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Bacterial Causes of Ovine Mastitis in Iraq: A Comprehensive Review

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Abstract Sheep constitute one of Iraq's most numerous livestock populations, and their milk is marketed both raw and in processed dairy products. Mastitis is the principal mammary disease affecting ewes; however, published Iraqi evidence concerning its bacterial aetiology has not been systematically consolidated. This structured narrative review examines the microbial causes, epidemiology, pathogenicity, antimicrobial resistance, diagnostic approaches, and treatment of ovine mastitis in Iraq. Relevant publications were sought in PubMed/PMC, Scopus, Web of Science, Google Scholar, the Directory of Open Access Journals, and the Iraqi Academic Scientific Journals portal, with reference-list screening for publications available before October 2026. Iraqi studies report clinical mastitis in approximately 2–7% and subclinical mastitis in approximately 12–26% of examined ewes, udder halves, or milk samples, although these denominators are not directly interchangeable. Coagulase-negative staphylococci, particularly *Staphylococcus epidermidis*, frequently predominate in subclinical infections. In clinical and gangrenous mastitis, *S. aureus* is a major pathogen; it was also detected in 23.3% of subclinical milk samples examined in Nineveh. Additional reported agents include *Escherichia coli*, *Proteus mirabilis*, *Streptococcus agalactiae*, *S. dysgalactiae*, *S. uberis*, *Mannheimia haemolytica*, *Pseudomonas aeruginosa*, *Histophilus ovis*, and *Mycoplasma agalactiae*. Staphylococcal and Enterobacteriaceae-associated mastitis are linked to markedly elevated milk-whey lactate dehydrogenase, alkaline phosphatase, and aspartate aminotransferase activities. Molecular investigations identified *clfA*, *clfB*, *coa*, and *mecA* in ovine *S. aureus*, while some coagulase-negative variants lacked *coa*. Extended-spectrum β-lactamase-producing *E. coli* carrying *bla*CTX-M were isolated from the milk and faeces of ewes and lambs and frequently showed co-resistance to tetracycline, ciprofloxacin, and trimethoprim–sulfamethoxazole. Overall, staphylococci account for an important share of reported ovine mastitis in Iraq, alongside emerging antimicrobial-resistance concerns. Geographical coverage, definitions, and laboratory methods remain inconsistent. Priorities include standardized multi-governorate surveillance, phenotypic confirmation of methicillin resistance, toxin-gene profiling, responsible antimicrobial use, and feasible improvements in milking hygiene.

Index Terms Ovine mastitis; Awassi sheep; *Staphylococcus aureus*; Coagulase-negative staphylococci; Methicillin resistance; Extended-spectrum β-lactamases; *Mycoplasma agalactiae*; Iraq

I. Introduction

Sheep constitute a major part of Iraq's livestock population, which has been estimated at approximately eight million animals distributed across diverse climatic zones, from the mountainous regions of Kurdistan to the arid landscapes of Anbar and the southern plains [1]. Among the principal sheep breeds are Awassi, including the Naimi and Shafali types, which are estimated to account for approximately 60% of the national flock, followed by Karadi (also known as Hamdani) and Arabi sheep [1]. Sheep are traditionally raised under extensive and semi-intensive production systems, and milking is frequently performed by hand. Their milk is consumed fresh or processed into cheese and other dairy products. Consequently, udder health has direct implications for household income, food quality, animal productivity, and the livelihoods of sheep-rearing families.

Mastitis, the inflammation of the mammary gland, is the most important disease of the udder in small ruminants and is almost always of infectious, predominantly bacterial, origin [2], [3]. In dairy flocks worldwide the annual incidence of clinical mastitis is usually below 5%, although outbreaks may affect 30–50% of ewes, and gangrenous forms can kill or force the culling of a large fraction of a flock [2]. Subclinical mastitis is far more frequent and is the main source of economic loss through reduced milk yield, altered milk composition, poor cheese-making properties, impaired lamb growth and premature culling [3], [4]. Staphylococci dominate the aetiology: coagulase-negative staphylococci (CoNS, now often termed non-aureus staphylococci) are the leading cause of subclinical infection, whereas *Staphylococcus aureus* is the principal agent of clinical and gangrenous mastitis [2], [4].

In Iraq, investigations of ovine mastitis have been con-

ducted for several decades by researchers at veterinary institutions in Baghdad, Mosul, Basrah, Anbar, Fallujah, Diyala, Al-Qadisiyah, Kufa, Thi-Qar, and Al-Muthanna. Early studies estimated the occurrence of clinical and subclinical mastitis using the California mastitis test (CMT) and conventional bacterial culture, identifying organisms that had not previously been reported in the Iraqi ovine-mastitis literature, including *Histophilus ovis* [5]. Subsequent investigations combined bacteriological examinations with biochemical analyses of milk and whey. Hassan and Yousif demonstrated that subclinical mastitis associated with staphylococci and Enterobacteriaceae is accompanied by substantially elevated whey activities of lactate dehydrogenase, alkaline phosphatase, and aspartate aminotransferase; these enzymes may therefore have diagnostic value when interpreted alongside established tests [6], [7]. During the past decade, investigations have increasingly incorporated molecular pathogen identification, virulence-gene profiling, detection of genetic markers associated with methicillin resistance, and phylogenetic analysis of bacterial sequences submitted to GenBank [8].

Despite the number of published investigations, the Iraqi literature on ovine mastitis remains fragmented. Many studies appear in national journals with limited visibility in international bibliographic databases, and investigators have used inconsistent case definitions and sampling units. Some report disease frequency per ewe, whereas others use udder halves or individual milk samples as denominators. These differences complicate direct comparisons of prevalence and pathogen-isolation frequencies. Previous reviews have addressed bovine mastitis in Iraq [9], but the available ovine evidence has not been brought together in a dedicated country-focused review, even though transmission patterns, treatment options, and husbandry conditions differ between cattle and sheep [2], [3].

The aim of this review is to synthesize published evidence on the bacterial aetiology of clinical and subclinical ovine mastitis in Iraq. The specific objectives are (i) to summarize reported disease frequency across Iraqi governorates and clinical forms; (ii) to evaluate the importance of individual bacterial genera and species; (iii) to examine virulence factors and molecular characteristics of the recovered isolates; (iv) to describe antimicrobial resistance, particularly methicillin resistance and biofilm-associated persistence; (v) to assess reported risk factors, diagnostic approaches, and zoonotic implications; and (vi) to identify the principal research gaps requiring attention under Iraqi production and veterinary-service conditions. Because the available evidence is methodologically heterogeneous, the review distinguishes observational findings from interpretations and recommendations wherever possible.

II. Literature Search Methodology

This article adopts a structured narrative-review approach. Searches were performed in PubMed, PubMed Central, Scopus, Web of Science, Google Scholar, the Directory of Open Access Journals, and the Iraqi Academic Scientific Journals (IASJ) portal, which provides access to numerous Iraqi veterinary journals. The final search was conducted in October 2026. The approach was designed to identify both internationally indexed reports and relevant local publications that may otherwise be missed by conventional database searches.

Search expressions combined three groups of terms: (sheep OR ovine OR ewe* OR Awassi OR Karadi OR Hamdani) AND (mastitis OR "intramammary infection" OR udder OR milk) AND (Iraq OR the name of an Iraqi governorate). Geographic variants included Nineveh, Mosul, Anbar, Fallujah, Baghdad, Basrah, Diyala, Diwaniyah, Najaf, Karbala, Thi-Qar, Muthanna, Sulaimaniyah, Erbil, Duhok, Kirkuk, Wasit, and Maysan. Targeted searches also used pathogen- and resistance-specific expressions, including *Staphylococcus*, MRSA, *mecA*, *Streptococcus*, *Escherichia coli*, *Mannheimia*, *Mycoplasma agalactiae*, *Pseudomonas*, *Klebsiella*, biofilm, and enterotoxin. Reference lists of selected studies and a national review of bovine mastitis [9] were manually screened to identify additional reports not captured by electronic indexing. Search terms were adapted to the coverage and functionality of individual databases.

Studies were eligible if they (i) were undertaken in Iraq, (ii) examined milk or mammary tissue from sheep, either independently or alongside other ruminant species, and (iii) reported bacteriological, molecular, antimicrobial-susceptibility, or mastitis-related diagnostic findings. Case reports were considered when they documented bacterial causes of clinical or gangrenous mastitis. Studies restricted to cattle, buffaloes, goats, or camels were used only as contextual comparisons and were not treated as direct evidence of ovine disease frequency in Iraq. International studies were consulted to interpret Iraqi findings and to describe established mechanisms of pathogenesis, diagnosis, prevention, and control.

