was constituted at 54g/L of water in a clean glass flask and sterilized under a pressure of 15mmHg, a temperature of 121°C for 30 minutes, allowed to cool to a temperature of 55 - 60°C and poured gently into sterile Petri dishes (20ml/Petri dish). The poured media was then allowed to set and was dried in an incubator at a temperature of 40 - 42°C (OIE, 2012).

Brilliant Green Agar

This media was used as a selective media for salmonella. It was prepared at 58g/L of water in a clean glass flask, sterilized in an autoclave under a pressure of 15mmHg, a temperature of 121 °C for 30 minutes, allowed to cool to a temperature of 55 - 60°C and poured carefully into sterile Petri dishes (20ml/Petri dish). The poured media was then dried in incubator at a temperature of 40 - 42°C (OIE, 2012).

Nutrient Agar

This media was used as an enrichment media for the positive isolates before culturing for

antibiotic sensitivity test. It was prepared at 15g/L of water in a clean glass flask which was then sterilized in an autoclave at a pressure of 15mmHg, a temperature of 121°C for 30 minutes and allowed to cool to a temperature of 40 - 42°C and then gently dispensed into sterilized Bijou bottles (OIE, 2012).

Peptone Water

This media was used for antibiotic sensitivity testing. It was prepared at 28g/L of water in a clean glass flask, sterilized in an autoclave under a pressure of 15mmHg and at a temperature of 121°C for 30 minutes, allowed to cool to a temperature of 55°C - 60°C and gently poured onto sterile Petri dishes. This was allowed to set and was dried in an incubator at a temperature of 40°C - 42°C (OIE, 2012).

Procedure for isolation and identification of Salmonellae

One milliliter (1ml) of blood sample from each sheep was dispensed into selenite - F broth. The suspension was then incubated at 37°C for 24 hours as described by Fricker (1987). Similarly, a loopful of faecal samples were dispensed into selenite-F broth at the rate of 10g of the sample to 10 times the volume of the broth. The broth emulsifies the faecal samples forming a dense suspension as an enrichment broth. The enriched suspensions were then inoculated into brilliant green agar plates by first spreading a loopful of the former, uniformly over an area equivalent to one - fifth of the plate surface area. The inoculating loop was later flamed and cooled at the edge of the agar and recharged by rubbing it over the seeded area. The inoculum was then plated out on the remainder of the plate surface area without further flaming or recharging. The plates were then incubated at 37°C for 24 hours as described by Vassiliadis *et al.* (1981).

Heavy inoculation of Mac Conkey agar plates as selective media was expected to yield separate presumptive Salmonellae and *E-coli* colonies. The presumptive Salmonellae colonies were then picked with sterilized inoculating loop and

streaked on to separate Mac Conkey agar plates and were incubated at 43°C for 24 hours as described by Post (1993).

Biochemical test

Biochemical tests were carried out for confirmation for the presence of Salmonellae where all presumptive Salmonellae colonies were inoculated into kohns or Trippie Sugar Iron (TSI) agar using an inoculating needle. The inoculum was stab down through the butt, and the needle was pulled out and streaked up the slant and incubated at 37°C for 24 hours as described by Old, (1998); ISO (2002); Habtamu *et al.* (2011) and OIE (2012).

Antibacterial susceptibility test

Antibacterial Susceptibility test was carried out on all positive isolates using Nitrofurantoin (100mcg), Ciprofloxacin (5mcg), Tetracycline (50mcg), Norfloxacin (10mcg), Amoxicillin

(30mcg), Ofloxacin (5mcg), Chloramphenicol (10mcg), Cefuroxime (30mcg), Ampicillin (30mcg), Gentamycin (10mcg). Agar diffusion method was employed. Peptone water was prepared into sterilized universal bottles and inoculated with the isolates and incubated for 48hours at 37°C. After the incubation, 10 fold serial dilutions was carried out i.e. 1ml of the broth culture into 9mls of normal saline from tube 1 to tube 3 and 0.1ml of the broth culture was poured on prepared Mac Conkey agar and impregnated antimicrobial disc were placed using sterile forceps and pressed down to achieve adequate contact. These were then incubated for 48hours to observe for zones of inhibition which was measured to the nearest millimeter and interpreted as sensitive, intermediate or resistant as described by Cumming (1991).

