Review on the Prevalence and Drug Resistance Patterns of Staphylococcus aureus in Food Producing Animals, Their Products and Humans

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ABSTRACT

Staphylococcus aureus is a gram positive bacterium that belongs to coagulase positive staphylococcus. It is widely distributed in the environment and causes diseases due to direct infection or due to the production of toxins by the bacteria. The prevalence of S. aureus ranges from 4% to 83% in different countries of the world from samples of food producing animals and their products. In Ethiopia the lowest and highest prevalence is reported as 4.2% and 48.75%, respectively. All mammals and birds are susceptible to colonization with S. aureus. Staphylococcus aureus can be treated with a wide range of antibiotics but there are efficient and inefficient antibiotics. Antibiotic resistance tests that have been conducted in different countries revealed that S. aureus were highly resistant to Ampicillin, Cloxacillin and Penicillin and less susceptible to Vancomycin and Rifampicin. The emergence of methicillin resistant Staphylococcus aureus in animal and human has become a worldwide problem.

Keywords: Staphylococcus aureus, Prevalence, Drug resistance, Food producing animal
Introduction

Staphylococcus aureus is a gram-positive, catalase-positive, usually oxidase-negative, facultative anaerobic coccus, which belongs to the family of Micrococcaceae and the group of Staphylococci. It can be distinguished from other staphylococcal species on the basis of gold colony pigmentation, production of coagulase, fermentation of mannitol and trehalose, and production of heat stable thermonuclease (Stewart, 2003). Staphylococcus aureus is a type of bacteria commonly found on the skin and hair as well as in the noses and throats of humans and animals (Graham et al., 2006).

In human and veterinary medicine, infections due to S. aureus are of major importance. It can cause a wide range of infections in food producing animal and is recognized worldwide as a major pathogen causing subclinical intramammary infection in dairy cows causing significant losses in the dairy industry (Smith et al., 2005; Turutoglu et al., 2005; Sung et al., 2008).

It is one of the most common causes of severe community associated infections of skin and soft tissue hospital acquired infections such as surgical and catheter site infections, bacteremia and pneumonia (Sung et al., 2008). It is the most important species involved in staphylococcal food poisoning and its severity and location vary from superficial skin infections, to severe infections like septicemia and meningitis (Filmon et al., 2009). Staphylococcus organisms are widely spread in many foods in Ethiopia and low contamination levels that favor growth and multiplication could induce staphylococcal food poisoning (Addis et al., 2011).

According to studies conducted in different countries, S. aureus have been isolated from most food producing animals and foods of animal origin with the prevalence of 12.2% in China (Li et al., 2009), 12.7% in Iraq (Ebrahimii et al., 2010), 25% in USA (Bhargava et al., 2011), 30.6 % in Turkey (Turutoglu et al., 2005), 34.2% in Kenya (Shitandi et al., 2004), 68% in Brazil (De oliveira et al., 2011), 74.5% in India (Sarkar et al., 2014) and 83% in Nigeria (Suleiman et al., 2013).

In Ethiopia the prevalence of S. aureus varies in different districts and it was reported as 4.2% (Husein et al., 2013) and 48.6% (Abera et al., 2012) in Jigjiga, 16.5% in Gondar (Moges et al., 2011), 21.13% in Addis Ababa (Abunna et al., 2013), 27.7% in Tigray (Gebrewahid et al., 2012), 44% in Bishoftu (Desissa et al., 2013), 44.5 % in Adama (Abera et al., 2013a) and 48.75 % in Hawassa (Daka et al., 2012).

The rise of drug resistant virulent strains of Staphylococcus aureus, particularly methicillin resistant S. aureus (MRSA) is a serious problem in the treatment and control of staphylococcal infections because these are resistant to most of the antibiotics such as beta-lactams, aminoglycosides, and macrolides (Duran et al., 2012).

Since Staphylococcus aureus causes diseases that are difficult to treat and eradicate both in people and animals, it attracts considerable attention particularly from the point of view of antimicrobial resistance and its prevalence. The main objective of this paper is to review the prevalence and antimicrobial resistant of Staphylococcus aureus in food producing animals, animal products and humans.