Where information was available, the following characteristics were extracted from each study: governorate and study period, sheep breed, number of ewes and samples, unit of analysis, case definition, screening procedure, bacterial identification method, isolates recovered, and antimicrobial-resistance results. Clinical signs, CMT, somatic cell count, and culture were recorded as distinct diagnostic criteria rather than treated as equivalent measures. Given the variation in sampling units, case definitions, and denominators, reported disease frequencies are presented in the form supplied by each study. No pooled meta-analytic prevalence estimate was calculated, and cross-study comparisons are necessarily descriptive.

III. Epidemiology of Ovine Mastitis in Iraq

Available surveys from Iraq report clinical mastitis frequencies of approximately 2–7% and subclinical mastitis frequencies of approximately 12–26%, broadly comparable with selected reports from neighbouring countries [2], [5], [6], [10], [11]. These values refer to different sampling units and should not be interpreted as directly pooled incidence estimates. The principal Iraqi studies providing bacteriological evidence from sheep are summarized chronologically in Table 1, together

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with their sampling designs, case definitions, and main findings.

Table 1: Principal Iraqi studies reporting the bacterial aetiology of ovine mastitis (in chronological order).

Study	Governorate / area	Animals and samples	Case definition	Main findings
Hassu, 2006 [5]	Not specified	205 local ewes; 400 milk samples	Clinical signs; CMT	Clinical 7.25%, subclinical 26.25%; first Iraqi record of *Histophilus ovis*
Al-Jubouri, 2012 [10]	Baghdad (university farms)	88 ewes; 168 udder-half samples	Clinical signs; CMT; direct microscopic SCC	Clinical 5.11%, subclinical 14.20%; *S. aureus* 44.4% of clinical isolates; *S. epidermidis* 53.8% of subclinical isolates; *Pseudomonas aeruginosa* recorded
Hassan and Yousif, 2013 [6]	Not stated in abstract	161 lactating ewes; 310 udder-half samples	CMT, white side, chloride and pH tests; culture	Staphylococcal clinical mastitis 2.25%, subclinical 12.22%; *S. aureus* and CoNS; raised whey LDH, ALP, AST
Hassan and Yousif, 2014 [7]	Same flocks as [6]	161 ewes; 310 samples	As above	Subclinical *Proteus mirabilis* 8.88% and *E. coli* 3.33% of samples
Hammadi et al., 2015; Hammadi and Yousif, 2018 [12], [13]	Baghdad surroundings	Awassi ewes with mastitis	Clinical; culture	Slime-producing *S. aureus* isolated, used for experimental infection and vaccine trials
Al-Khudher and Kshash, 2016 [14]	Al-Muthanna	150 clinical mastitic milk samples	Clinical; culture on PPLO agar; PCR	40% culture-positive for mycoplasmas; 11.4% of PCR-positive mycoplasmas were *M. agalactiae*
Al Salihi, 2018 [15]	Al-Muthanna	2 ewes (case report)	Gangrenous mastitis	*S. aureus* alone and *S. aureus* with *Mannheimia haemolytica*
Rasheed and Jwher, 2021 [16]	Nineveh	133 milk samples and 133 udder-skin swabs	Clinical mastitis	*M. haemolytica* isolated from milk and udder skin (matching rate 51.1%)
Mahmood and Ahmed, 2022 [17]	Mosul (Nineveh)	40 ewes with clinical mastitis; 60 healthy ewes and their lambs	Clinical; selective culture	ESBL-producing *E. coli* in 10% of mastitic milk and 11.7% of milk from healthy ewes
Alalaf et al., 2025 [8]	Nineveh (4 districts)	60 CMT-positive milk samples	Subclinical (CMT)	*S. aureus* 23.3%; all isolates *mecA*-positive (MRSA)
Abdulrazzaq et al., 2025 [18]	Nineveh (4 districts)	60 CMT-positive milk samples	Subclinical (CMT)	Coagulase-negative *S. aureus* 11.7%; all *mecA*-positive

The abbreviations used in Table 1 and throughout this review are California mastitis test (CMT), somatic cell count (SCC), coagulase-negative staphylococci (CoNS), pleuropneumonia-like organism medium (PPLO), and extended-spectrum β-lactamase (ESBL). Distinguishing the sampling unit and the diagnostic test remains essential when interpreting the reported percentages.

Across the surveys, subclinical mastitis is three to five times more frequent than clinical disease. Hassu recorded 7.25% clinical and 26.25% subclinical mastitis among 400 milk samples [5]. Al-Jubouri reported 5.11% and 14.20% respectively at the udder-half level in Baghdad and found direct microscopic somatic cell counting more reliable than the CMT in ewes [10]. Hassan and Yousif, working on 310 udder halves from 161 ewes in mid-lactation, found clinical and subclinical staphylococcal mastitis in 2.25% and 12.22% of samples and additional subclinical infections due to *Proteus mirabilis* and *E. coli* [6], [7].

The values reported by Iraqi investigators overlap with the ranges described internationally, although they cannot be classified as acceptable or unacceptable without considering flock characteristics, diagnostic definitions, and production objectives. In northern Jordan, a study of 3,472 udder halves reported mastitis in 29.8% of examinations and a disease incidence of 1.7 per 100 ewe-months [11]. Bergonier and colleagues described clinical mastitis occurrence of approximately 5% and subclinical frequencies of roughly 10–50% in dairy sheep flocks [2]. Such comparisons illustrate that clinical and subclinical disease contribute differently to udder-health burdens and that prevalence and incidence must not be treated as interchangeable measures.

Research on ovine mastitis in Iraq has been concentrated in Nineveh, including the University of Mosul, as well as Baghdad, Al-Qadisiyah/Diwaniyah, and Al-Muthanna. Nineveh has supplied several recent molecular investigations, and reported *S. aureus* isolation rates have differed between local study areas, including 13.3% in Al-Shamseeat and 33.3% in Al-Qasra [8]. Published ovine investigations remain limited in Anbar, Salah al-Din, Kirkuk, Basrah, Maysan, and the Kurdistan Region, despite the significance of sheep husbandry in these areas [1]. Consequently, the current literature may not adequately represent geographical variation in pathogen exposure, flock management, veterinary access, and antimicrobial-use practices. This uneven coverage is a major limitation of the national evidence base.

Gangrenous ("blue bag") mastitis is reported sporadically but is clinically important because of its high case fatality. In Al-Muthanna, one of two ewes with peracute gangrenous mastitis died despite parenteral and intramammary penicillin–streptomycin and fluid therapy; *S. aureus* was isolated from both cases and *M. haemolytica* from the fatal case [15]. The original case report recommended prompt surgical removal of the affected half, in line with international experience [15]. In neighbouring south-eastern Turkey, *S. aureus* accounted for 75% of isolates from 264 gangrenous milk samples of Awassi ewes, followed by *M. haemolytica* (7.2%) [19].

The available Iraqi investigations differ in their units of analysis, including ewes, udder halves, and individual milk samples; screening methods, including CMT, white-side testing, and somatic cell counts; CMT thresholds; culture media; and organism-identification procedures. Most studies are

cross-sectional and rely on conveniently accessible flocks, while confidence intervals for reported disease frequencies are often unavailable. Several recent investigations sampled only CMT-positive milk, so their organism-isolation percentages are conditional on a positive screening result and must not be interpreted as flock-level prevalence estimates [8], [18]. These methodological differences warrant caution in comparisons across governorates and study periods.

IV. Staphylococci as the Leading Cause of Ovine Mastitis in Iraq

Staphylococci are the most frequently isolated bacteria from both clinical and subclinical ovine mastitis in Iraq, as elsewhere. Internationally, *S. aureus* accounts for roughly 20–60% of clinical cases and CoNS for 30–95% of subclinical infections in dairy ewes [2], [4]. Iraqi data agree with this division of roles.

In the Baghdad investigation, *S. aureus* was the leading isolate among clinical mastitis cases, accounting for 44.4% of clinical isolates, and was associated with higher somatic cell counts [10]. In Nineveh, *S. aureus* was recovered from 23.3% of CMT-positive subclinical milk samples; all isolates carried *nuc*, *mecA*, *clfA*, and *coa*, whereas 92.9% carried *clfB* [8]. The same species was also isolated from ewes with gangrenous mastitis in Al-Muthanna [15]. Earlier work in Nineveh reported *S. aureus* in milk from several ruminant species, including sheep, together with resistance to commonly used antimicrobial agents [20]. The combined evidence establishes the importance of the organism in both clinically apparent and subclinical infections, although the extent of its distribution in Iraqi flocks remains uncertain.

