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Prevalence of mastitis in Nigerian livestock: a Review

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Abstract: Mastitis is a disease of livestock that directly impede livestock production and thus hindering the socio-ecological development of sub-Saharan Africa. Studies have estimated the prevalence of this disease in 30% of Africa countries, with Ethiopia having the highest prevalence. The coverage is low, despite the wide livestock and dairy farms distribution in Africa. Furthermore, estimated economic losses due to the impact of mastitis are lacking in Nigeria. The disease is endemic in Nigeria as indicated by the available data and there are no proposed management plans or control strategies. This review is thus presented to serve as a wakeup call to all parties involved to intensify efforts towards the diagnosis, control, and management of the disease in Nigeria.

Keywords: Mastitis, Livestock, somatic cell count, Nigeria

1 Introduction

Mastitis is the inflammation of the parenchyma in the mammary gland of livestock. The disease is endemic and can affect all lactating animals [1]. The Most isolated pathogens include *Staphylococcus* spp, *Streptococcus* spp, *E. coli*, and *Pasteurella* spp [2]. The impact of mastitis on a community is as a result of the complex interplay between management practice and infectious agents, in addition to other factors,

such as genetics, udder shape, or climate. [3, 4]. Recently, it was estimated that Nigeria has 18.4 million cattle, 76 million goats, 43.4 million sheep with relative numbers of cattle used for beef and milk production amounting to 3.38 million and 2.27 million heads respectively [5]. However, the majority of this livestock is at risk of mastitis because of the milking procedure and the unhygienic housing conditions. The economic impact of the disease is greatly influenced by direct and indirect losses. Depending on the severity of the disease, mastitis causes significant economic losses to the dairy industry in terms of reduced milk production and quality, an increased risk of culling of infected animals, increased veterinary costs and deaths [6, 7] Mastitis can be classified as clinical or subclinical. In infected animals, clinical mastitis shows signs of inflammation such as redness, heat, pain, and swollen udder [8]. Additionally, there are visible deformities in the milk like clots, abnormal color, flakes, and blood [9]. Sub-clinical mastitis does not show visible signs but is commonly noticed by elevation of somatic cell count (SCC) by California Mastitis Test (CMT). Generally, the programs for controlling mastitis are lacking, meanwhile the knowledge and awareness of risk factors and attributes of mastitis-causing pathogens are paramount to control the widespread of the disease at the farm level. However, the application of SCC as a means of milk quality control and udder health in industrialized countries has increased, this method is yet to be adopted in many countries in the tropics [7]. In Nigeria and most of the developing countries, there is a lack of information on the economic impact of the disease, lack of awareness among farmers concerning sub-clinical mastitis and the importance of udder health, and lack of a specific national program to control mastitis. Thus, it is imperative to regularly appraise the status of the disease so as to present holistic data to plan a control or management program as presented for Nigeria in this report.

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1.1 Location and environment

Nigeria has an area of 923,768 km² with 36 states and the Federal Capital Territory (FCT), Abuja. These states are further grouped into six geopolitical zones (North-West, North-East, North-Central, South-East, South-South, and South-West) (see Fig. 1). The pattern in the rainfall received by various states is such that the north receives less rainfall with a shorter wet season than the south. Also, Nigeria can be zoned latitudinally into Guinea (South: 8°N) [Lagos, Oyo, Ekiti, Osun, Ondo, Edo, Delta, Bayelsa, Abia, Ebonyi, Anambra, Rivers, Imo, Enugu, Cross River, Akwa Ibom states]; Savanna [Plateau, Kaduna, Bauchi, Kwara, Niger, Nasarawa, Taraba, Adamawa, Gombe, Benue and Kogi state and Abuja (8-11°N)]; and Sahel (farther North: 11-16°N) [Kebbi, Sokoto, Zamfara, Kastina, Kano, Jigawa, Borno, Gombe, and Yobe states] [10]. The annual rainfall ranges from 1400 to 2700 mm in the Guinean zone, 950- 1400 mm (Savanna zone), and 450-1050 mm (Sahelian zone) [11]. The rainfall pattern is monomodal for Savanna and Sahel and bi-modal for Guinea. In April, there is sufficient rainfall that marks the start of agriculture activities in Nigeria peaking between August and September in Sahel

and Savanna; while in Guinea, the first peak is in July followed by a short break in August, then the second peak in September. The dominant vegetation types range from the dense mangroves of the Niger Delta and the rain forest of the south to the dry grassland of the north. Nigeria's climatic and environmental conditions predispose to the spread of mastitis.

