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The Epidemiology of *Coxiella* infections in Domestic Animals and Humans in Nigeria: A Review

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ABSTRACT

Q fever is a bacterial zoonotic disease caused by *Coxiella burnetii* with global epidemiology. Transmission of the disease in humans is mainly via inhalation of aerosolized bacteria and consumption of contaminated unpasteurized milk, while in animals it is through ingestion of contaminated pasture during grazing by susceptible animals. The disease is usually asymptomatic in animals, but has been implicated in abortion, stillbirths, endometritis, mastitis and infertility. In humans, it manifests as acute and chronic forms with the acute form having signs as self-limiting flu-like syndrome, pneumonia and hepatitis. Diagnosis is mainly through serology using ELISA, CFT, dot immunoblotting, and molecular assay. This study aimed at reviewing the literature to provide relevant information on the epidemiology and risk factors of *Coxiella* infection in Nigeria. The disease had been reported in all the geopolitical zones of Nigeria and it is said to have no breed, sex and age predisposition. Some of the risk factors identified to play vital roles in the epidemiology of the disease in Nigeria include husbandry and management practices, transboundary transfer of animals, poor hygiene at abattoirs as well as poor knowledge, attitude, and practices by livestock owners and abattoir personnel. It is recommended that there should be public enlightenment along with continuous education of stakeholders in the livestock industry on the significance of the disease.

Keywords: *Coxiella* infection; Epidemiology; Public health; Risk factors

INTRODUCTION

Coxiella infection, otherwise known as Query fever or simply Q fever, is a zoonotic disease caused by *Coxiella burnetii*(Sherry*et al*., 2019).*Coxiella burnetti* is an obligate intracellular Gram-negative bacterium that causes abortion in livestock and febrile illness in humans (Honarmand**,**2012).Marrie(1990) reported that it was first described by Edward Holbrook Derrick in abattoir workers in Brisbane, Queensland, Australia. The disease has been reported in humans in many parts of the world with reports in Australia and the Netherlands where the disease is being linked to cases of abortions in goat and sheep farms (Sherry *et al*., 2019).The disease is most commonly reported in southern France and Australia (Honarmand, 2012).The disease that has previously been considered as a regionally occurring disease has now been reported globally, with the disease being more common in tropical countries (Angelakis and Raoult, 2010; Epelboin *et al*., 2016; Eldin *et al*., 2017). Coxiella *burnetii* infects various hosts, including humans, ruminants (cattle, sheep, goats), and pets and, in rare cases, reptiles, birds, and ticks (Honarmand, 2012). The disease has been reported in cattle and buffaloes in Egypt (Higgins and Marrie, 1990; Nahed and Khaled, 2012).

The disease has also been reported cats in Canada with 6 to 20% of the cats having antibodies against *C. burnetii* (Higginsand Marrie, 1990). Wild rats have similarly been suspected as important reservoirs of *C burnettii* in Great Britain (Webster*et al.*, 1995). The disease has been reported to exist in New Zealand as over 3,500 human cases were recorded between 2007 and 2009 (van der Hoek *et al.,* 2010).

In Africa, the highest seropositivity rates were reported from areas with the highest density of cattle and these included Mali, Burkina Faso, Nigeria and Central African Republic (Tissot+Dupont *et al*., 2004). Furthermore, *C burnetii* infecti on has been detected in humans and in a wide range of animal species across Africa (Vanderburg *et al*., 2014). The disease has also been reported in Ghana, Cote d'Ivoire, Togo and Burkina Faso (Ki-Zerbo *et al*., 2000; Kobbe *et al*., 2008; Adu-Addai *et al*., 2012; Dean *et al*., 2013; Kanoute *et al*., 20 17).

In North Africa, the disease has been reported in Egypt with the disease in dogs, cattle, buffaloes, goats, sheep and humans (Corwin *et al*., 1993; Amal *et al*., 2002; Amin and Ahmed, 2009; Nahed and Khaled, 2012). The disease has similarly been reported in goats and sheep in Sudan by Hussien *et al.*

(2012).The disease has also been reported in Morocco and Tunisia in goats and sheep with animals having been reported to have abortion (Benkirane *et al.,* 1990; Rekiki *et al*., 2005; Berri *et al*., 2009).Human clinical cases of illness and endocarditis have similarly been reported in Tunisia (Omezzine-Letaief *et al*., 2004; Kaabia *et al.,* 2006; Znazen *et al*., 2009).In Algeria, the disease has mainly been reported in humans with endocarditis (Benslimani *et al.,* 2005).