Hassan and Yousif [6] provided one of the relatively few Iraqi datasets linking staphylococcal intramammary infection to biochemical evidence of mammary tissue damage. They examined 310 udder-half milk samples and reported staphylococcal infection involving both *S. aureus* and coagulase-negative staphylococci. The reported isolation proportions included 27.8% for *S. aureus* among infected cases and 12.22% for specified subclinical categories, with denominators requiring careful interpretation. Whey aspartate aminotransferase increased from approximately 38.8 U/L in uninfected samples to approximately 222 U/L in subclinical cases and 272 U/L in clinical cases. Lactate dehydrogenase and alkaline phosphatase activities showed similarly pronounced elevations [6]. The authors suggested that these enzymes could provide useful supplementary diagnostic information where routine somatic cell counting is unavailable. Nevertheless, their diagnostic specificity requires consideration alongside the observed infection status and sampling design.

Experimental work in Iraq has also demonstrated the pathogenic potential of slime-producing *S. aureus*. In the reported challenge study, the inoculum was 7×10^2 colony-forming units (CFU) in 1 mL of phosphate-buffered saline, as documented in the original article. Following inoculation, all five lactating Awassi ewes developed acute mastitis within approximately one day [12]. Histopathological examination revealed interstitial fibrosis, infiltration by neutrophils and macrophages, abscess formation, and necrosis involving the mammary ducts [12]. These findings support the clinical importance of the organism, and this controlled experimental observation should not be extended to a quantitative dose–response relationship without further evidence.

Infection with *S. aureus* in ewes can range from mild or persistent intramammary infection to severe necrotizing disease and fatal gangrenous mastitis. A study of a French dairy flock found genetic differences between a strain associated with gangrenous disease and a closely related strain associated with subclinical infection, particularly in genes encoding adhesins and surface proteins; the organism was also detected in the nares of other flock members [21]. In addition to the nasal cavity, teat skin and other colonized mucosal sites may contribute to persistence and transmission within a flock. The absence of consistent teat preparation and post-milking disinfection can further increase opportunities for contamination and ewe-to-ewe spread [22]. These observations emphasize that pathogen virulence and management-related exposure must be considered together.

Coagulase-negative staphylococci are among the most frequently detected organisms in subclinical ovine mastitis worldwide and are associated with persistent infection, increased somatic cell counts, reduced milk production, and changes in milk composition [4], [23], [24]. In the Baghdad study, *S. epidermidis* accounted for 53.8% of isolates from subclinical mastitis cases [10]. Hassan and Yousif also identified CoNS in a substantial proportion of affected udder-half samples, including a reported 27.8% in the relevant infection category. Infected ewes, rather than lambs, showed markedly higher whey activities of AST, ALP, and LDH than uninfected animals, with elevations comparable to those observed in other staphylococcal infections [6]. These findings argue against treating all coagulase-negative staphylococci as harmless commensals of the ovine mammary gland. Species-specific identification and confirmation of infection remain important for interpreting their clinical significance.

An additional identification challenge concerns coagulase-negative variants of *S. aureus* (CNSA). In Nineveh, CNSA was found in 11.7% of subclinical milk samples; all isolates carried *nuc*, *mecA*, *clfA*, *clfB* and 16S rRNA genes, but none carried *coa* [18]. Routine identification based on tube coagulase alone would misclassify such isolates as CoNS and underestimate *S. aureus* prevalence [18]. Molecular confirmation, at least with a *nuc*-based PCR, is therefore desirable in Iraqi diagnostic laboratories.

Many Iraqi studies have not identified coagulase-negative staphylococci to the species level. International investigations have frequently detected *S. epidermidis*, *S. chromogenes*, *S. simulans*, *S. haemolyticus*, *S. xylosus*, and *S. caprae* in sheep milk, and species identity can influence persistence and virulence [4], [25]. Phenotypic identification kits may misclassify ovine staphylococci, particularly closely related species. Where resources permit, confirmation using PCR-RFLP, sequencing of the *gap* or 16S rRNA genes, or MALDI-

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TOF mass spectrometry would improve the reliability and comparability of Iraqi surveillance data [25]. Laboratory protocols should also distinguish true intramammary infections from organisms introduced during sample collection.

In ewes of a dairy breed, mastitis due to some major pathogens like S. *aureus results* in a very high increase in somatic cell count along with a substantial decrease in the quantity of milk produced [24]. However, to date, no study has assessed these losses in Iraq. With the fact that Awassi dairy breeds produce average to low amounts of milk and the majority of milk produced is processed at farms, even a moderate reduction in milk production and cheese quality entails great economic losses to households.

V. Other Bacterial Agents of Ovine Mastitis in Iraq

Beyond staphylococcal species, Iraqi literature documents streptococci, Enterobacteriaceae, *Mannheimia haemolytica, Pseudomonas aeruginosa, Mycoplasma agalactiae,* and several less common pathogens. Table 2 summarizes the epidemiological data for these organisms.

Table 2: Bacterial agents of ovine mastitis reported in Iraq, with their main reservoir and usual clinical presentation.

Agent	Main reservoir / route	Usual presentation	Iraqi evidence
Staphylococcus aureus	Infected udder, teat skin, nares; milker's hands	Clinical, gangrenous and persistent subclinical	Baghdad, Nineveh, Al-Muthanna [6], [8], [10], [15]
Coagulase-negative staphylococci	Teat skin, environment	Mostly subclinical, persistent	Baghdad, Nineveh [6], [10], [18]
Streptococcus agalactiae, *S. dysgalactiae*, *S. uberis*	Infected udder (*S. agalactiae*); environment (*S. uberis*)	Clinical and subclinical	Baghdad [10], [26]
E. coli, *Proteus mirabilis* and other Enterobacteriaceae	Faeces, bedding, soil	Subclinical and acute clinical	Baghdad, Nineveh [7], [17], [26]
Mannheimia haemolytica	Nasopharynx of suckling lambs	Acute clinical and gangrenous	Nineveh, Al-Muthanna [15], [16]
Pseudomonas aeruginosa	Water, contaminated intramammary products	Clinical, often refractory	Baghdad [10]
Mycoplasma agalactiae	Infected flock-mates, milkers' hands	Contagious agalactia; chronic interstitial mastitis	Al-Muthanna [14]
Histophilus ovis	Mucosae of sheep	Subclinical	Single report [5]
Bacillus spp.	Environment	Subclinical; often contaminant	Baghdad [26]

Published evidence indicates that streptococci are reported less frequently from Iraqi sheep than staphylococci, although species-level investigations remain limited. An early Iraqi study of 80 ewes identified *S. agalactiae* and *S. dysgalactiae* together with *S. aureus*, *E. coli*, and *Bacillus* spp. among organisms associated with clinical mastitis [26]. Subsequently, *S. uberis* was reported in a mixed subclinical infection with *S. epidermidis* in Baghdad [10]. Ovine mastitis had been documented in Iraq by at least 1985 [27], but detailed molecular characterization of the streptococcal species affecting Iraqi sheep has remained scarce. In Awassi flocks from northern Jordan, *S. agalactiae* accounted for 6.8% of isolates associated with subclinical mastitis [11]. The neighboring-country data offer a useful comparison but cannot substitute for contemporary species-level sampling in Iraq.

Enterobacteriaceae are environmental opportunistic pathogens that may reach the teat from faeces, bedding, soil, and contaminated housing surfaces. Exposure is potentially increased when sheep are housed in crowded or poorly drained pens during lambing. In their examination of 310 udder-half milk samples, Hassan and Yousif reported subclinical infections associated with *Proteus mirabilis* in 8.88% and *E. coli* in 3.33% of the examined samples. These infections were accompanied by increased whey LDH, ALP, and AST activities and by changes in CMT findings, white-side testing, chloride concentration, and milk pH [7]. The findings support the involvement of environmental Gram-negative organisms in persistent or subclinical ovine intramammary inflammation, rather than only in overt acute clinical disease. However, repeated isolation and appropriate sampling procedures are essential for differentiating infection from incidental contamination.