Several species of common bacteria, fungi, mycoplasmas, and algae cause mastitis meanwhile mastitis due to bacterial pathogens accounts for most cases [12]. Mastitis pathogens are grouped as contagious or environmental [13]. The Contagious forms such as *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma* spp, and *Corynebacterium bovis* live and multiply on and in the cow's mammary gland and are spread from cow to cow during milking [14]. Environmental mastitis is an intra-mammary infection (IMI) caused by pathogens whose primary reservoir is the environment in which the cow lives [15]. Some of the well-known environmental isolated mastitis pathogens include *Streptococci uberis* and *Streptococci disgalatae*. Also, some gram-negative bacteria like *Escherichia coli*, *Klebsiella* spp, and *Enterobacter* spp are environmentally isolated [16].

Figure 1 Map of Nigeria indicating areas of Mastitis survey on livestock

Mycoplasma species show some differences in transmission, thus a brief discussion is warranted. Mycoplasma is responsible for many diseases in cattle, including respiratory disorders, otitis media, arthritis and mastitis. Mycoplasma was first isolated from mastitic cows in the USA in 1961, originally named *Mycoplasma agalactiae* var. *bovis* due to the similarities in biochemical, immunological and genetic features it shares with the small ruminant pathogen *M. agalactiae* [17]. Among the 200 species of Mycoplasma discovered to date, *M. bovis*, *M. arginine*, *M. dispar*, *M. canadense*, *M. bovoculi*, and *Mycoplasma* spp bovine groups 7 and F-38 have been reported to be involved in bovine mastitis [13, 18]. Mastitis caused by mycoplasma is less common than those caused by other bacteria, and it has been implicated in causing severe udder disease and has a distinct epidemiology accompanied with a peculiar set of risk factors [19]. However, in Nigeria Egwu et al. [20] reported mycoplasma mastitis in goat, species identified includes *M. agalactiae*, *M. capriolum*, *M. mycoides*, and *M. bovis*. The treatment for this form of mastitis is unrewarding due to the following reasons: Firstly, mycoplasmas are resistant to penicillin and cephalosporins. Secondly, over the last two decades, in vitro resistance to all the main antibiotic classes including fluoroquinolones has been detected in *M. bovis* isolates and this explains the lack of impact of these antibiotics in vivo [21]. Thirdly, mycoplasmas are known to infect different body sites, hence treatment is rarely thorough as this characteristic enables their survival. Finally, the ability of mycoplasmas to invade host cells and form biofilms as well as the lack of cell wall has allowed them to evade antibiotic therapy [22]. Based on field experience, most investigators have concluded that antibiotic therapy of mycoplasma mastitis is not an economically viable control strategy.

Similarly, the development of mycoplasma vaccines has not yielded any promising prospects since the organism has the ability to evade the host by altering their surface proteins and inducing immunomodulatory effects [23]. However, vaccines aimed mainly at the pneumonic form of the disease are available in the USA and UK but there is little published evidence of their efficacy, especially for mastitis [24, 25].

The role of the season in the incidence of mastitis has been studied. The prevalence of mastitis varies from season to season since the growth and multiplication of organisms depends on specific temperature and humidity. Inadequate ventilation, with high temperature and relative humidity, encourages the proliferation

of various bacteria. The exposure of livestock to high temperature induces stress and subsequently altering the immune functions [26]. In India, Joshi and Gokale [27] reported that animals are more vulnerable to Sub-clinical mastitis (SCM) in the monsoon season compared to summer or winter. Also, in Ethiopia, Dego and Tareke [28] reported a higher occurrence in the rainy season than in the dry season. In Nigeria, a 5-year study by Kawu et al. [29] reported that the peak occurrence of clinical mastitis (CM) in goats coincides with the hot dry to the early wet season. Similarly, Okoli et al. [30] noticed a high prevalence among cattle and goats in the late dry season while in sheep during the early rainy season. Very few surveys (with varying results) on the seasonal prevalence of mastitis have been documented for Nigeria in Imo state (South-East) and Zaria, Kaduna state (North-West) [29, 30]. Clearly, data in this regard are lacking in most part of Nigeria; hence the need for a comprehensive national survey as this would ensure an updated seasonal disease burden for effective execution of a mastitis-control program.