Table 1: Types, Codes and Concentrations of Antibiotic Sensitivity Test Disc

ANTIBIOTICS	CODE	CONCENTRATIONS
Nitrofurantoin	N	100mcg
Ciprofloxacin	CIP	5mcg
Tetracycline	TE	50mcg
Norfloxacin	NB	10mcg
Amoxicillin	AX	30mcg
Ofloxacin	OF	5mcg
Chloramphenicol	C	10mcg
Cefuroxime	CF	30mcg
Ampicillin	AM	30mcg
Gentamycin	GN	10mcg

STATISTICAL ANALYSIS

The data generated was analyzed using simple descriptive statistics and presented as percentages of the variables as described by Bluman (2004).

RESULTS

A total of 329 comprising of 192 of blood samples and 137 of faecal samples was examined for detection of the presence of Salmonellae infections in sheep using abattoir materials. Of the total blood samples examined, 42(12.77%) represent the number of samples screened for detection of salmonellae infections in rams alone while 150(45.59%) were values of samples examined for detection of salmonellae infections in ewes alone. Similarly, the breakdown of a total of 137 faecal samples examined for detection of the prevalence of salmonellae infections in sheep was represented by 25(7.6%) of the total samples but for detection of salmonellae infections in rams alone while 112(34.04%) represents faecal samples screened for detection of the prevalence of salmonellae infections in ewes alone as were respectively represented in Table 2 below.

The overall prevalence of Salmonellae infections from the present study was 20(6.08%) cases following simultaneous screening of blood and faecal samples. Salmonellae isolates exclusively from blood samples screening alone was 7(2.13%) while exclusive screening of faecal samples alone revealed samples 13(3.95%) cases. Values representing detection of Salmonellae infections from rams and ewes following blood sample screening were 2.0 and 5.0 cases respectively accounting for the

prevalence of 0.61% and 1.52%. Similarly, the prevalence of salmonellae infections detected following faecal sample screening of rams and ewes were 2.0 and 11.0 cases and respectively accounting for 0.61% and 3.34% as shown in Table 3 below.

Preliminary microbiological examination of blood and faecal samples which revealed smooth, blue-gray, moist, circular and entire colonies indicates prevalence of Salmonellae. Presentation of red slant with a yellow butt that showed delayed blackening following H₂S production was one of the biochemical tests employed for confirmation for the presence of Salmonellae species. However, findings that revealed red rings suggesting presence of indole signified negative results. Fermentations of arabinose, glucose, trehalose and xylose and non-fermentation of lactose were sugar reactions used to further augment positive isolation of Salmonellae species.

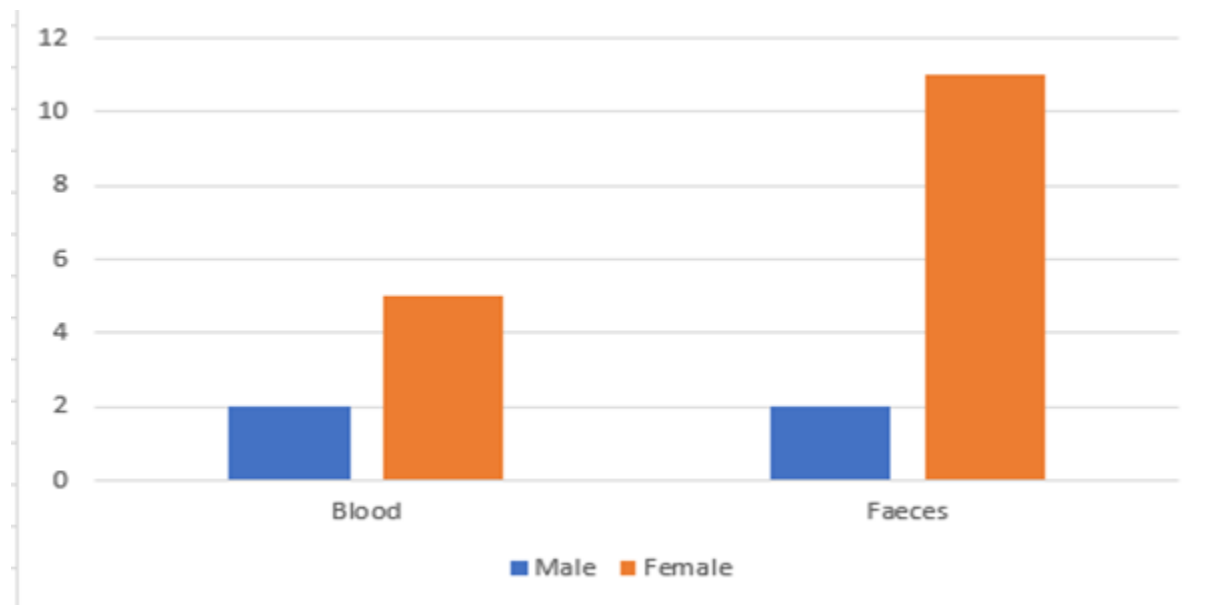
Microbial growth noted on some areas of agar during susceptibility testing was indicative of insensitivity of the isolates to the antibiotic at the area while zones of no growth recorded on antibiotics-impregnated disk coupled MacConkey agar plates was confirmatory that Salmonellae was sensitive to the antibiotics. It was established therefore, that Salmonella were more sensitive to Ciprofloxacin, Ofloxacin and Norfloxacin, and had intermediate sensitivity to Nitrofurantoin, Tetracyclines and Amoxicillin whereas the salmonellae isolates were totally resistant to Gentamycin, Ampicillin, Chloramphenicol and Cefuroxines.