Diseases caused by Staphylococcus aureus

Disease pattern in food producing animals

Staphylococcus aureus can cause many forms of infection such as mastitis, dermatitis, omphalitis, bumble foot and arthritis in different animal species. (Table 1)
Table 1. Major diseases caused by *S. aureus* in food producing animals

| Host  | Disease       | References                                                                 |
|-------|---------------|---------------------------------------------------------------------------|
| Cattle| Mastitis      | Abera et al., 2010; Abera et al., 2013a; Abera et al., 2013b; Abera et al., 2012; Abunna et al., 2013; Daka et al., 2012; De oliveira et al., 2010; Katsande et al., 2013; Megersa et al., 2012; Mekbib et al., 2010; Mork et al., 2005; Sharma and Brintya, 2014; Shitandi et al., 2004; Zeryehun et al., 2013 |
| Sheep | Mastitis      | Koop et al., 2010; Mork et al., 2005 |
| Sheep | Dermatitis    | Batha et al., 2011; Scott and Murphy, 1997; Edwards et al., 2008 |
| Goat  | Mastitis      | Ebrahimi et al., 2010; Mork et al., 2005; Ribeiro et al., 2007; Shearer and Harris, 1997 |
| Pig   | Exudative Epidermitis | Foster, 2012 |
| Poultry | Bumble foot       | Butterworth, 1999 |
| Poultry | Arthritis   | Rasheed, 2011 |
| Poultry | Omphalitis | Amare et al., 2013 |
| Camel | Skin infection | Rathore and Kataria, 2012 |

**Disease pattern in human**

Approximately 20–30% of people are colonized with *S. aureus*, with the most common site for colonization being the anterior nares (Graham et al., 2006). While colonization itself does not harm the host, it has been associated with increased risk of developing infections (Wertheim et al., 2005). *S. aureus* is widespread in the environment and has become one of the most commonly isolated pathogens in hospital acquired infections. It can cause different diseases, from minor skin infections to life threatening diseases, such as abscesses (Fridkin et al., 2005; Chen et al., 2008), pneumonia (Hageman et al., 2006; Rubinstein et al., 2008), meningitis (Aguilar et al., 2010; Gordon et al., 1985), endocarditis (Fowler et al., 1999; Fernandez et al., 2009), toxic shock syndrome (Davis et al., 1980) and septicemia (Peake et al., 2006). *Staphylococcus aureus*-mediated TSS usually is caused by strains producing toxic-shock syndrome toxin-1 (TSST-1) (Dinges et al., 2000).

*Staphylococcus aureus*, especially MRSA (Methicillin resistant *S. aureus*) is a major health problem recognized as the most important nosocomial pathogen, often causing postoperative wound infections (Hussain et al., 2005; Kahasay et al., 2014). Staphylococcal food poisoning is an intoxication that is caused by the ingestion of food containing pre formed *Staphylococcal* enterotoxin (Argudin et al., 2010; Le Loir et al., 2003).

**Prevalence**

Different studies on the prevalence of *S. aureus* in food producing animals showed its presence in several countries of the world ranging from 4.2% to 83%( Table 2 and 3).

Prevalence of *S. aureus* from swab samples of humans was 29.03% in Egypt (Suelam et al., 2012), 13.9% in Nigeria (Okwu et al., 2014), 70% in India (Sarkar et al., 2014). According to a study conducted by Taddesse et al. (2014) at Dessie referral hospital in Ethiopia, the prevalence of *S. aureus* were 31.5%, 19.2% and 49.3% from inpatients, health personnel...
### Table 2. Prevalence of *S. aureus* in different countries of the world