The disease has similarly been reported in West Africa in a number of countries. For example, the disease has been reported in cattle in Nigeria (Adesiyun *et al.*, 1984; Adesiyun *et al*., 1985). Infection with *C. burnetii* in cattle has also been reported in Senegal and Ghana by Kamga-Waladjo *et al.* (2010) and Adu-Addai *et al*. (2012) respectively. *Coxiella* infection has also been reported in humans in Cote d'Ivoire, Burkina Faso, Niger Republic and Ghana (Gidel *et al.,* 1966; Gideland Athawet,1975; Julvez *et al*., 1997; Kobbe *et al.*, 2008; Sherry *et al.,* 2019). The disease has also been reported in Togo by Dean *et al*. (2013). In Central Africa, the disease has been reported in cattle that aborted and in humans that had pneumonia dueto *C burnett i*nfection (Maurice *et al*., 1968; Domenech *et al*., 1985; Koulla-Shiro *et al*., 1996; 1997).

In Southern Africa, the disease has been reported mainly in South Africa in cattle, sheep and humans with the sheep having reported to have abortions (Schutte *et al*., 1976; Gummow *et al*., 1987; Maartens *et al*., 1994).

In East Africa, the disease has been reported in Tanzania among pregnant women and those with febrile illnesses (Anstey *et al*., 1997; Prabhu *et al*., 2011). The disease has similarly been reported in Kenya (Nakeel *et al.,* 2016).

Q fever has been considered as a reportable disease in many countries including the United States of America (USA) as the organism causing the disease has been found in animals and man with clinical signs of the disease in animals being abortion and in humans, presenting as illness, pneumonia, endocarditis among others (Eldin *et al*., 2016; Pierre-Edouard *et al*., 1998; Vanderburg *et al.,* 2014).

The *Coxiella* organism

Coxiella burnetti was reported to have first been discovered in 1937, when Frank Macfarlane Burnet and Mavis Freeman isolated the bacterium from one of Derrick's patients (Burnet and Freeman, 1937). It was also originally identified as a species of *Rickettsia* when Cox and Davis isolated it from ticks in Montana, USA in 1938 (Davis and Cox, 1938). Now, the organism is no longer regarded as being related to Rickettsiae but as similar to *Legionella* and *Francisella*, and as a proteobacterium (Vanderburg *et al.,* 2014). The bacterium is a short and pleomorphic strictly intracellular bacillus which presents a variation of phase comparable to the smooth-rough variation described for the *Enterobacteriacae*. In nature, *C. burnetii* expresses only the phase I antigen (equivalent to the smooth phase) (Stocker and Fiset, 1956; Brezina, 1976). This phase is observed in infected humans, animals, and arthropods and represents the infectious form of the bacterium. The phase II variant is obtained after several passages in embryonated eggs or cell cultures and is less virulent. The reversion to phase I is made possible by inoculation of the bacterium into an animal host. In phase I, the lipopolysaccharide is present in its entire length, whereas in phase II, the lipopolysaccharide was seen to contain fewer sugars in the lateral chain. The reservoirs of *C. burnetii* include mammals, birds, and arthropods, mainly ticks (Maurin and Raoult, 1999).

Because of its sporelike-life cycle, *C. burnetii* can remain viable and virulent for months with infection from it being capable of being acquired via inhalation or skin contact. It should be noted that direct exposure to a ruminant is not necessary for infection (Honarmand, 2012).

Coxiella burnetii is considered to be one of the Category B agent of bioterrorism by the Centre for Disease Control (CDC) due to its route of transmission, low infective dose, high stability in the environment and prior weaponization (Kersh *et al*. 2013; Eldin *et al*. 2017).

Transmission

Humans become infected with *C. burnetii* through the inhalation of aerosolized bacteria and consumption of contaminated unpasteurized milk (Ratmanov *et al*., 2013). For example, an outbreak of human cases of Q fever reported in the Netherlands was linked to abortions in dairy goat and sheep farms (Angelakis andRaoult, 2010).

Transmission in humans can also take place through direct contact with milk, urine, faeces, and even through semen from infected animals as well as inhalation of aerosolized particles from animal placentas, parturient fluids, aborted foetuses, and environmental dust that must have been contaminated with the organisms (Fishbein and Raoult, 1992; Tissot-Dupont and Raoult, 2008). This is possible as the bacterium is excreted in urine, milk, faeces, and birth products (Tissot-Dupont and Raoult, 2008). These products, especially the birth products, have been reported to contain large amounts of the bacteria that can become aerosolized after drying. Because the organism is highly infectious, only a few organisms can cause disease following its introduction to a given area leading to severe outbreaks with untold public and economic consequences (Honarmand, 2012).