In Mosul, investigators isolated extended-spectrum β-lactamase (ESBL)-producing *E. coli* from 10% of milk samples collected from ewes with clinical mastitis and from 11.7% of samples collected from clinically healthy ewes; higher frequencies of faecal carriage were reported in particular animal groups, ranging from approximately 30% to 65% [17]. Among 40 ESBL-associated isolates examined by PCR, all carried *bla*CTX-M, while *bla*SHV and *bla*TEM were detected in 17.5% and 12.5%, respectively; no AmpC-associated genes were identified in the tested isolates [28]. The recovery of resistant organisms from both milk and faecal samples is consistent with possible environmental transfer, although shared resistance markers alone do not establish the direction or route of transmission between sites.

Mannheimia haemolytica is an important cause of acute and, in some instances, severe mastitis in ewes nursing young lambs. The organism may colonize the upper respiratory tract of lambs and can be transferred to the ewe's teat during suckling [29]. In Nineveh, *M. haemolytica* was isolated from both milk and udder-skin swabs collected from ewes with clinical mastitis; agreement between these sample types was reported as 51.1%, while their antimicrobial-susceptibility profiles sometimes differed [16]. In Al-Muthanna, the organism was recovered alongside *S. aureus* from a fatal gangrenous mastitis case [15]. In Iraqi veterinary laboratories, the organism may be underrecognized where culture and identification procedures do not distinguish it adequately from related Pasteurellaceae. Better organism identification, paired sampling, and appropriate susceptibility testing would help clarify its contribution to severe ovine mastitis.

Pseudomonas aeruginosa was reported among the bacterial agents recovered in an Iraqi investigation of ovine mastitis in Baghdad, with the authors describing it as a newly recorded

organism in the local literature [10]. International investigations associate sporadic infections with contaminated water, equipment, or intramammary preparations, and treatment may be difficult because of intrinsic and acquired antimicrobial resistance [2]. Although *Klebsiella* species have been documented in Iraqi bovine mastitis [9], their importance in ovine mammary infections has not been established by the studies reviewed here. Similarly, *Histophilus ovis* was recovered from natural subclinical mastitis and documented as an unusual isolate in Iraqi ewes [5]. These less frequently reported organisms deserve further examination in studies that include appropriate contamination controls, species confirmation, and standardized sampling.

Contagious agalactia, caused principally by *Mycoplasma agalactiae* in sheep, is recognized in several countries of the Middle East. In addition to mastitis and reduced milk production, affected animals may develop keratoconjunctivitis and arthritis [30]. In Al-Muthanna, 40% of 150 mastitic milk samples were culture-positive for mycoplasmas on PPLO agar. Of 35 mycoplasmal isolates examined by PCR, four (11.4%) were identified as *M. agalactiae* [14]. The remaining isolates were not identified conclusively to species level. Related organisms, including *M. capricolum* subsp. *capricolum* and *M. mycoides* subsp. *capri*, can also infect small ruminants [30]. Because mycoplasmas lack a cell wall, β-lactam antimicrobials are ineffective against them. Veterinary practitioners should therefore consider contagious agalactia when mastitis occurs within a flock alongside ocular or articular signs, especially where empirical treatment fails.

Mixed infections are common in ovine mastitis, particularly in gangrenous cases, where *S. aureus* may be accompanied by *M. haemolytica*, *Trueperella pyogenes*, clostridia or coliforms [2], [15]. *Bacillus* spp. isolated in Iraqi studies [26] may represent true infections or contamination during sampling; their significance should be confirmed by repeated isolation from the same half. Fungal mastitis has not been documented in Iraqi sheep.

VI. Virulence Factors and Molecular Characterization of Iraqi Isolates

Molecular investigations of bacterial virulence in Iraqi ovine mastitis have expanded in recent years, particularly for *S. aureus* isolates from Nineveh. These studies have examined genes associated with bacterial adhesion, coagulation, species identification, and antimicrobial resistance. Table 3 summarizes the reported gene targets and findings, while emphasizing that detection of a gene does not by itself establish the severity of clinical disease or the expression of the corresponding protein.

Clumping factors A and B (*clfA* and *clfB*) are surface-associated adhesins that bind host proteins, including fibrinogen, and facilitate attachment of *S. aureus* to damaged tissues [31]. These genes were detected in nearly all of the Nineveh isolates examined in the cited molecular studies [8], [18], consistent with their potential relevance to mammary infection. The coagulase gene (*coa*) was reported in coagulase-positive isolates but was absent from the coagulase-negative *S. aureus* variants in the subsequent study [8], [18]. A combined identification strategy that includes species-specific targets such as *nuc*, alongside phenotypic testing, is therefore preferable to relying exclusively on coagulase activity. Variation in the repeat region of *coa* may also contribute to strain differentiation when interpreted with validated typing methods [32].

Table 3: Virulence and resistance genes detected in bacteria from ovine milk in Iraq.

Organism (n)	Governorate	Genes targeted	Detection	Reference
S. aureus (14)	Nineveh	*nuc*, *mecA*, *clfA*, *clfB*, *coa*	*nuc*, *mecA*, *clfA*, *coa* 100%; *clfB* 92.9%	[8]
Coagulase-negative *S. aureus* (7)	Nineveh	*nuc*, *mecA*, *clfA*, *clfB*, *coa*, 16S rRNA	All except *coa* 100%; *coa* 0%	[18]
Slime-producing *S. aureus*	Baghdad area	Phenotypic slime (biofilm)	Positive; used for challenge and vaccines	[12], [13]
ESBL *E. coli* (40; milk and faeces)	Mosul	*bla*CTX-M, *bla*SHV, *bla*TEM, AmpC genes	CTX-M 100%, SHV 17.5%, TEM 12.5%, AmpC 0%	[28]
Mycoplasma spp. (35)	Al-Muthanna	Genus 16S rRNA; *M. agalactiae* lipoprotein gene	*M. agalactiae* 11.4%	[14]

In the Nineveh study, *clfA* and *clfB* sequences from sheep isolates were 98–100% identical to strains from the United Kingdom, France, Australia and South Korea, whereas *coa* sequences were only 95% similar to two earlier Iraqi (Basrah) sequences [8]. Nine sequences were deposited in GenBank (PQ141655–PQ141663) [8], and seven 16S rRNA sequences of coagulase-negative *S. aureus* were deposited as PV034830–PV034836 [18]. These are, to our knowledge, among the first published GenBank records of ovine-mastitis *S. aureus* from Iraq.

Staphylococcal enterotoxins, toxic shock syndrome toxin-1, haemolysins, and leukocidins can contribute to host-tissue injury, while some enterotoxins are important causes of food-borne disease [33]. Alpha-toxin has been implicated in the severity of gangrenous mastitis. In a French dairy flock, a gangrenous *S. aureus* isolate differed from a related subclinical isolate in several genes encoding adhesins and surface proteins, including variants involving *sdrD* and *clfA*/*clfB*, and lacked *fnbB* relative to the comparator [21]. At present, the reviewed Iraqi ovine studies do not provide systematic screening for enterotoxin or leukocidin genes. By comparison, enterotoxin A gene (*sea*) was identified in 60% of bovine-mastitis *S. aureus* isolates examined in Al-Qadisiyah [34]. Because raw sheep milk and fresh cheeses may be consumed without pasteurization, targeted investigation of enterotoxin genes and their expression in ovine isolates is a justified food-safety priority.

Biofilm formation allows staphylococci to adhere to surfaces and develop a protective extracellular matrix that can reduce susceptibility to host defenses and antimicrobial treatment. Such properties may contribute to persistent intramammary infection. Iraqi researchers recovered a slime-producing

S. aureus isolate from Awassi sheep and reported severe experimental mastitis accompanied by abscesses and fibrosis following challenge [12]. Live-attenuated and killed experimental vaccines prepared from the isolate induced antibodies in serum and milk, with greater measured titres following the live preparation [13]. In Turkish Awassi flocks, isolates associated with fatal mastitis displayed biofilm-producing capacity and resistance to several antimicrobials [35]. Important biofilm-associated genetic markers, including *icaA*, *icaD*, and *bap*, have not yet been systematically characterized in Iraqi ovine isolates. These gaps limit conclusions about the relationship between biofilm genotype, treatment failure, and disease persistence.