| Country | Prevalence (%) | Samples | Detection method | References |
|---------|----------------|---------|------------------|------------|
| Brazil  | 68             | Bovine milk | Tube Coagulase test | De oliveira *et al.*, 2011 |
| China   | 12.2           | Bovine milk | Biochemical tests | Li *et al.*, 2009 |
| Egypt   | 29.03          | Bovine milk | Biochemical tests and API staph system | Suelam *et al.*, 2012 |
| India   | 74.5           | Bovine milk | Tube coagulase test and other biochemical tests | Sarkar *et al.*, 2014 |
| India   | 6.25           | Bovine milk | Biochemical tests | Thaker *et al.*, 2013 |
| Iran    | 12.17          | Milk from goat | Biochemical tests | Ebrahimi *et al.*, 2010 |
| Iraq    | 11.1           | Traditional cheese | Biochemical tests | Rahimi, 2013 |
| Iraq    | 52.04          | Tracheal Swab from layers breed | Coagulase test and APIStaphIdent miniaturized test strip system | Shareef *et al.*, 2009 |
| Iraq    | 50.98          | Tracheal swab from broiler chickens | Biochemical tests | Rasheed, 2011 |
| Iraq    | 40             | Cheese | Biochemical tests | Jaber, 2011 |
| Kenya   | 34.2           | Bovine milk | Biochemical tests | Shitandi *et al.*, 2004 |
| Netherland | 10.6        | Beef meat | Biochemical tests | Boer *et al.*, 2009 |
| Nigeria | 83             | Tracheal swab from broiler chickens | Biochemical tests | Suleiman *et al.*, 2013 |
| Nigeria | 49.2           | Ocular swab from bovine, caprine, ovine, porcine | Biochemical tests | Udegbnunam *et al.*, 2014 |
| Turkey  | 30.6           | Bovine milk | Tube coagulase test | Turutoglu *et al.*, 2005 |
| U.S.A   | 20.5           | Beef meat | Biochemical tests | Bhargava *et al.*, 2011 |
| U.S.A   | 25             | Chicken meat | Biochemical tests | Bhargava *et al.*, 2011 |

### Table 3. Prevalence of *S. aureus* in different districts of Ethiopia

| District      | Prevalence | Sample            | Detection method | References |
|---------------|------------|-------------------|------------------|------------|
| Adama         | 33.3       | Milk from mastitic cow | Biochemical tests | Abera *et al.*, 2013a |
| Adama         | 44.5       | Milk from subclinical cases | Biochemical tests | Abera *et al.*, 2013a |
| Addis Ababa   | 21.13      | Bovine milk       | Biochemical tests | Abunna *et al.*, 2013 |
| Location     | Count | Sample Type          | Test Type          | Reference                      |
|--------------|-------|----------------------|--------------------|--------------------------------|
| Addis Ababa  | 16.2  | Bovine milk          | Biochemical tests  | Mekuria et al., 2013           |
| Addis Ababa  | 28.8  | Bovine milk          | Biochemical tests  | Zeryehun et al., 2012          |
| Areka        | 54.4  | Bovine milk          | Biochemical tests  | Gebremichael et al., 2013      |
| Asella       | 35.71 | Bovine milk          | Biochemical tests  | Abera et al., 2013b            |
| Bishoftu     | 44    | Bovine milk          | Biochemical tests  | Desissa et al., 2013           |
| Bishoftu     | 5     | Cottage cheese       | Biochemical tests  | Addis et al., 2011             |
| Borenna      | 12.8  | Camel milk           | Biochemical tests  | Regassa et al., 2013           |
| Gondar       | 16.5  | Bovine milk          | Biochemical tests  | Mokes et al., 2011             |
| Hawassa      | 53.5  | Milk from mastitic cows | Biochemical tests | Megersa et al., 2012           |
| Holeta       | 13.8  | Bovine milk          | Biochemical tests  | Ayano et al., 2013             |
| Hawassa      | 48.75 | Bovine milk          | Biochemical tests  | Daka et al., 2012              |
| Jijiga       | 4.2   | Camel milk           | Biochemical tests  | Husein et al., 2013            |
| Jijiga       | 48.6  | Bovine milk          | Biochemical tests  | Abera et al., 2012             |
| North Tigray | 27.7  | Sheep and goat milk | Biochemical tests  | Gebrewahid et al., 2012        |
| Wolayita sodo | 30   | Bovine milk          | Biochemical tests  | Yohannis and Molla, 2013       |
| Wolayita sodo | 32.14| Bovine milk          | Biochemical tests  | Tessema, 2016                  |
| Asella       | 19.7  | Beef meat            | Biochemical tests  | Abunna et al., 2016            |
| Asella       | 11.9  | Bovine udder milk    | Biochemical tests  | Abunna et al., 2016            |
| Asella       | 11.1  | Bovine tank milk     | Biochemical tests  | Abunna et al., 2016            |