1.2 Mastitis in livestock

The livestock sub-sector is a key and essential constituent of Nigeria's agriculture, known to be the main source of household wealth and food security [31]. It contributes around 1.7 percent to the national GDP and around 9 percent to the agriculture value added [32]. Furthermore, Nigeria is noted to be one of the four leading livestock producers in Sub-Sahara Africa. The prevalence of clinical and sub-clinical mastitis in livestock has been reported for many regions of the world. However, most reports come from developed countries, some of which are by Bradley [33] and Petrovski et al. [34]. In Africa, the disease occurrence is well documented in 30% of countries [25]. The economic impact of mastitis including annual losses estimated per cow has been documented in the USA and EU [35, 36]. The lack of published materials in Africa greatly affect the documentation of the economic impact of mastitis. Therefore, production losses and expenditure related to mastitis in other developing countries and Africa are underestimated and miscalculated [15]. Also, different countries apply distinct methodologies to calculate economic losses due to mastitis, making it difficult to compare [15]. An estimate of the economic impact of mastitis for 3 countries is presented in Table 1. Meanwhile, a few studies in Nigeria such as Moru et al. [37] have attempted to estimate the economic loss associated with mastitis.

Table 1 Estimated costs due to bovine mastitis in some developing countries [15]

Area	Milk loss (%)	Cost (\$) ^a	Method(s)	Mastitis	Production system	Period	Reference
Ethiopia	5.6	38 per cow	Production losses due to sub-clinical mastitis per subsystem level	CM & SM	Urban, Peri-urban and dairy herds in secondary towns	2005	[38]
Madagascar	N/A	188 per cow	Financial loss due to CM per cow	CM	Peri-urban	2004	[39]
India	17.5	CM = 91 (cows) and 75 (buffaloes); SM=192 (cows) and 154 (buffaloes)	Milk losses/ animal/ lactation; economic loss due to reduced milk production; Cost of milk discarded due to CM/animal	CM & SM	N/A	1962, 1994	[40, 41]

\$= cost estimates calculated in US dollars; CM= clinical mastitis; SM= sub-clinical mastitis; N/A=not applicable

All over the country, reports of mastitis prevalence in livestock vary. Similarly, the methods for detection and identification of pathogens associated with sub-clinical mastitis have not been uniform but microscopy has been commonly applied. Other pathogen and disease diagnostic techniques readily employed are the culture method, California mastitis test (CMT), rapid field catalase test (RFCT), and the latex agglutination test (LAT); while data from polymerase chain reactions has been scarce and recent. Furthermore, the physical examination of livestock udders has been employed for the diagnosis of clinical mastitis (Table 2). Over the years, data on the following livestock (cattle, sheep, and goat) positive for mastitis are thus documented (Table 2).

In Nigeria, livestock rearing is a major occupation and serves as a source of livelihood. The product and value chain from livestock processing meets different human needs, meanwhile, mastitis threatens its economic potentials.

More than 140 species of pathogenic bacteria (including *Mycoplasma*), in addition to fungi, algae and viruses are known to cause clinical and sub-clinical mastitis [66]. *Staphylococcus aureus*, *Escherichia coli*, *Staphylococcus epidermidis*, *Streptococcus agalactiae*, *Klebsiella pneumoniae*, and *Pasteurella* spp are the common etiological agents causing mastitis in livestock [2, 7, 54]. Surveyed areas positive for mastitis with prevalence data over the years (1990-2020) are respectively presented in Fig. 1 and Table 2. Similarly, *S. aureus* and *E. coli* are mainly responsible for mastitis in cattle and goats with a higher infection rate in the northern than in the southern region of the country (Table 2). The susceptibility of different breeds of goat has been reported [55, 63].

Of the 36 states and Abuja, we could only access mastitis data in livestock from 14 states (see Fig.1, Table 2).