Table 2: Blood and Faecal Samples Examined for Detection of Salmonellae Infections in Sheep in Maiduguri and Environs

S/No.	Types of Samples Examined	Samples Examined		Total
		Rams	Ewes	
1	Blood	42(12.77%)	150(45.59%)	192(58.36%)
2	Faeces	25(7.6%)	112(34.04%)	137(41.64%)
	Total	67(20.37%)	262(79.63%)	329

Table 3: Salmonellae infections detected from Blood and Faecal samples of Sheep from Maiduguri and Environs

Types of Samples Examined	Number of Salmonellae Positive Detection		Total
	Male	Female	
Blood	2(0.61%)	5(1.52%)	7(2.13%)
Faeces	2(0.61%)	11(3.34%)	13(3.95%)
Total	4(1.22%)	16(4.86%)	20 (6.08%)

**Figure 1:** Salmonellae infections in Blood and Faeces of Sheep from Maiduguri and environs

DISCUSSION

A total of 329 comprising of 192 of blood and 137 of faecal samples were examined for detection of the presence of Salmonellae infections in sheep using abattoir materials. An overall prevalence of 20 (6.08%) of Salmonellae infections was detected from the present study following simultaneous screening of blood and faecal samples. Although the findings of the present studies presented lower prevalence rate, it however fall within the range of values reported by D. Aoust (1989) who detected the prevalence of Salmonellae infections in sheep in New York, U.S.A. ranging from 2.0% to 51.5%. In the same context, the work of Woldemariam *et al.* (2005) who also reported similar but lower findings of salmonellae infections with the prevalence of 2.8% after examining apparently healthy slaughtered sheep in Ethiopia augment the higher findings of the present studies with the overall prevalence of 6.08%.

However, the work of Wassie (2004) from Addis Ababa, Ethiopia had a contrary representation as a high prevalence of 41.5% salmonellae infections was reported in sheep. Although the findings was by far higher than that recorded in the present studies, but still fall within the range given by the New York researchers and was not therefore the highest in terms of prevalence of salmonellae infection in sheep in the present context of comparison with other researchers on salmonellae infection in sheep across the globe.

On the contrary also, Yadav *et al.* (2006) reported a lower prevalence of 3.0% of salmonellae infection after analyzing meat sample in sheep in studies conducted in Northern India. This was typically a contrary finding of lower prevalence of salmonellae infection as compared with the findings of the present studies where the prevalence rate of 6.08% was recorded.

Similarly, Yan *et al.* (2003) have reported a contrary view of detection of 9.0 cases of

salmonella infections in sheep with a high prevalence of 14.3% following screening of 63 rectal swab samples from sheep collected in and around Bangladesh Agriculture University campus. Despite detection of lower cases of salmonellae infections after screening rectal swab samples, higher prevalence rate of 14.3% was recorded compared with that obtained in the present studies where as high as 13 faecal samples were screened for detection of salmonellae infection but lower prevalence of 3.95% was recorded and was attributed to overall larger sample size of 329 comprising of blood and faeces as was screened during the present studies.