and objects, respectively. In a study undertaken in Debremarkos referral hospital in Ethiopia by Kahsay et al. (2014), *S. aureus* was isolated in a rate of 39.7% from surgical patients who had developed surgical site infection and out of those isolates of *S. aureus*, 49.7% were MRSA. Kejela and Bacha (2013) reported the overall prevalence of MRSA 23.08 % among the study population and specifically, the prevalence of MRSA among primary school children and prisoners were 18.8% and 48% respectively.

**Antimicrobial resistance**

The emergence of antibacterial resistance among pathogens that affect animal health is of growing concern in veterinary medicine as these resistant pathogens in animals have been incriminated as a potential health risk for humans (Moon et al., 2007). *S. aureus* exhibits resistance to a wide range of antimicrobial agents including disinfectants (Bjorland et al., 2001).

In the past, staphylococcal infections were treated using penicillin, but over the years this pathogen developed resistance to penicillin by building penicillinase. Methicillin was the next drug of choice as it is not cleaved by the penicillinase. While methicillin is very effective in treating most *Staphylococcus* infections, some strains have developed resistance to methicillin by production of penicillin binding protein and can no longer be killed by this antibiotic. These resistant bacteria are called Methicillin Resistant *Staphylococcus aureus* (MRSA) (Siegrist, 2011).
The antimicrobial resistance test conducted in Nigeria by Okwu et al. (2014) showed that the *S. aureus* isolates were resistant to Ampicillin, Cloxacillin and Penicillin with 100% while Tetracycline with 84%, Chloramphenicol and Gentamicin 66%, Erythromycin 62%, Streptomycin 58% and Methicillin 50%. Shittu et al. (2011) reported that *S. aureus* isolates were susceptible to Teicoplanin, Vancomycin, Phosphomycin, Fusidic acid, Rifampicin, Daptomycin, Mupirocin, Linezolid and Tigecycline. However, 16% of the isolates were resistant to Oxacillin, while 55% and 72% of isolates were resistant to Tetracycline and Trimethoprim/Sulphamethoxazole (Cotrimoxazole), respectively.

On the other hand Filmon et al., (2009) reported that the most efficient antibiotic was Oxacillin (76.66%), followed by Rifampicin and Ciprofloxacin from tested antibiotics of *Staphylococcus aureus*. A study conducted by Uwaezuoke and Aririatu (2004) shows a high sensitivity percentage to Gentamicin (91.7%) and Cloxacillin (85.4%) followed by Erythromycin (66.7%) and Streptomycin (66.7%) and a percentage sensitivity of 4.2%, 10.4%, 12.5% and 25% were recorded against Penicillin, Ampicillin, Tetracycline and Chloramphenicol, respectively.

Antimicrobial susceptibility tests conducted in India by Sharmaa and Brintya (2014) revealed that *S. aureus* isolates were highly susceptible towards Chloramphenicol and Gentamicin exhibiting 71.5% and 78.58% susceptibility and resistance was detected for Norfloxacin (64.28%), Penicillin (76.78%), Ciprofloxacin (73.21%), Vancomycin (94.64%), Nalidixic acid (91.07%) and Ampicillin (50%).