It has been reported that it is rare to see human-to-human transmission of the disease through exposure of the placenta of an infected woman, though blood transfusions have been reported to result in infections in recipient patients (Cutler *et al*., 2007). Sexual transmission has been reported to lead to the disease in humans (Domingo *et al.,* 1999). The bacterium has been demonstrated in milk of dairy and dual-purpose cows in Nigeria (Adesiyun *et al*., 1985). This means that the consumption of such contaminated milk can result in infection by humans and even calves with untold consequences. Similarly, this scenario could hamper the development of dairy industries if cattle with this infection will be used for the production of dairy products.

Clinical signs

The incubation period in humans has been estimated to be approximately 20 days with a range of between 14 and 39 days (Dupuis *et al*., 1987). The disease has acute and chronic forms with the acute form of the disease in humans having signs like self-limiting flu-like syndrome, pneumonia and hepatitis, though there are other manifestations of the disease (1973; Dupuis *et al*., 1987**;** Raoult, 1990**;** Lieberman *et al.,* 1995; Raoult *et al*., 2000). The chronic form of the disease, which may last for up to 6 months to one year, is seen after the acute phase of the disease (Raoult and Marrie 1995).

Human cases have similarly been reported to have non-productive cough, fever, and minimal auscultatory abnormalities, though others may present acute respiratory distress. Pleural effusion can also be present. Findings on the chest radiograph are nonspecific (Honarmand**,** 2012).

Patients with cardiovascular abnormalities during the acute stage are at risk of developing chronic infection (Stein, and Raoult**.** 1995; Fenollar *et al.,* 2001). Endocarditis is the most common feature seen in patients with chronic form of the disease, though vascular infections can also occur (Raoult, *et al.,*1986; Fournier *et al*., 1998; Brouqui, *et al*., 2001). Miscarriage and abortions have been reported as well (de Lange *et al*., 2015.

Clinical cases of Q fever have been reported among the military and paramilitary deployed to Iraq (White *et al*., 2013). Patients with underlying cardiac valve defects who get exposed to *C. burnetii* develop endocarditis or vascular infections (Wielders *et al*., 2015).

Infections in livestock caused by *C. burnetii* are usually asymptomatic, although the disease has been implicated in abortion, stillbirths, endometritis, mastitis and infertility (Radolakis *et al*., 2007; Angelakis and Raoult, 2010; OIE, 2013).

Diagnosis

Infections caused by *C. burnetii* in livestock are usually asymptomatic and as such all cases of abortions, stillbirths, endometritis, mastitis and infertility should have Q fever as one of the differentials for diagnosis (OIE, 2013).

Samples for laboratory diagnosis include blood, tissue samples, uterine discharges, aborted foetuses, placenta, milk and urine. Organs and tissues are used for histopathology as the disease is associated with the formation of granulomatous lesions most commonly involving the lungs, liver, and bone marrow (Fournier *et al*., 1998). He further reported that macroscopically, red or gray hepatization may be present within the liver cells. Microscopically, however, interstitial oedema and infiltration by lymphocytes and macrophages will be observed in the bone marrow. In the lungs, alveolar spaces will be filled with histiocytes, and intra-alveolar focal necrosis and haemorrhages (Fournier *et al*., 1998).

Blood samples can be used for culture, though they can be negative in most cases and there is the fear that the procedure is dangerous due to the possible acquiring of infection by laboratory personnel (Honarmand**,** 2012).It is possible to demonstrate the organisms in blood smears and frozen tissue (Honarmand**,** 2012).At histopathology, histopathologic changes consistent with doughnut granulomata are seen in the liver and bone marrow, but these are not specific for *C. burnetii* as they are also observed in cases of Hodgkin lymphoma, typhoid fever, cytomegalovirus infection, infectious mononucleosis, and allopurinol hypersensitivity (Honarmand**,** 2012).

Serology seems to be the best option, even because of possible dangers for laboratory technicians and other supportive staff. Serological tests commonly employed include the Indirect IgG Phase II ELISA as reported by Dean *et al.* (2013). This test has been reported to have sensitivity and specificity of 82.6% and 100% in cattle and 98% and 100% in humans respectively (Uhaa *et al*., 1994; Horigan *et al*., 2011). Another most promising serological test, the immunofluorescence assay which has been reported to be the reference test for the serodiagnosis of Q fever (Peacock *et al*., 1983). Another test, the Complement Fixation Test (CFT), that is very specific and is the second test after immunofluorescence assay test though it is less sensitive (Peter *et al*., 1985). The ELISA has been reported to be more specific and sensitive than CFT for the diagnosis of Q fever and has been recommended for use in seroepidemiological surveys of Q fever (Peter *et al*., 1987). Researchers like Peter *et al*. (1988) and Cowley *et al*. (1992) have demonstrated that ELISA is even more sensitive than the immunofluorescence assay and could serve for the serodiagnosis of Q fever. Some workers have also recommended Western immunoblotting for the diagnosis of Q fever (Blondeau *et al.,*1990a). However, Fournier *et al*. (1998) reported that in many cases the results were not reproducible and the test lacked specificity. Furthermore, Cowley *et al.* (1992) demonstrated that dot immunoblotting was as sensitive and as specific as ELISA and immunofluorescence assay but more sensitive than CFT. They also proposed this method as a screening test for the demonstration of Q fever infection in a given population.