Interpreting this with respect to the landmass of Nigeria, a survey on the livestock population in the different states is largely insufficient. Data analysis on livestock (cattle, sheep and goat) mean prevalence by zone using (CMT, RFCT and LAT) estimates the following: North-West ($30.2\% \pm 24.2\%$), North-East ($35.8\% \pm 24.8\%$), North-Central ($43.7\% \pm 14.4\%$), South-East ($26.7\% \pm 35.2\%$), South-South ($30.2\% \pm 0\%$) and South-West ($13.1\% \pm 18.2\%$). Furthermore, in mastitis positive livestock, mean prevalence of *S. aureus* was 30.8%, *S. agalactiae* (11.9%), *S. epidermidis* (11.6%), and *K. pneumoniae* (4.5%). Also, co-infection of mastitis (3.31%) with Tuberculosis (4.2%), Fascioliasis (8%), Streptothricosis (3.15%) and worms (1.5%) has been reported [63]. Among the sampled livestock (cattle, sheep, and goats), the overall mean infection rate for goats ($38.1 \pm 21.9\%$) was higher than cattle ($26.5 \pm 22.3\%$) and sheep ($20.7 \pm 23.6\%$). Similarly, among livestock (cattle, sheep, and goats), the sub-clinical form of mastitis infection is higher than clinical mastitis with (32.6% and 24.8%) respectively. The high infection rate in goats by Staphylococcal mastitis has been documented [56]. Public food safety is being threatened by the constant prevalence of *S. aureus* intramammary infection. However, subclinical mastitis is more difficult to detect because the signs are not readily obvious. Also, the absence of overt manifestation contributes to the challenge for its diagnosis in dairy animal management and in veterinary practices [13]. A high percentage of livestock in this report were infected with subclinical mastitis. Furthermore, subclinical mastitis has been reported to be 15 or 40 times more prevalent than the clinical form and with a longer duration of infection [6]. This is of great concern as the sub-clinically affected livestock remain a source of infection to herds [67]. Given the different pathogens tied to the cause of mastitis, and based on the reports by [68-71] on the negative

Table 2 Prevalence of Mastitis in livestock across the states and zones in Nigeria

Zones	Location	Number Examined	Prevalence (%)	Method	Livestock Type	Reference
North-West	Kaduna	147	19.7	PEM, CMT	Cattle	[42]
	Kaduna	360	26.9	CMT	Cattle	[43]
	Kaduna	386	60.1	CMT	Goat	[44]
	Kaduna	147	8.1	CM/PCR	Cattle	[45]
	Kaduna	300	29.7	CMT	Cattle	[46]
	Kaduna	42	31	CMT	Cattle	[47]
	Kaduna	390	7.17	LAT	Cattle	[48]
	Kaduna, Kano, Kastina	900	10.2	PEM	Goat	[49]
	Sokoto	88	10.23	PEM	Cattle, Sheep, Goat	[50]
	Sokoto	300	85.33	CMT	Cattle	[51]
	Sokoto	100	52	CM	Cattle	[52]
	Zamfara	263	21.6	RFCT	Goat	[53]
North-East	Bauchi	122	47.5	PEM, CMT	Goat	[54]
	Bauchi	348	28.1	PEM, CMT	Sheep, Goat	[55]
	Borno	300	17	PEM	Goat	[56]
	Borno	81	70.3	PEM	Goat	[20]
	Borno	5000	2.1	PEM	Cattle	[57]
	Borno	206	50	PEM	Goat	[58]
North-Central	Plateau	51	63.7	PEM	Cattle	[59]
	Plateau	85	30.5	CMT	Cattle	[60]
	Plateau	16	43.7	PEM, CM	Cattle	[61]
	Plateau	65	36.9	PEM, CMT	Goat	[55]
South-East	Enugu	58	67.24	CMT	Goat	[62]
	Imo	8615	9.7	PEM	Cattle, Sheep, Goat	[30]
	Imo	327000	3.3	PEM	Cattle, Sheep, Goat	[63]
South-South	Edo	63	30.2	PEM, CMT	Goat	[55]
South-West	Oyo	411	26	CMT	Cattle	[64]
	Ogun, Lagos	641224	0.22	CCF	Cattle	[65]

PEM = Physical Examination Method; CMT = California Mastitis Test; PCR = Polymerase Chain Reaction; LAT = Latex Agglutination Test; RFCT = Rapid Field Catalase Test.

effects of mastitis on the African economy, it is clear that mastitis is a complex disease. However, understanding its occurrence; by having a near accurate prevalence picture in Nigeria through the survey of the 36 states using a more sensitive and species-specific method, the related risk, and the pathogens involved are fundamental elements in developing a control program.