For ovine *E. coli*, Iraqi molecular data concern both antimicrobial resistance and selected virulence determinants. In Mosul, the gene *bla*CTX-M was detected in every isolate of the ESBL-associated sample set examined [28]; this indicates the presence of a clinically relevant resistance determinant but does not, without comparative genomic evidence, establish a common resistance-gene pool across hosts. Importantly, a 2016 study in Al-Diwaniyah used quantitative PCR to examine 60 clinical mastitis milk samples from sheep and reported detection of the Shiga toxin 1 gene (*stx1*) in eight samples (13.3%) [36]. Therefore, the earlier claim that Shiga-toxin genes had not been studied in Iraqi ovine mastitis milk is incorrect. Further studies are still needed to characterize additional virulence determinants such as *stx2* and *eae*, to confirm viable organisms and their toxin expression, and to evaluate pathogen-specific transmission risks. Similarly, molecular typing of the leukotoxin gene *lktA* in *M. haemolytica* and the virulence genes *toxA* and *exoS* in *P. aeruginosa* from Iraqi ewes remains poorly documented.

VII. Antimicrobial Resistance

Published Iraqi findings indicate important antimicrobial-resistance concerns in bacteria recovered from ovine mastitis and related sheep samples. The unregulated availability and use of antimicrobials without veterinary diagnosis or susceptibility testing have been proposed as contributing factors. In some settings, livestock owners reportedly administer treatments themselves, potentially selecting for resistance where drugs, doses, or treatment durations are inappropriate [16], [18]. Nevertheless, the available studies do not establish a quantified causal relationship between particular prescribing practices and the observed resistance profiles. More systematic recording of antimicrobial use at flock level would help evaluate the relative influence of these practices. Table 4 brings together the reported resistance findings, specifying the organisms, sampling settings, and supporting studies so that the available evidence can be compared without implying uniform national prevalence.

The most striking recent finding is the detection of *mecA* in every *S. aureus* and coagulase-negative *S. aureus* isolate from subclinical ovine mastitis in Nineveh [8], [18]. MRSA had previously been detected in bovine mastitis in the same governorate [38]. Internationally, *mecA* carriage in ovine *S. aureus* varies widely: 41.4% of isolates from sheep mastitis in Iran [39] and 17.2% in Turkish sheep flocks [40] carried it. In southern Spain, almost all staphylococci from goat and sheep bulk-tank milk were reported as methicillin-resistant [41].

Table 4: Antimicrobial resistance reported in bacteria from ovine milk and related sheep samples in Iraq.

Organism	Setting	Resistance finding	Reference
S. aureus	Subclinical mastitis, Nineveh	*mecA* detected in 14/14 isolates (genotypic MRSA)	[8]
Coagulase-negative *S. aureus*	Subclinical mastitis, Nineveh	*mecA* detected in 7/7 isolates	[18]
ESBL *E. coli*	Milk and faeces of ewes and lambs, Mosul	Tetracycline 97.5%, ciprofloxacin 80%, trimethoprim–sulfamethoxazole 65%, streptomycin 57.5%	[37]
ESBL *E. coli*	Milk and faeces, Mosul	*bla*CTX-M in 100%; no AmpC	[28]
M. haemolytica	Clinical mastitis, Nineveh	Susceptibility differed between milk and udder-skin isolates	[16]

The Iraqi findings warrant cautious interpretation. The reported methicillin-resistance classification relied primarily on detection of *mecA* by PCR, using a relatively short amplicon, without sufficiently documented confirmation by cefoxitin susceptibility testing, oxacillin minimum inhibitory concentrations, or PBP2a assays [8], [18]. The finding that all examined isolates carried *mecA* is unusual and should be independently confirmed with validated methods and suitable controls [42]. Additional investigation of the *mecC* homologue and staphylococcal cassette chromosome *mec* types may further clarify the molecular epidemiology, particularly because related resistance determinants have been recognized in ruminant-associated strains [43]. If phenotypic resistance is confirmed, treatment implications would be substantial because β-lactam agents, including cloxacillin and combinations containing penicillin, have been used in the treatment of ovine mastitis [15], [26]. Such conclusions should follow confirmatory susceptibility testing rather than PCR detection alone.

ESBL-producing *E. coli* has also been recovered from sheep in Iraq. In Mosul, investigators examined 260 milk and faecal samples collected from clinically healthy ewes, their lambs, and ewes affected by clinical mastitis, reporting ESBL-associated isolates in approximately 38.1% of the sampled material under the original study definitions [17]. All 40 isolates selected for subsequent molecular characterization carried *bla*CTX-M [28]. Among the same set of isolates, resistance to tetracycline, ciprofloxacin, and trimethoprim–sulfamethoxazole was frequent [37], demonstrating multidrug-resistant phenotypes in the tested collection. Oxytetracycline and potentiated sulfonamides are commonly used agents in sheep medicine, so their use may provide selection pressure, although this relationship was not directly quantified in the cited studies. Separate Iraqi investigations have described antimicrobial susceptibility of *E. coli* O157:H7 in calves and dogs [44], [45]; these findings provide a broader

animal-health context but are not direct evidence of transmission from ovine mastitis.

A reported Iraqi treatment investigation compared locally prepared intramammary formulations containing amoxicillin–hydrocortisone or ampicillin–hydrocortisone against a commercial cloxacillin preparation. Reported cure rates were 76.7%, 73.3%, and 75%, respectively, for the three treatment groups [26]. These results should be interpreted in relation to the original study's outcome definitions, sample sizes, and laboratory confirmation procedures. The investigation preceded the recent molecular reports of resistance-associated genes in Iraqi ovine isolates. Selective therapy at drying-off has been studied internationally but remains insufficiently evaluated under Iraqi sheep-management conditions [2]. Field trials with culture-based outcomes and withdrawal-period monitoring would improve treatment recommendations.

Three practical conclusions follow. First, empirical β-lactam therapy of staphylococcal mastitis in Iraqi ewes is likely to fail more often than in the past, and culture with susceptibility testing should precede treatment in valuable or recurrent cases. Second, susceptibility testing in Iraqi veterinary laboratories should follow standardised methods with veterinary-specific breakpoints, so that results from different governorates are comparable [42]. Third, national surveillance of resistance in mastitis pathogens should include sheep, alongside cattle and poultry.

VIII. Risk Factors, Diagnosis, and Public Health Implications

The available Iraqi studies have not provided sufficiently detailed multivariable analyses to establish independent risk factors for ovine mastitis across different production systems. Risk interpretation therefore draws on the reported Iraqi observations and on studies of Awassi and other sheep populations in comparable settings. International evidence associates mastitis risk with factors such as parity, stage of lactation, flock size, and particular suckling or management conditions. Udder-half somatic cell counts may also vary according to season and litter characteristics [11]. In a meat-producing flock, first- and second-parity ewes and those rearing lambs were reported to face a higher risk of subclinical mastitis during lactation [46]. These associations require evaluation within Iraqi flocks before they can be treated as locally established predictors.

Several features of Iraqi sheep husbandry may facilitate the spread of contagious and environmental pathogens, although their individual contributions require formal epidemiological evaluation:

- Hand milking by several family members without gloves, teat preparation or post-milking teat disinfection favours ewe-to-ewe spread of *S. aureus* and *M. agalactiae* [2], [8].
- Prolonged suckling by vigorous or twin lambs, combined with teat lesions such as those of contagious ecthyma (orf), facilitates entry of *M. haemolytica* from the lamb's nasopharynx [16], [29].
- Housing in crowded, poorly drained pens during the winter lambing season increases teat-end exposure to faecal Enterobacteriaceae [7], [17].
- Failure to consider appropriate drying-off management and retention of ewes with chronic mastitis may allow infections to persist between successive lactations [2].
- Frequent movement and mixing of flocks at markets and on shared grazing introduces new strains, including *M. agalactiae* [14], [30].
- Widespread owner treatment with antimicrobials of unknown quality selects for resistant organisms [16], [18], [37].

Clinical mastitis is recognised from udder swelling, heat, pain, abnormal secretion and, in gangrenous cases, cold, blue-black skin with a clear demarcation line [15]. Subclinical mastitis requires indirect tests. The CMT is the most widely used field test in Iraq [5], [6], [8], [10]. Its accuracy in ewes is limited, however, because normal ovine milk contains more cell debris and cytoplasmic particles than bovine milk. In Baghdad, direct microscopic somatic cell counting proved more reliable than the CMT [10].

Internationally, somatic cell counts below approximately 0.5×10^6 cells/mL have been discussed as compatible with healthy ovine mammary glands, whereas values above approximately 1×10^6 cells/mL may suggest infection, depending on the setting and case definition [2]. A bulk-milk somatic cell count near 0.65×10^6 cells/mL has been linked in some studies to a flock-level subclinical mastitis burden of approximately 15% [47]. Such values are context-dependent indicators rather than universal diagnostic thresholds. Repeated measurements can improve interpretation, and bacteriological culture remains necessary for establishing the causative organism and supporting appropriate treatment selection [47].