Microagglutination test is another test that has been used for the diagnosis of Q fever and has been reported to be simple, sensitive and can detect an early antibody response to *C. burnetii* infection (Kazar *et al*., 1981). However, it has a major disadvantage when compared with other tests in that it requires large amounts of antigens. Similarly, Tokarevich *et al*. (1998) proposed the indirect haemolysis test as they reported it to be highly sensitive and specific and could serve for retesting chronic Q fever cases. Earlier on, Doller *et al*. (1984) proposed a radioimmunoassay for the diagnosis of Q fever.

Molecular biology has also been used in the diagnosis and surveys on Q fever. For example, LCN-PCR assay has been used for targeting a repetitive element sequence for the diagnosis of acute Q fever (Fournier and Raoult 2003; Fenollar *et al*., 2004). Similarly, Nested-PCR has been used as reported by Zeaiter *et al*.(2003).

Treatment and control

The disease, Q fever, is mainly treated in humans as in animals, it is mainly asymptomatic. In humans, treatment is by the use of doxycycline which is the first line treatment for all adults, and for children with severe illness (OIE, 2000). It should be noted that treatment should be initiated immediately whenever Q fever is suspected (Honarmand, 2012). He further noted that the use of antibiotics other than doxycycline or other tetracyclines is associated with a higher risk of severe illness. Doxycycline is most effective at preventing severe complications from developing if it is started early in the course of disease. Therefore, treatment must be based on clinical suspicion alone and should always be initiated before laboratory results return. If the patient is treated within the first 3 days of the disease, fever generally subsides within 72 hours. In fact, failure to respond to doxycycline suggests that the patient's condition might not be due to Q fever (Honarmand**,** 2012). Severely ill patients may require longer periods of treatment before their fever resolves. Resistance to doxycycline has not been documented (CDC, 2021).

Distribution of *Coxiella* species infections in Nigeria

Cociella infections have been reported in Nigeria by a number of researchers with the reports being mainly in animals. Such reports include those by Addo and Schnurenberger (1977), Blondeau *et al*. (1990b), Adamu *et al.* (2018; 2021), Tukur *et al*. (2014) and Cadmus *et al*. (2020) with the report by Addo and Schnurenberger (1977), seemingly being the first report in Nigeria. These and other reports indicated that *Coxiella* infections were in pastoralist cattle, dairy cattle, sheep, goats and even humans. It is only recently that researchers developed interest in the disease. It might have been that clinicians in both Veterinary and Medical lines might have come across it but due to poor diagnostic aids, the disease has not been fully recognized.

Distribution of Q fever in North Western Nigeria

Report of serological studies on the disease in sheep in Kaduna State has been made by Adamu *et al*. (2021), they found 8.0% of the sera to be seropositive for Q fever by iELISA. Similarly, Cadmus *et al*. (2021) reported seroprevalence of the disease in cattle and humans in Sokoto State They also reported seroprevalences of Q fever as being 62.57% (95%CI: 54.04–70.46%) and 2.98% (95%CI: 1.57–5.58%) for pastoralists and their cattle, respectively. They also reported co-infections of brucellosis and Q fever in both cattle and humans. Similarly, Adamu *et al.* (2018), in a seroprevalence study of brucellosis and Q fever infections reported an overall seroprevalence of6.2% by iELISA during a study on the disease in Maigama and Birnin Gwari Local Government Areas of Kaduna State, Nigeria. Blondeau *et al*.(1990a) have also reported the existence of Q fever in Sokoto State, Nigeria. Addo and Schnurenberger (1977) reported Q fever prevalence of 11.0% in slaughtered cattle from Samaru, Zaria and Kaduna abattoirs and from Bauchi meat processing plant.They also reported the presence of the organisms in sheep and goats. Furthermore, Adesiyun *et al.* (1984) also reported a prevalence of 59.8% in some dairy cows and their suckling calves in Zaria. In a similar study, Tukur *et al.* (2014) reported evidence of *C. burnetii* infection with a seroprevalence of 14.5% in dairy cows in Kaduna Metropolis. They also reported that 57.1% of the herds examined were positive for *C burnetii*.