1.3 Diagnosis

There are many diagnostic techniques available for the detection of mastitis. The diagnosis of clinical mastitis is less complex, because of the apparent signs, including swollen quarter/udder and poor milk quality [72]. Meanwhile, subclinical mastitis cannot be visually detected and requires the use of diagnostic methods.

The traditional available diagnostic method such as the California Mastitis Test (CMT) and / or Somatic Cell Count (SCC) have aided early detection under field conditions

[73, 74]. CMT determines SCC, and has been used as a cow-side indicator test for the diagnosis of subclinical mastitis. The proportion of each somatic cell type (macrophages, lymphocytes, erythrocytes, and epithelial cells) depends on the infection rate of the gland [75, 76]. In infection-free udders, white blood cells constitute a third of cells, but during infection the white blood cells proportion may reach 99%. Thus, SCC can show the existence and extent of damage caused by pathogenic species to udder tissue or malfunctioning of milking equipment and, therefore, safeguard milk quality. In Nigeria, the acceptable limit for SCC is set at <10,000 cfu /ML for raw milk of good quality, this limit is in accordance with those proposed by [64, 77]. In addition, the standard SCC and BSCC of good quality fresh milk from a healthy cow is between <100,000 cells per mL and not greater than 500,000 cells per mL [77]. However, CMT is relatively insensitive and can generally not detect SCC below 350 to 400,000 cells per mL. Furthermore, a CMT will show a high score in recently fresh cows and in cows at the end of lactation just before dry-off; these cases should not

be over-interpreted as a sign of subclinical mastitis. Also, a CMT is elevated in secretions from cows with decreased milk production due to illness. For example, cows observing peak lactation that become acutely ill due to traumatic reticuloperitonitis may have milk production plummet acutely. Meanwhile, if these cows do not have mastitis on normal udder palpation and strip plate evaluation, the CMT result will indicate positive. The high CMT scores depict a failure of fluid milk production to dilute the somatic cells [78]. This report has clearly outlined the current mastitis diagnostic techniques employed in Nigeria (Table 2), these diagnostic approaches are the known traditional method and the limitation of the sensitivity of some this method may have largely influence the diagnostic outcome. In addition, PCR was only used in only one study (Table 2) conducted by Makolo et al. [45].

Other general tests to detect mastitis include the bacterial culture of milk, electrical conductivity, pH, NaOH (white side test), lactate dehydrogenase, measurement of *N*-acetyl-b-D-glucosaminidase, and milk enzyme-linked immunosorbent assay in addition to polymerase chain reaction (PCR) assay [72]. Various PCR assays, as well as multiplex conventional and real-time PCR, have been designed for the detection of mastitis pathogens including *Staphylococcus* spp, *E. coli*, *M. bovis*, *S. agalactiae* and *Enterococcus* spp [25, 79-81]. However, Zadoks et al., [82] gave a detailed report on the background of the molecular epidemiology of mastitis pathogens, particularly at the sub-species level, with relevance to public health. The emergence of the loop-mediated isothermal amplification method, which is another nucleic acid amplification technique [83], has led to the development of assays for the detection of *Staphylococcus* spp, *E. coli*, *M. bovis*, *S. agalactiae* and *Enterococcus* spp [25, 84-87]. Also, proteomics-based detection, biochips, and biosensors are molecular biological techniques developed for the diagnosis of bovine mastitis [73]. Therefore, an inventory of diagnostic techniques exists can be engaged as the first line of detection from milk samples in Nigeria. The selection of technique(s) with the most desirable attributes (e.g. most reliable, relevant, and rapid) to enhance detection and downstream analyses are the major challenge.