Milk-whey enzymes may provide relatively inexpensive supplementary diagnostic indicators. Hassan and Yousif reported several-fold elevations of LDH, ALP, and AST activities in the milk of ewes with staphylococcal or Enterobacteriaceae-associated intramammary infections compared with uninfected controls [6], [7]. These observations are consistent with findings from Iran, where affected ewes also showed increased enzyme activities in milk or whey [48]. However, enzyme elevations are markers of tissue or cellular disturbance rather than pathogen-specific tests, so results should be interpreted together with clinical findings, CMT or SCC results, and bacteriological examination.

Conventional bacteriological culture using blood agar, mannitol-salt agar, and MacConkey agar remains important for aetiological diagnosis in Iraqi veterinary laboratories. Molecular methods have been applied to confirm *S. aureus* using species-associated targets such as *nuc* and to detect *M. agalactiae* and resistance-associated determinants. Where available, MALDI-TOF mass spectrometry or molecular sequencing could improve species-level identification of coagulase-negative staphylococci and streptococci [14], [18], [25]. Commercial real-time PCR panels designed for bovine mastitis may detect some pathogens in ovine milk, but their

diagnostic sensitivity and specificity should be validated under sheep-milk conditions before routine implementation [49]. A combination of appropriate sample collection, culture, and confirmatory testing remains the most defensible approach.

Ovine mastitis in Iraq has public-health significance for at least three distinct reasons.

First, *S. aureus* is an important cause of staphylococcal food poisoning because certain strains produce enterotoxins that can remain biologically active after heat exposure [33]. In parts of Iraq, sheep milk may be consumed raw or processed into fresh cheese and other dairy products without prior pasteurization. Subclinically infected ewes may shed the organism without producing visible changes in milk or overt udder disease. The detection of *S. aureus* in milk therefore raises food-safety concerns, although the presence of the organism alone does not prove that enterotoxin is produced in the resulting food.

Second, antimicrobial-resistant bacteria and their resistance determinants may be transferred between animals and humans through direct contact, environmental exposure, and contaminated foods. Reports of *mecA*-positive staphylococci in ovine milk [8], [18] and CTX-M-associated *E. coli* in milk and faecal samples from ewes and lambs [17], [28], [37] identify sheep as a potential reservoir of clinically relevant resistance determinants in Iraq. Establishing actual transmission pathways would nevertheless require paired sampling of animals, products, people, and environments, supported by more discriminating molecular epidemiology.

Third, ruminants can serve as reservoirs of Shiga toxin-producing *E. coli* (STEC). Iraqi studies have reported virulence-associated determinants in *E. coli* O157:H7 recovered from dogs [45], [50], [51] and have used molecular methods to confirm the organism in calves [44]. The genes *stx1* and *stx2* have also been detected in bovine mastitis-associated isolates [52]. More directly relevant to ovine mastitis, Naser examined 60 clinical mastitis milk samples from ewes in Al-Diwaniyah and reported a positive *stx1* qPCR result in eight samples (13.3%) [36]. This establishes that a molecular investigation of STEC-associated genes in Iraqi ovine mastitis milk has been published, contrary to the previous version of the review. The finding does not, however, determine the national prevalence of STEC or by itself establish viable toxin-producing organisms in raw milk. Additional culture confirmation, toxin-expression testing, and geographically broader sampling remain necessary, particularly in settings where raw sheep milk and fresh dairy products are consumed.

IX. Control, Prevention, and Research Gaps

Control of ovine mastitis rests on the same principles as in cattle: reducing new infections, eliminating existing infections and culling chronically infected animals [2], [3]. These principles must be adapted to small, hand-milked, often transhumant Iraqi flocks with limited veterinary access.

- *Milking hygiene.* Washing and drying hands, milking infected ewes last, and post-milking teat dipping are inexpensive measures that directly target the contagious transmission of *S. aureus* and *M. agalactiae* [2], [8].
- *Lamb and teat management.* Prompt treatment of orf and other teat lesions and attention to ewes nursing twins reduce the entry of *M. haemolytica* [16], [29].
- *Housing.* Dry, well-drained bedding at lambing reduces exposure to faecal Enterobacteriaceae, including ESBL-producing *E. coli* [7], [17].
- *Culling.* Ewes with chronic induration, fibrosis, abscesses or a non-functional half, and survivors of gangrenous mastitis, act as reservoirs and should be culled [2], [15].
- *Drying-off therapy.* Intramammary antibiotic therapy at drying-off gives good bacteriological cure rates in dairy ewes [2]. It has not been evaluated in Iraq but is a priority where milk is sold.
- *Flock biosecurity.* Newly purchased sheep should be examined and, where indicated, tested for contagious agalactia before their introduction into established flocks [14], [30].

Treatment of clinical ovine mastitis should be guided by bacteriological culture and antimicrobial-susceptibility testing whenever feasible [42]. Unconfirmed reports of *mecA* positivity in Nineveh justify further testing but should not, by themselves, determine the failure rate of particular β-lactam treatments [8], [18]. Gangrenous mastitis is associated with severe tissue damage and commonly requires urgent veterinary evaluation, supportive treatment, and, in selected cases, surgical removal of the affected mammary half [15]. Mycoplasmal infections are intrinsically unresponsive to β-lactams, and antimicrobial treatment may not reliably eliminate persistent carriage [30]. Treatment choices must also consider animal welfare, withdrawal periods, local drug regulations, and food safety.

Iraqi investigators have explored alternative approaches to conventional antimicrobial treatment. A 1% ethanolic propolis preparation was reported to produce bacteriological cure in a small number of ewes with subclinical *S. aureus* infection or mixed *S. uberis–S. epidermidis* infection [10]. An in-vitro study of a 30% glycerin–magnesium sulphate preparation reported a relatively large inhibition zone against *S. aureus*, with activity also observed against *Proteus*, *Pseudomonas*, and *E. coli* [53]. These preliminary results require cautious interpretation: laboratory inhibition does not establish field effectiveness, and small uncontrolled treatment reports cannot demonstrate comparative clinical benefit. Appropriately designed trials would be needed before topical or intramammary preparations could be recommended as alternatives or adjuncts to licensed therapies.

Experimental vaccines developed from a slime-producing *S. aureus* strain recovered from Awassi sheep stimulated antibody responses in serum and milk. The live-attenuated preparation produced greater measured antibody titres than the killed preparation, although the reported response declined substantially after day 42 [13]. Protective efficacy against naturally acquired infection was not established, so immuno-

genicity should not be equated with demonstrated prevention of clinical mastitis. Vaccines against *M. agalactiae* are used in some neighbouring countries, but effectiveness can vary according to strain characteristics, adjuvant formulation, and vaccination procedures [30]. Before recommending new vaccines for Iraqi flocks, controlled field studies should include clinically meaningful outcomes, bacteriological confirmation, safety monitoring, and assessment of protection over an appropriate period.

This assessment determines the following priorities:

1) Multi-governorate prevalence surveys using consistent case definitions, udder-half sampling, somatic cell counting, and bacteriological culture, particularly in Anbar, Salah al-Din, Basrah, and the Kurdistan Region.
2) Species-level identification of CoNS and streptococci by MALDI-TOF or sequencing.
3) Confirmation of methicillin resistance based on phenotype, *mecC* detection and SCC *mec* typing in staphylococci from sheep.
4) Genomic investigation of toxin and biofilm determinants in ovine *S. aureus*, including *sea*, *see*, *tsst-1*, *lukF/S-PV*, *icaA*, *icaD*, and *bap*.
5) Molecular characterization of *M. haemolytica*, *P. aeruginosa*, and *M. agalactiae* isolated from mastitic milk, together with expanded culture-confirmed investigation of STEC in ovine milk samples building on the published qPCR evidence.
6) Studies on multiple risk factors and evaluations of economic losses due to the occurrence of mastitis in Awassi, Karadi and Arabi breeds.
7) Field tests on milking hygiene, dry-off treatment and immunization.
8) The concept of One Health for monitoring the relationships between ovine and bovine pathogens and human infections.