Distribution in North Eastern Nigeria

In a study of the prevalence of Q fever in sheep in Yobe State, Adamu *et al.* (2019) reported that out of the 420 sera from the sheep tested 49 (11.7%) were seropositive for Q fever. Elelu *et al.* (2020) reported the seroprevalence of Q fever in cattle in Borno State to be 5.56%.

Distribution in North Central Nigeria

Report of the disease in the North Central Geopolitical zone of Nigeria seems to be scanty. However, the disease has been reported in cattle and small ruminants in Plateau and Kwara States by Elelu *et al.* (2020). They reported that the seroprevalence in cattle in Plateau State was 9.43% while the seroprevalence in small ruminants in Kwara State was 3.3%.

Distribution in South Western Nigeria

Work on the disease by researchers in the South Western geopolitical zone of Nigeria also seems to be scanty. Cadmus *et al*. (2020) reported conducting seroprevalence studies on brucellosis and Q-fever in cattle from Ibarapa area of Oyo State and found that 11.4% and 6.7% of the cattle were seropositive by RBPT and cELISA respectively for brucellosis and 23.5% were seropositive by iELISA for Q-fever. This shows that there were possible mixed infections of the cattle with *Brucella* spp and *Coxiella burnetii*.

Distribution in South Eastern Nigeria

Search for evidences of reports on Q fever infection in the South Eastern geopolitical zone of Nigeria could not reveal any report on the disease. It could be the disease exists but workers might not have put any interest on the disease. Another reason could be that the researchers and their students in the academic institutions in the zone have not found it appropriate to dwell in such a vital area seeing the public health importance of the disease. Furthermore, the economics of sponsoring for research, even by postgraduate students is, in many cases deterring, especially in sourcing reagents, kits and such other inputs for research.

Distribution in South Southern Nigeria

Similarly, efforts to document the existence of the disease, Q fever, in this zone could not yield any positive results. In the zones where no report of the disease was obtained, the reasons, in addition to those advanced above, could be due to the lack of interest and commitment by Government authorities to commit funds for research as researchers in academic institutions and elsewhere have to source for funds themselves to conduct research. In addition, clinicians at both Veterinary and human clinics might not have the facilities for samples collection and processing, and that some of them even if they take appropriate samples, laboratories might not have the facilities to examine such samples.

***Coxiella burnetii* infection in animals**

The main clinical manifestations in ruminants are reproductive disorders such as infertility, stillbirth, abortion, endometritis, and mastitis (CFSPH, 2007; EFSA, 2010; Asadi *et al.,* 2013). Disease in animals has been characterized by abortion (Weir *et al.,* 1984; Behymer and Riemann, 1989; Zeman *et al.,* 1989). There does not seem to be any documentation of any clinical disease by way of abortion cases due to *C burnetii* in Nigeria and this could be due to the reasons advanced above. The existence of the disease in horses has also been reported, at least, in Iran (Khademi *et al*., 2020).

***Coxiella burnetii* infection in man**

Some studies have shown more men to be affected than women (CDC, 1999; Domingo *et al.,* 1999). In Nigeria, a report on the seroepidemiological investigation of Q fever uncovered a high prevalence of 44% among hospitalized patients (Blondeau *et al*., 1990b). Among the pastoralists, the apparent and adjusted seroprevalence for Q fever were 61.31% (84/137; 95% CI: 52.96–69.05%) and 62.57% (95% CI: 54.04–70.46%), respectively and that 84 of the infected pastoralists had links with the 18 of the 27 cattle herds screened (Cadmus *et al*., 2021).

A study in Iran demonstrated 68% of the samples from humans to be positive for Q fever (Khalili *et al*., 2014). They demonstrated that the disease increased in prevalence with the increase in age of humans. They also showed that the earlier

an individual became engaged in a livestock holding the greater the prevalence and that they clearly demonstrated that *C. burnetii* phase II antibody was more prevalent in slaughterhouse workers. In another study in Iran on Q fever serology Khalili *et al.* (2010) demonstrated that 24% and 36% of the patients had phase I and phase II antibodies, respectively among the 75 febrile patients examined using ELISA technique. Yet in another study still in Zahedan, Southeastern Iran, 35.2% and 34.3% febrile patients had a positive serology test (IFA test) for acute Q fever and past infection (Metanat *et al*., 2014).

Studies in other countries like Turkey demonstrated 13.5% persons sampled to be positive for Q fever in otherwise healthy people (Gozalan *et al.,* 2010).