In a study done by Thaker et al. (2013), *S. aureus* isolates showed highest sensitivity towards Cephalothin (100%), Cotrimoxazole (100%), Cephallexin (100%) and Methicillin (100%) followed by Gentamicin (90%), Ciprofloxacin (80%), Oxacillin (70 %), Streptomycin (60%) and Ampicillin (60%). The overall high percent of *S. aureus* isolates were resistant to Penicillin-G (100%) followed by Ampicillin (40%), Oxytetracycline and Oxacillin (20%) and Streptomycin and Gentamicin (10%). Also intermediate sensitivity of *S. aureus* isolates was highest towards Oxytetracycline and Tetracycline (60%), followed by Streptomycin (30%), Ciprofloxacin (20%) and Oxacillin (10%) (Thaker et al., 2013).

A study conducted by Rathore and Katharia (2012) on *S. aureus* isolates from camel revealed that the most effective antibiotic was linezolid against which all the isolates were sensitive followed by Azithromycin and Gentamicin against which 93.33% of the isolates were sensitive; 80% isolates were sensitive to Methicillin, Levofoxacin, Rifampicin, Ofloxacin and Vancomycin, 73.33% to Azlocillin, 60% to Bacitracin and Norfloxacin and other antibiotics were less effective. Four of the antibiotics: Ampicillin, Cefexime, Metronidazole and Nalidixic acid were found completely ineffective as resistance to these antibiotics was shown by all the isolates.

According to a study conducted on drug susceptibility of *S. aureus* isolated from layers by Shareef et al. (2009), *S. aureus* were 100% sensitive to five antimicrobials, namely; Enroflaxacin, Methicillin, Trimethoprim with Sulfamethoxazole and Vancomycin, while in the opposite direction, 100% resistance were recorded for two antimicrobial, ampicillin and amoxicillin.

The results of antimicrobial susceptibility testing conducted in Ethiopia by Abera et al. (2013a) in Adama revealed that *S. aureus* was highly susceptible to Chloramphenicol (100%) followed by Gentamycin (91.7%), Kanamycin (88.9%) and Streptomycin (86.1%). In contrast, isolates were highly resistant to Penicillin (94.4%), Trimethoprim sulfamethoxazole.
According to a study conducted by Daka et al., (2012) in Hawassa Ethiopia, *S. aureus* strains were resistant to Penicillin G (67.9%), Ampicillin (70.9%), Amoxicillin-Clavulanic acid (30.9%), Ciprofloxacin (0%), Erythromycin (32.1%), Ceftriaxone (23.1%), Trimethoprim-Sulfamethoxazole (7.7%), Oxacillin (60.3%) and Vancomycin (38.5%).

According to the report of Tessema et al. (2016) *S. aureus* from poultry were resistant to Penicillin G (92.2%), Tetracycline (74.5%), Amoxicillin (58.8%) and 82.4% of *S. aureus* isolates were susceptible to Ciprofloxacin. Taddesse et al. (2014) reported that high level of *S. aureus* resistance was demonstrated to Penicillin G (90.4%), Nalidixic acid (93.2%), and Amoxicillin (82.9%), whereas, Gentamicin (84.3%), Tetracycline (62.9%) Chloramphenicol (63.6%), Ciprofloxacin (61.6%) and Kanamycin (64.4%) were relatively sensitive to *S. aureus* infection and Vancomycin exhibited 100% susceptible. Study conducted in Wolayta sodo by Tessema (2016) revealed that *S. aureus* isolated from cow milk was highly susceptible to Ciprofloxacin (100%) and highly resistant to Penicillin G (93.3%), Streptomycin (53.3%), Tetracycline (40%) and Sulfamethoxazole-trimethoprim (26.7%).

**Conclusion**

*Staphylococcus aureus* is a bacterium that causes a diversity of diseases in humans and animals. It is a common cause of contagious mastitis in dairy cows that cause a huge loss in dairy industry. The emergence of antimicrobial resistance to the bacteria especially methicillin resistance *Staphylococcus aureus* results in difficulty of the treatment of diseases caused by the bacteria. Its colonization and infection in food producing animals is a serious problem and risk to public health in addition to the economic impact of the disease on food animal production. Staphylococcal food poisoning that is caused by ingestion of *S. aureus* enterotoxins is a major problem in humans all over the world. Studies have been conducted in Ethiopia and other countries only on isolation and drug resistance of *S. aureus* both in human and animals that revealed the bacteria is a serious problem. Therefore researches are required to be done thoroughly on the molecular epidemiology of *S. aureus*, evolution, reservoirs and routes of transmission of different *S. aureus* strains in different hosts.