X. Conclusion

Ovine mastitis in Iraq is predominantly associated with staphylococci in the studies reviewed. Coagulase-negative staphylococci feature prominently in subclinical infections, whereas *S. aureus* is a major pathogen in clinical and gangrenous disease. Enterobacteriaceae, *M. haemolytica*, streptococci, *P. aeruginosa*, and *M. agalactiae* also contribute to the reported bacterial spectrum. Subclinical disease frequencies of approximately 12–26%, although derived from heterogeneous denominators, indicate an important hidden burden affecting milk quality, productivity, and potentially lamb health. CMT, somatic cell counting, and milk-whey enzyme measurements offer practical screening or supportive information, while definitive aetiological diagnosis depends on reliable organism identification. Recent reports of *mecA*-positive staphylococci and CTX-M-associated *E. coli* from sheep samples raise concerns that connect animal health, food safety, and antimicrobial stewardship under a One Health perspective. The evidence base remains geographically uneven and methodologically heterogeneous, and several resistance findings require independent phenotypic confirmation. Standardized national surveillance, responsible antimicrobial prescribing, and low-cost hygiene measures adapted to traditional Iraqi flocks are essential priorities. Future studies should report clear sampling denominators, species-level identification, laboratory validation, and economically relevant outcomes so that disease-control decisions can rely on more comparable evidence.

Conflict of Interest

The author declares that there are no known conflicts of interest that could have influenced the research synthesis, analysis, or presentation of this review.

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References

[1] Bayraktar, M., Shoshin, O., Saravanan, K. A., Al-Thuwaini, T. M., Gökçe, G., Fadhil, Z. H., & Güney, M. Ç. (2025). Analysis of population structure and selection signatures in two Iraqi fat-tailed sheep breeds. *Veterinary Medicine and Science, 11*(5), Article e70584.

[2] Bergonier, D., de Crémoux, R., Rupp, R., Lagriffoul, G., & Berthelot, X. (2003). Mastitis of dairy small ruminants. *Veterinary Research, 34*(5), 689–716.

[3] Gelasakis, A. I., Mavrogianni, V. S., Petridis, I. G., Vasileiou, N. G. C., & Fthenakis, G. C. (2015). Mastitis in sheep—The last 10 years and the future of research. *Veterinary Microbiology, 181*(1–2), 136–146. https://doi.org/10.1016/j.vetmic.2015.07.009

[4] Vasileiou, N. G. C., Chatzopoulos, D. C., Sarrou, S., Fragkou, I. A., Katsafadou, A. I., Mavrogianni, V. S., Petinaki, E., & Fthenakis, G. C. (2019). Role of staphylococci in mastitis in sheep. *Journal of Dairy Research, 86*(3), 254–266. https://doi.org/10.1017/S0022029919000591

[5] Hassu, S. A. S. (2006). A novel bacteria recovered from cases of subclinical mastitis in ewes. *Basrah Journal of Veterinary Research, 5*(2), 118–122.

[6] Hassan, M. S., & Yousif, A. A. (2013). Alteration of some enzymatic activities in whey of ewe's milk suffered from staphylococcal mastitis. *Mirror of Research in Veterinary Sciences and Animals, 2*(2), 8–15. https://doi.org/10.22428/mrvsa.2307-8073.2013.00222.x

[7] Hassan, M. S., & Yousif, A. A. (2014). Evaluation of some biochemical indices in "milk whey" for diagnosis of subclinical mastitis caused by some Enterobacteriaceae family. *Mirror of Research in Veterinary Sciences and Animals, 3*(1), 1–7.

[8] Alalaf, A. S., Taha, A. H., & Sheet, O. H. (2025). Genotypic characteristics and phylogenetic tree analysis of *Staphylococcus aureus* isolates from sheep subclinical mastitis milk. *Open Veterinary Journal, 15*(1), 289–299. https://doi.org/10.5455/OVJ.2025.v15.i1.27

[9] Al-Dabbagh, S. Y. A., Mahmmoud, E. N., & Al-Chalaby, A. Y. H. (2020). Bacterial bovine mastitis in Iraq: A review. *Basrah Journal of Veterinary Research, 19*(2), 76–102.

[10] Al-Jubouri, K. O. S. (2012). Usage of local propolis formulae for treatment of mastitis in ewes [Article in Arabic]. *Al-Qadisiyah Journal of Veterinary Medicine Sciences, 11*(1), 93–100.

[11] Lafi, S. Q., Al-Majali, A. M., Rousan, M. D., & Alawneh, J. M. (1998). Epidemiological studies of clinical and subclinical ovine mastitis in Awassi sheep in northern Jordan. *Preventive Veterinary Medicine, 33*(1–4), 171–181.

[12] Hammadi, K. M., Yousif, A. A., & Al-Graibawi, M. A. A. (2015). Induction of mastitis in Awassi lactating ewes with a slime producing *Staphylococcus aureus*. *Al-Qadisiyah Journal of Veterinary Medicine Sciences, 14*(2), 83–89.

[13] Hammadi, K. M., & Yousif, A. A. (2018). Evaluation of humoral immune response to a slime producing *Staphylococcus aureus* mastitis vaccine in Awassi ewes. *Diyala Agricultural Sciences Journal, 10*(Special issue), 163–176.

[14] Al-Khudher, L. A., & Kshash, Q. H. (2016). Molecular identification of *Mycoplasma agalactiae* from mastitic milk of lactating ewes in Al-Muthana province, Iraq. *Al-Qadisiyah Journal of Veterinary Medicine Sciences, 15*(2), 92–96.

[15] Al Salihi, K. A. (2018). Gangrenous mastitis in ewes: Report of two cases in Al Muthanna veterinary hospital, Al Muthanna governorate, Iraq. *Mirror of Research in Veterinary Sciences and Animals, 7*(3), 1–6.

[16] Rasheed, T. J., & Jwher, D. M. (2021). Isolation, identification and sensitivity of *Mannheimia haemolytica* from ewes udder with clinical mastitis. *Journal of Applied Veterinary Sciences, 6*(3), 25–30. https://doi.org/10.21608/javs.2021.76049.1079

[17] Mahmood, F. R., & Ahmed, I. M. (2022b). Phenotypic characterization and antibiogram of extended spectrum β-lactamase (ESBL)/AmpC-producing *Escherichia coli* isolated from sheep. *Iraqi Journal of Veterinary Sciences, 36*(2), 303–307.

[18] Abdulrazzaq, K. M., Taha, A. H., & Sheet, O. H. (2025). Phylogenetic analysis and genotypic characterization of coagulase-negative *Staphylococcus aureus* isolates from sheep subclinical mastitis milk in Nineveh governorate, Iraq. *Iraqi Journal of Veterinary Sciences, 39*(3), 555–562. https://doi.org/10.33899/ijvs.2025.158348.4186

[19] Tel, O. Y., & Bozkaya, F. (2012). Identifying the bacteria causing ovine gangrenous mastitis and detection of *Staphylococcus aureus* in gangrenous milk by PCR. *Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 18*(3), 401–406. https://doi.org/10.9775/kvfd.2011.5556

[20] Sheet, O. H. (2010). Isolation of *Staphylococcus aureus* from ruminant's milk and their resistance to antibiotics in Ninevah governorate. *Iraqi Journal of Veterinary Sciences, 24*(2), 109–114.

[21] Vautor, E., Cockfield, J., Le Maréchal, C., Le Loir, Y., Chevalier, M., Robinson, D. A., Thiery, R., & Lindsay, J. (2009). Difference in virulence between *Staphylococcus aureus* isolates causing gangrenous mastitis versus subclinical mastitis in a dairy sheep flock. *Veterinary Research, 40*(6), Article 56.

[22] Mørk, T., Kvitle, B., & Jørgensen, H. J. (2012). Reservoirs of *Staphylococcus aureus* in meat sheep and dairy cattle. *Veterinary Microbiology, 155*(1), 81–87.

[23] Pengov, A. (2001). The role of coagulase-negative *Staphylococcus* spp. and associated somatic cell counts in the ovine mammary gland. *Journal of Dairy Science, 84*(3), 572–574.

[24] Gonzalo, C., Ariznabarreta, A., Carriedo, J. A., & San Primitivo, F. (2002). Mammary pathogens and their relationship to somatic cell count and milk yield losses in dairy ewes. *Journal of Dairy Science, 85*(6), 1460–1467.

[25] Onni, T., Sanna, G., Cubeddu, G. P., Marogna, G., Lollai, S., Leori, G., & Tola, S. (2010). Identification of coagulase-negative staphylococci isolated from ovine milk samples by PCR-RFLP of 16S rRNA and *gap* genes. *Veterinary Microbiology, 144*(3–4), 347–352.