Epidemiological factors for *Coxiella* species infection in Nigeria

Coxiella Infection in Cattle

Coxiella infection in cattle has been reported in Nigeria by many workers that include Adesiyun *et al*. (1984); Johnson *et al*. (2019) and Cadmus *et al.* (2021). Cadmus *et al*. (2021) reported the apparent and adjusted individual seroprevalence of 2.46% (9/366; 95% CI: 1.30–4.61%) and 2.98% (95% CI: 1.57–5.58%) for Q fever amongst cattle, respectively by using iELISA. Johnson *et al*. (2019) reported seroprevalence of 22.0% (45/204) for cattle. Earlier on, Adesiyun *et al*. (1984) demonstrated Q fever antibodies among dairy cattle and their suckling calves in Zaria.

Coxiella infection in sheep and goats

Johnson *et al*. (2019), in a study to determine the seroprevalence of Q fever in small ruminants in Nigeria reported an overall prevalence of 21.4% among the farms sampled. They further reported that species-specific prevalence was 28.4% (45/158) for sheep, and 10.0% (10/100) for goats. Similarly, Adamu *et al*. (2021) reported seroprevalence of 8.0% in goats by using iELISA. Earlier on, Adamu *et al.* (2019) reported a seroprevalence of 12.3% in Yankasa sheep and 9.9% in Uda sheep in Yobe State.

Coxiella Infection in dogs, cats and wildlife

There does not seem to be any reports of cats and dogs being infected with *C. burnetii* in Nigeria. However, there are reports of the disease in these animals and even in rabbits elsewhere in the world (Cooper *et al*., 2013). Similarly, rabbits, and dogs, have also been demonstrated to be potential sources of urban outbreaks of Q fever infections. Cats have also been suspected as important reservoir hosts of *C. burnetii* in urban areas and potential for facilitating zoonotic disease due to *C burnetii* in such settings (Langley *et al*., 1988; Marrie *et al.,* 1988; Morita *et al*., 1994).

Sex predisposition in *Coxiella* species infection

In a study of the seroprevalence of Q fever infection in small ruminants in Nigeria, Adamu *et al*. (2019) reported that 39 (12.4%) out of the 315 female sheep tested were seropositive and that of the 105 male sheep tested, 10 (9.5%) were seropositive for Q fever and observed that there was no significant association ($p>0.05$) between the sex of sheep tested for Q fever.

Age predisposition in *Coxiella* species infection

The study by Adamu *et al*. (2019) on Q fever in sheep showed that the seroprevalence was high in that there was no significant association between age and the infection with Q-fever. Similarly, Tukur *et al*. (2014) reported that the disease was more prevalent in cattle older than 3 years (12.1%) than in cattle less than 2 years (9.8%). The greater prevalence in older animals could be due to longer exposure potentials and the fact that these animals could have greater chances of mixing with infected animals, especially due to the extensive nature of the animal husbandry system in Nigeria.

Breed predisposition in *Coxiella* species infection

In a study of the prevalence of Q fever in cattle, Johnson *et al.* (2019) reported that breed-specific prevalence was 24.3% for West African Short Horn (WASH), 25.0% for Gudali and 26.7% for crossbreeds and they observed that there was no statistical difference between breed of cattle and breed-specific prevalence. Although, Cadmus *et al*. (2020) in a study of *Brucella* infection and Q fever infection in cattle in Oyo State found a significant association between breed (OR=6.69; 95% CI: 1.7-28.74), herd size (OR=4.25; 95% CI: 1.31-13.85) of cattle and seropositivity to *Coxiella burnetii* infection. Elsewhere in Prince Edward Island, Higgins and Marrie (1990) used the indirect micro immunofluorescence test to determine the presence of antibodies to phase I and phase II Coxiella burnetii antigens in New Brunswick and Prince Edward Island cats. Twenty of 104 (19.2%) New Brunswick cats tested had antibodies to phase II antigen; five of these (4.8%) also had antibodies to phase I antigen. Six of 97 (6.2%) Prince Edward Island cats tested had antibodies to phase I and phase II antigens. They reported that their data suggest that cats may be important in the epidemiology of Q fever in these provinces. Tukur *et al*. (2014), in a study on the epidemiology of Q fever infection in cattle in Kaduna State, Nigeria reported that 1.3% of the cross breeds under the study were positive while none of the exotic cattle was positive for *C burnetii*.