Although the findings of Grimont and Weill (2007) was in tandem with that of the present studies were the prevalence of Salmonellae infections was recorded in sheep after examining blood and faecal samples, but there was more emphasis about the prevalence of the infection as food borne leading to illnesses such as diarrhoea and vomiting in humans after sheep meat consumption especially in developing countries rather than detection of the salmonellae infection in the blood and faecal samples as was done in the present study. A similar work by Ryan and Ray (2004) emphasized that Salmonellosis was an important food borne disease that accounted for majority of outbreaks in developing countries where in most cases where hospitalizations occur, deaths were the terminal consequences especially after establishing salmonellae species as the causative agents of the diseases. These assertions may be valid especially when inferences were deduced from the findings of the present studies that without adequate washing and disinfections of affected sheep carcasses, food borne outbreaks may ensure after consumption of salmonellae infected meat. Although there may be apprehension in considering the validity of the comparison because the research objective in the present studies was limited to only screening of

blood and faeces of sheep and not the carcasses and therefore had a narrow view when compared with the findings that emphasized food borne outbreak as reported by Ryan and Ray (2004). However considering a wider usage of sheep species as sources of food in larger communities in the developing countries and the relevance of blood and gastrointestinal tract as essential systems in sheep, the comparison still stands and remained valid. Ryan and Ray (2004) further emphasized that emergency outbreak involving hundreds of cases of Salmonellosis can pose extremely difficult problems for public health authorities.

Urlings *et al.* (1992) reported that hazards associated with Salmonellae infections do occur in rapidly growing intensive animal production industry associated with processes of urbanization and all environmental and behavioural changes that to lead compromised immunity in most sheep species and was therefore with the view that under such conditions proper assessment of such hazards of Salmonellae infections should be made. That was exactly what one of the objectives of the present study achieved after screening blood samples for the presence of salmonellae infections despite a known fact that salmonellosis is an enteric disease and although not higher detection was made but at least it was positive.

Jones, (1992) was however with a contrary view that the role of animals in the spread of salmonellosis to man through food is perhaps less significant. But it was obvious according to Jones (1992) that animals live in close proximity or even together with man especially in rural areas and could therefore contaminate drinking water and the environment. The later claim by Jones (1992) was a clear self-contradiction which supports the claims of the present studies that asserts that there are possible contamination of drinking water and abattoir environment leading to outbreaks of salmonellosis as up to

6.08% prevalence of Salmonellae infection was detected after screening blood and faecal samples of sheep.

One of the constraints of the work was lack of fair distribution of sample size between blood and faecal samples during screening and the values presented may not be a true representations of the actual prevalence rate.

CONCLUSION

The outcome of the present studies affirmed that Salmonella infections in sheep was a common occurrence in Maiduguri and environ, although the prevalence rate was lower compared to the findings of other researchers across the globe. This might be attributed to the type of samples screened and the period of sampling. However, despite the lower prevalence, the finding was still higher compared to that of other workers. Salmonellae infections may lead to salmonellosis and food borne diseases.

Despite the record of low prevalence, it is yet reasonable to suggest ways of minimizing the infection using the following recommendations: Good husbandry practices such as provision of portable drinking water, adequate feeds, sanitary abattoir practices by abattoir managements, butchers enlightenment on importance of good sanitation as well as personal hygiene and clearing and disinfection of operational tools should be ensured. Slaughter of ante-mortemly detected sick sheep should be done in isolation slaughter slab to avoid contamination of healthy carcasses. Strict hygiene during post slaughter operations such as transportation, handling of the beef by the distributors and the retailers/meat sellers may reduce Salmonella contamination in beef.

ACKNOWLEDGMENT

The cooperation of the management of Maiduguri abattoir was highly appreciated for given the permission to undertake the study. The cooperation of Veterinarians, Para-vets, butchers and all other persons that contributed in making the work successful was highly appreciated too.

AUTHORS CONTRIBUTIONS

All authors contributed equally to this work

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CONFLICT OF INTEREST

The authors have declared no conflict of interest

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