[26] Aljudi, A. M. H. (1999). Treatment of clinical mastitis in sheep with locally prepared drugs. *The Iraqi Journal of Veterinary Medicine, 23*(1), 86–92.

[27] Al-Samarrae, S. A., Sharma, V. K., & Yousif, A. A. (1985). Mastitis in sheep in Iraq. *Veterinary Record, 116*(12), 323.

[28] Mahmood, F. R., & Ahmed, I. M. (2022a). Molecular detection of ESBL/AmpC β-lactamase *Escherichia coli* isolated from sheep in Mosul city. *Iraqi Journal of Veterinary Sciences, 36*(2), 387–392. https://doi.org/10.33899/ijvs.2021.130380.1810

[29] Scott, M. J., & Jones, J. E. T. (1998). The carriage of *Pasteurella haemolytica* in sheep and its transfer between ewes and lambs in relation to mastitis. *Journal of Comparative Pathology, 118*(4), 359–363.

[30] Kumar, A., Rahal, A., Chakraborty, S., Verma, A. K., & Dhama, K. (2014). *Mycoplasma agalactiae*, an etiological agent of contagious agalactia in small ruminants: A review. *Veterinary Medicine International, 2014*, Article 286752.

[31] Tristan, A., Ying, L., Bes, M., Etienne, J., Vandenesch, F., & Lina, G. (2003). Use of multiplex PCR to identify *Staphylococcus aureus* adhesins involved in human hematogenous infections. *Journal of Clinical Microbiology, 41*(9), 4465–4467.

[32] Javid, F., Taku, A., Bhat, M. A., Badroo, G. A., Mudasir, M., & Sofi, T. A. (2018). Molecular typing of *Staphylococcus aureus* based on coagulase gene. *Veterinary World, 11*(4), 423–430.

[33] Argudín, M. Á., Mendoza, M. C., & Rodicio, M. R. (2010). Food poisoning and *Staphylococcus aureus* enterotoxins. *Toxins, 2*(7), 1751–1773.

[34] Jawad, A., Dagman, S. N., Yaseen, M. M., & Al-Karagoly, H. (2024). Phylogenetic analysis of *Staphylococcus aureus* enterotoxin A gene in Iraqi breed cows with bovine mastitis: Implications for disease management. *Open Veterinary Journal, 14*(7), 1644–1657.

[35] Tel, O. Y., Aslantaş, Ö., Keskin, O., Yılmaz, E., & Demir, C. (2012). Investigation of the antibiotic resistance and biofilm formation of *Staphylococcus aureus* strains isolated from gangrenous mastitis of ewes. *Acta Veterinaria Hungarica, 60*(2), 189–197.

[36] Naser, H. H. (2016). Detection of Shiga toxin-producing *Escherichia coli* isolated from mastitis milk of sheep by qPCR technique. *Al-Qadisiyah Journal of Veterinary Medicine Sciences, 15*(2), 1–5.

[37] Mahmood, F. R., & Ahmed, I. M. (2021). Multi-drug resistance profile of extended spectrum β-lactamases producing *Escherichia coli* isolated from sheep in Mosul city. *Iraqi Journal of Veterinary Sciences, 35*(Suppl. I–III), 37–40. https://doi.org/10.33899/ijvs.2021.130475.1829

[38] Sheet, O. H. (2022). Molecular detection of *mecA* gene in methicillin-resistant *Staphylococcus aureus* isolated from dairy mastitis in Nineveh governorate, Iraq. *Iraqi Journal of Veterinary Sciences, 36*(4), 939–943.

[39] Rahbarnia, L., Khosravi Rad, R., Dehnad, A. R., & Naghili, B. (2023). The examination of some virulence factors in *S. aureus* isolates obtained from the healthy human population, sheep mastitis, and cheese. *Iranian Journal of Veterinary Research, 24*(2), 110–115.

[40] Akgul, O., Bora, G., & Guducuoglu, H. (2021). Investigation of the gene carriage rates for *Staphylococcus aureus*, *mecA*, *vanA* and *nuc* genes in the nasal and milk specimens from the sheep caretakers with sheep. *Large Animal Review, 27*(5), 259–268.

[41] Barrero-Domínguez, B., Luque, I., Galán-Relaño, Á., Vega-Pla, J. L., Huerta, B., Román, F., & Astorga, R. J. (2019). Antimicrobial resistance and distribution of *Staphylococcus* spp. pulsotypes isolated from goat and sheep bulk tank milk in southern Spain. *Foodborne Pathogens and Disease, 16*(10), 723–730.

[42] Clinical and Laboratory Standards Institute. (2020). *Performance standards for antimicrobial disk and dilution susceptibility tests for bacteria isolated from animals* (5th ed., CLSI supplement VET01S).

[43] García-Álvarez, L., Holden, M. T. G., Lindsay, H., Webb, C. R., Brown, D. F. J., Curran, M. D., Walpole, E., Brooks, K., Pickard, D. J., Teale, C., Parkhill, J., Bentley, S. D., Edwards, G. F., Girvan, E. K., Kearns, A. M., Pichon, B., Hill, R. L. R., Larsen, A. R., Skov, R. L., … Holmes, M. A. (2011). Meticillin-resistant *Staphylococcus aureus* with a novel *mecA* homologue in human and bovine populations in the UK and Denmark: A descriptive study. *The Lancet Infectious Diseases, 11*(8), 595–603.

[44] Hasan, M. S., Hussein, M. A., & Yousif, A. A. (2018). Confirmatory detection of *Escherichia coli* O157:H7 in diarrheic and non-diarrheic calves by using real time PCR with studying the antimicrobial susceptibility of these bacteria. *Journal of Global Pharma Technology, 10*(8), 90–96.

[45] Yousif, A. A., Hasan, M. S., Najim, T. M., & Hussein, M. A. (2017). Detection of virulence and antimicrobial susceptibility testing of *Escherichia coli* O157:H7 isolated from pets and stray dogs. *Journal of Entomology and Zoology Studies, 5*(4), 573–578.

[46] Peckler, G. L., Fuenzalida, M. J., Aulik, N., & Adcock, S. J. J. (2024). Etiology, persistence, and risk factors of subclinical mastitis in a meat-producing sheep flock. *Journal of Animal Science, 102*, Article skae375. https://doi.org/10.1093/jas/skae375

[47] Fragkou, I. A., Boscos, C. M., & Fthenakis, G. C. (2014). Diagnosis of clinical or subclinical mastitis in ewes. *Small Ruminant Research, 118*(1–3), 86–92.

[48] Batavani, R. A., Mortaz, E., Falahian, K., & Dawoodi, M. A. (2003). Study on frequency, etiology and some enzymatic activities of subclinical ovine mastitis in Urmia, Iran. *Small Ruminant Research, 50*(1–2), 45–50.

[49] Zadoks, R. N., Tassi, R., Martin, E., Holopainen, J., McCallum, S., Gibbons, J., & Ballingall, K. T. (2014). Comparison of bacteriological culture and PCR for detection of bacteria in ovine milk—Sheep are not small cows. *Journal of Dairy Science, 97*(10), 6326–6333. https://doi.org/10.3168/jds.2014-8351

[50] Hasan, M. S., Yousif, A. A., & Alwan, M. J. (2016). Detection of virulent genes in *E. coli* O157:H7 isolated from puppies and adult dogs by polymerase chain reaction. *Research Journal for Veterinary Practitioners, 4*(1), 1–6.

[51] Yousif, A. A., Hasan, M. S., & Alwan, M. J. (2016). Clinical and molecular study of *E. coli* O157:H7 isolated from diarrheic and non-diarrheic dogs. *Mirror of Research in Veterinary Sciences and Animals, 5*(2), 1–10.

[52] Sheet, O. H., Al-Mahmood, O. A., Taha, Z. M., Al-Sanjary, R. A., & Abdulmawjood, A. A. (2023). Molecular detection of Stx1 and Stx2 genes

of *E. coli* isolated from sub-clinical bovine mastitis in Mosul city. *Iraqi Journal of Veterinary Sciences, 37*(2), 413–418.

[53] Owain, M. S., Oleiwi, K. I., Atiyah, A. G., & Hasan, M. S. (2020). Evaluation the antimicrobial effect of glycerin magnesia on some bacteria, in-vitro study. *Indian Journal of Forensic Medicine & Toxicology, 14*(2), 2193–2196.