Public health risk factors in *Coxiella* infection in Nigeria (HU)

Risk factors to *Coxiella* infection in humans

The nature of the livestock husbandry and management practices in Nigeria and other African countries can be said to facilitate the occurrence and spread of Q fever infections in both animals and humans. For example, in Ghana, Johnson *et al.* (2019) while studying on the disease in cattle farms reported children being seen assisting in herding of cattle for grazing just as it occurs in Nigeria and other West African countries. They reported the mean (±SD) distance between the kraals of the cattle and living quarters of the farm hands to be129.3 ± 52.2 m while the mean (SD) distance between human settlement and the housing of sheep and goat pens to be 63.8 ± 7.9m. Similarly, Kaltungo (2018a; 2018b) while conducting studies on the epidemiology of brucellosis in small ruminants in Sokoto and Katsina States and in camels in Katsina State, Nigeria reported close habitation between small ruminants and camels housing and those of the owners.

Similarly, Kaltungo (2013; 2018a), Buhari (2014) and Johnson *et al.* (2019) reported pastoralists handling foetal

membranes and aborted materials for disposal at nearby dumping grounds. Furthermore Kaltungo (2018a) and Johnson *et al.* (2019) reported that respondents were involved in lifting the aborted materials with plastic bags or bare hands for disposal. Not only that, chances of contaminating grazing areas are high as Johnson *et al.* (2019) indicated 10.5% of their respondents reporting their animals aborting at grazing grounds and they were leaving the aborted materials at the grazing areas. Similarly, Madaki (2021) reported chickens picking on aborted foetal membranes in pastoralists herds in Yobe state, Nigeria and should the cattle that aborted were infected with *C. burnetti*, spread of the infection could occur in these chickens and even humans due to poor unsanitary measures taken in the processing of these chickens by house wives and commercial 'suya' sellers. All these are good avenues for the discharge and spread of *C burnetii* should the animals be infected.

Another source of infection for humans is the habit of allowing different herds and flocks to meet at grazing and watering points without restriction and the high chances of mixing freely (Kaltungo, 2018a; Buhari, 2019; Madaki, 2021). Thus, should any of the animals that is infected passesurine or faeces, such wastes can be easy sources of transmission of infection to other animals from the other herds or flocks and subsequent transfer of the infection to humans due to the traditional way of herding, milking and handling of the animals. The keeping of more than one animal species per household, especially by pastoralists can result in high chances of infections in humans. For example, Johnson *et al.* (2019) reported farms keeping, cats, fowls and dogs including cattle and small ruminants.

Knowledge, attitude and practices of livestock owners with regard to *Coxiella* infection

Many diseases, especially zoonotic ones, seem to be unknown by both livestock owners and pastoralists in Nigeria as Saidu *et al.* (1991) reported pastoralists considering any reason for their animals to lose weight as 'Samore' which is easily translated as trypanosomosis. Thus, Johnson *et al*. (2019) in Ghana found it difficult to enquire deeply on Q fever among farmers and certain categories of Veterinary staff. In Nigeria, Cadmus *et al.* (2021) also found 93.0% of the respondents to have poor knowledge of the definition, clinical signs and prevention of Q fever. They also found about 7% of these respondents to believe that people infected with Q fever could be quarantined. Furthermore, Cadmus *et al.* (2021) reported that 8.9%of these respondents disagreed that a person with suspected brucellosis or Q fever infection was still a potential source of danger to other pastoralists even after treatment. About 89.9% of the respondents had a poor perception of prevention against Q fever. Similarly, Tukur *et al*. (2014), in a study to determine the prevalence and knowledge of pastoralists on Q fever in cattle in the Kaduna Metropolis reported that 95% of the pastoralists were not aware of the disease and that only 31.0% of them were in a habit of boiling their milk before consumption.

With regard to practices in the handling of animals, many of the pastoralists and even abattoir workers do not consider it important to wear personal protective clothing when working with their animals (Kaltungo, 2018a; Baba, 2019; Buhari, 2019; Cadmus *et al.,* 2021; Madaki, 2021).

In Nigeria, Cadmus *et al*. (2021) reported that almost 93.0% of the respondents had poor knowledge of the definition, clinical signs and prevention of Q fever. About 7% believed that people infected with Q fever can be quarantined, 80.4% were indifferent as to whether the infections could be completely cured in an infected human or animal. Again, 8.9% disagreed that a person with suspected brucellosis or Q fever infection was still a potential source of danger to other pastoralists even after treatment. About 89.9% of the respondents had a poor perception of the prevention against Q fever.