**References**

1. Abera M, Demie B, Aragaw K, Regassa F and Regassa A (2013a) Isolation and identification of *Staphylococcus aureus* from bovine mastitic milk and their drug resistance patterns in Adama town, Ethiopia. African Journal of Dairy Farming and Milk Production, 1 (2):19-23.
2. Abera B, Diriba L and Iticha I (2013b) Study of bovine mastitis in Asella government dairy farm of Oromia regional state, south eastern Ethiopia. International journal of current research and academic review. 1 (2): 134-135.
3. Abera M, Habte T, Aragaw K, Asmare K and Sheferaw D (2012) Major causes of mastitis and associated risk factors in smallholder dairy farms in and around Hawassa, Southern Ethiopia. Trop Anim Health Prod, 44: 1175-1179.
4. Abunna F, Abriham T, Gizaw F, Beyene T, Feyisa A, Ayana D, Mamo B and Duguma R (2016) *Staphylococcus*: Isolation, Identification and Antimicrobial Resistance in Dairy Cattle Farms, Municipal Abattoir and Personnel in and Around Asella, Ethiopia. J Vet Sci Technol. 7: 383.
5. Abunna F, Fufa G, Megersa B and Regassa A (2013) Bovine Mastitis: Prevalence, Risk Factors and Bacterial Isolation in Small-Holder Dairy Farms in Addis Ababa City, Ethiopia. Global Veterinaria, 10 (6): 647-652.
6. Addis M, Pal M and Kyule M (2011) Isolation and identification of *Staphylococcus* species from Ethiopian Cottage Cheese (Ayib) in Bishoftu, Ethiopia. Vet. Res., 4: 13-17.
7. Aguilar J, Urday-Cornejo V, Donabedian S, Perri M, Tibbetts R and Zervos M (2010) *Staphylococcus aureus* Meningitis Case Series and Literature Review. Medicine, 89(2).
8. Amare A, Mohammed-Amin A, Shiferaw A, Nazir S and Negussie H (2013) Yolk Sac Infection (Omphalitis) in Kombolcha Poultry Farm, Ethiopia.
9. Argudin M A, Mendoza M C and Rodicio M R (2010) Food Poisoning and *Staphylococcus aureus* Enterotoxins. Toxins, 2: 1751-1773.

10. Ayano A A, Hiriko F, Simyalew A M and Yohannes A (2013) Prevalence of subclinical mastitis in lactating cows in selected commercial dairy farms of Holeta district. Journal of Veterinary Medicine and Animal Health, 5(3): 67-72.

11. Batha G F, Rensburga A J, Petteyka K P V, Vuuren C M V and Kidanemariam A (2011) A literature review and investigation of staphylococcal necrotic dermatitis in sheep. J S Afr vet. Ass., 82(4): 227–231.

12. Bhargava K, Wang X, Donabedian S, Zervos M, da Rocha L and Zhang Y (2011) Methicillin-Resistant *Staphylococcus aureus* in Retail Meat, Detroit, Michigan, USA. Emerging infectious disease, 17(6).

13. Bjorland J, M Sunde and S Waage (2001) Plasmid-borne smr gene causes resistance to quaternary ammonium compounds in bovine *Staphylococcus aureus*. J. Clin. Microbiol. 39:3999–4004.

14. Boer E D, Zwartkruis-Nahuis J T M, Wit B, Huijsdens X W, Neeling A J, Bosch T, Oosteromb R A A, Vila A and Heuvelink A E (2009) Prevalence of methicillin-resistant *Staphylococcus aureus* in meat. International Journal of Food Microbiology, 134:52–56.