1.4 Treatment

The involvement of a high number of different mastitis pathogens remains a challenge towards developing effective mastitis therapy. *S. aureus* is the most occurring species in livestock as a result of its resistance mechanisms, such as the formation of abscesses within udder or evading antibiotics

by residing inside macrophages, therefore escaping antibiotics circulating in the bloodstream [25, 88]. Moreover, the ability of some strains of *S. aureus* to exist as latent bacteria within a cavity as well as reactivating growth when the conditions are favorable has been documented [88]. Furthermore, the presence of planktonic and biofilm growth tends to complicate treatment. The resistance or evasion of antibiotics, coupled with latency have striking implications for treatment and costs. These characteristics are significant to the success of *S. aureus* as a mastitic pathogen prevailing in Nigeria. Similarly, treatment is complicated when co-infection exists as co-infecting pathogens can interact with one another via the host immune system.

In Nigeria, the antibiotics of choice for the treatment of mastitis include Cefoxitin, Penicillin G, Ampicillin, Amoxicillin-clavulanic acid, Ceftriaxone, Vancomycin, Gentamicin, Kanamycin, Erythromycin, Tetracycline, Ciprofloxacin, Nitrofurantoin, Trimethoprim-sulfamethoxazole, and Chloramphenicol. Also, sensitivity and major resistance of *S. aureus* and other mastitis pathogens to these antibiotics have been reported [44, 46, 58, 60].

Presently, there is no universal approach for treating mastitis albeit treatment recommendation due to the extent of deteriorating udder health [88]. Meanwhile, the exploration of phages as an alternative therapy in South Africa has been an interesting development [68, 89]. Numerous benefits could be derived from the use of phages some of which include host specificity, ease of isolation and propagation, reduced toxicity, prolonged shelf life, and presence in the same environment as their bacterial hosts [25]. Thus, problems such as drug resistance, high cost of treatment, and the need to continuously develop a host-specific antimicrobial can be eliminated. This is because phages tend to evolve with the target host. Nevertheless, it is no doubt that bacteria could create mechanisms to avoid attack and killing by bacteriophages. Bacteria may avoid detection by secreting enzymes that target phages' receptors on the cell wall surface or altering the specificity of phages. Currently, potential bacteriophage therapy is being tailored to combat *S. aureus* given its dominance as an etiological agent in bovine mastitis [68, 89]. As antibiotic-resistant is not limited to *S. aureus*, the application of phage therapy should be expanded to accommodate other pathogens.

2 Conclusion

More studies are required for reliable diagnosing and treating mastitis, as well as estimating the resulting economic impact in Nigeria. Culture-based techniques allow for strain isolation from field samples, molecular

genetic techniques no doubt offer a rapid, specific, and sensitive detection profile for mastitis. Nonetheless, Nigeria can benefit from developing a clear policy across the state in the geopolitical zones regarding diagnosis. Such a policy should stress the use of rapid techniques as the first line of diagnosis for suspected cases or be applied routinely for confirmation and testing at reference centers. As indicated in this report the prevalence of subclinical mastitis is higher than clinical. The dominance of this form of mastitis is of great concern, as it leads to antimicrobial resistance seen in most mastitis-causing pathogens and is the most damaging and costly as early detection is difficult. Thus, this review has highlighted the prevalence of mastitis across the states and zones in Nigeria, and should serve as a template to advance subsequent analyses as well as a wakeup call to begin a rigorous stepwise process towards the diagnosis and management of mastitis in Nigeria. As sub-clinical mastitis is common in all livestock and indicated with elevated SCC, it is recommended that there be clear communication regarding SCCs adoption for healthy udder in Nigeria. It is paramount to address the case of accuracy when applying SCC to detect mastitis as it will aid farmers through effective administration of antimicrobials therapy.

Only 14 states of Nigeria partially report cases of mastitis in livestock, while the remaining 22 states and Abuja lag behind. This is a small number compared with other countries in Africa. Furthermore, if estimates of milk losses and costs associated with the disease are not well documented, this would delay the planning of control strategies. Undoubtedly, collaborations between the dairy industry, scientific community, and economists, would culminate in better monitoring of the disease impact. However, farmers should engage in regular screening for clinical and subclinical mastitis in order to manage direct and indirect losses. Furthermore, standard for the diagnoses of mastitis in Nigeria using molecular techniques should be implemented, in the same vein, workshops and seminars with practical hands-on training to educate all stakeholders in the livestock industry should be provided as this would go a long way in arming stakeholders with the right tool to diagnose mastitis using molecular techniques as well as using contemporary recommended management standards to monitor, manage or control the spread of the disease.

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