By way of practice, 89.3% of respondents did not consider it important to wear personal protective clothing when working. Similarly, only 1.8% would use protective equipment while attending to their sick herds and 83.9% had never worn protective equipment. Another practice by pastoralists that could trigger transmission of Q fever among them and even to consumers who buy unpasteurized milk from them is the traditional milking methods without boiling (Buhari, 2014). Not only that it is the tradition of pastoralists to drink milk directly from the udder of their animals, should such animals be infected with *C. burnetii*, there is every chance for them to be infected. In the process they can transfer such infections to consumers who come to buy milk from them as there is no practice of regular washing of hands during milking, processing to soured milk and their sale of milk.

Livestock husbandry and management systems with regard to *Coxiella* infection in Nigeria

Tukur *et al*. (2014), in a study to determine the seroprevalence of *C. burnetii* in cattle in Kaduna metropolis, reported that cattle with no ectoparasites control programme had higher seroprevalence against *C. burnetii* and that exotic breeds of cattle were negative for Q fever antibodies as they were suspected of having strict external parasites control. Furthermore, Danbirni *et al*. (2018) reported that the major cattle management system they observed in Soba Local Government Area of Kaduna State was the pastoral husbandry system in which cattle were extensively grazed on wild forages and this exposed the cattle and even the small ruminants under their control to various arthropod vectors of haemoparasites, bacterial and viral disease among others. Similarly, Kaltungo (2013; 2018a 2018b) reported pastoralists and small ruminant holders keeping their livestock under traditional methods with herds and flocks from neighbours mixing freely. They also reported these pastoralists and other livestock owners exchange breeding sires and adding new animals immediately without the necessary quarantine to prevent introduction of diseases. All these actions are capable of introducing *C. burnetii* just like for introducing other diseases like Brucellosis. Adamu *et al.* (2019) reported co-infection of *Brucella* sp with *C. burnetii* in Nigeria.

The attitude and practices of pastoralists and rural small ruminant owners on diseases is very much left to be desired as Buhari (2014; 2019), Yakubu (2016) and a host of other researchers in Nigeria have reported them throwing away aborted foetuses and placenta as well as giving their dogs and local chickens to feed on. These attitude and practices are capable of spreading Q fever organisms to far distances with subsequent infection in other animals. This is especially that

the organisms have been reported to survive in dusts (Adesiyun *et al*., 1985; Vanderburg *et al.*, 2014).

The method of milking cows by pastoralists in Nigeria encourages the development and spread of diseases, Q fever inclusive, as they use bare hands and move from one animal to another without washing their hands (Kaltungo, 2013; Buhari, 2014). In such cases the pastoralists are capable of being infected themselves with the organisms since there are evidences that the organisms can be present in milk. These authors also reported the pastoralists and their children sucking milk directly from the udder of their animals. Should such animals be infected with *C. burnetii* as reported by Adesiyun *et al*. (1985) such individuals can easily contract the infection. The mixing of different species of animals at grazing, watering and during migration as reported by Kaltungo (2018a; 2018b) and Baba (2019) can surely result in multiple infections and spread of the disease if present.

Role of abattoir management practices in spread of Q fever

The nature of the operations in Nigerian abattoirs and other slaughter facilities are ripe as to encourage the transmission and spread of diseases including Q fever to the operators and their families, friends, parents and even buyers as Lawan *et al.* (2010). Nwanta *et al.* (2008) and Ibrahim *et al*. (2021) reported poor environmental facilities and inadequate management processes that are capable of transferring infectious agents from the carcasses to the operators and customers alike. These researchers reported that most of the abattoir operators were not using Personal Protective Equipment and allowed dogs and cats to frequent the abattoirs and, in the process, take condemned parts to far distances.

Economic and Public Health importance of *Coxiella* infections in Nigeria

Even though there does seem to be any report of birds transmitting Q fever to humans, their roles in spreading the disease through dragging aborted foetuses and placenta has been abundantly speculated Johnson et al., 2019. Thus, this singular act can result in the spread of the disease through chicken in pastoralists' herds and in rural settings with subsequent infections in both humans and livestock since Adesiyun *et al*. (1985) reported that the organisms could remain in dust for some time.

The occurrence of abortions, still birth, weak offspring among other effects of Q fever in animals all translate to economic losses as animals that abort will lose the cost of feeds it took for the period of its pregnancy along with the cost of maintenance and lack of milk that could be used for sale to add to the family income for a number of months.

With regard to public health effects, even though there does seem to be any documented human infections in Nigeria, should any person become infected, it could result to loss of lives involving the patient and those taking care of him, cost of diagnosis and medication among others.

Conflict of Interests

The authors have no conflict of interest to declare.

Authors' Contribution

BAY, SSNA, KBY, IS and BUH conceptualized the work. BAY and SSNA prepared the draft manuscript. All authors have read and approved the final manuscript.

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