15. Butterworth A (1999) Infectious components of broiler lameness: A review. World’s Poultry Science Journal, 56(4):327-352.

16. Chen W C, Wang J L, Wang J T, Chen, Y.C. and Chang S C (2008) Spinal epidural abscess due to *Staphylococcus aureus*: clinical manifestations and outcomes. J Microbiol Immunol Infect., 41:215-221.

17. Daka D, Gislassie G and Yihdego D (2012) Antibiotic resistance *Staphylococcus aureus* isolated from cow’s milk in the Hawassa area, South Ethiopia. Annals of Clinical Microbiology and Antimicrobials, 11: 26-31.

18. Davis J P, Chesney P J, Wand P J and LaVenture M N (1980) Toxic-shock syndrome: epidemiologic features, recurrence, risk factors, and prevention. Engl J Med., 18:1429-1435.

19. De Oliveira A P, Watts J L, Salmon S A and Aarestrup F M (2000) Antimicrobial Susceptibility of *Staphylococcus aureus* Isolated from Bovine Mastitis in Europe and the United States. Journal of Dairy Science, 83(4): 855–862.

20. Desissa F, Makita K, Teklu A and Grace D (2013) Contamination of informally marketed bovine milk with *Staphylococcus aureus* in urban and peri urban areas of Debre-Zeit, Ethiopia. African Journal of Dairy Farming and Milk Production, 1 (1): 008-011.

21. Dinges M M, Orwin P M and Schlievert P M (2000) Exotoxins of *Staphylococcus aureus*. Clinical microbiology reviews, 13(1): 16-34.

22. Duran N, Ozer B, Duran, G Y, Yusuf Onlen and Demir C (2012) Antibiotic resistance genes and susceptibility patterns in *Staphylococci*. Indian J Med Res, 135: 389-396.

23. Ebrahim A, Shams N, Shahrokh S and Mirshokraei P (2010) Characteristics of *Staphylococci* isolated from mastitic goat milk in Iranian dairy herds. Veterinary World, 3(5): 205-208.

24. Edwards J F, Lassala A L and Spencer T E (2008) *Staphylococcus* associated Abortions in Ewes with Long-term Central Venous Catheterization. Vet Pathol., 45: 881.

25. Fernandez G M L, Gonzalez L J J, Goyenechea A, Fraile J and De-Gorgolas M (2009) Endocarditis caused by *Staphylococcus aureus*: A reappraisal of the epidemiologic, clinical and pathologic manifestations with analysis of factors determining outcome. Medicine (Baltimore), 88(1):1-22.

26. Filimon M N, Borozan A B, Gotia S L, Popescu R, Gherman V D (2009) Testing the sensitivity of *Staphylococcus aureus* Antibiotics. Analele Universititii din Oradea, Fascicula Biologie.

27. Foster A P (2012) Staphylococcal skin disease in livestock. Vet Dermatol., 23(4):342-351.

28. Fowler V G, Sanders L L, Kong L K, McClelland R S, Gottlieb G S, Li J, Ryan T, Sexton D J and Roussakis G (1999) Endocarditis Due to *Staphylococcus aureus*: 59 Prospectively Identified Cases with Follow-up. CID, 28.

29. Fridkin S K, Hageman J C, Morrison M, Sanza L T, Como-Sabetti K, Jernigan J A, Harriman K, Harrison L H, Ruth L, and Farley M M (2005) Methicillin-Resistant *Staphylococcus aureus* Disease in Three Communities, for the Active Bacterial Core Surveillance Program of the Emerging Infections Program Network. n eng j med., 352:1436-1444.

30. Gebrewahid T T, Abera B H and Menghistu H T (2012) Prevalence and Etiology of Subclinical Mastitis in Small Ruminants of Tigray Regional State, North Ethiopia. Vet. World, 5(2): 103-109.
31. Gebremichael L, Deressa B, Begna F and Mekuria A (2013) Study on prevalence of bovine mastitis in lactating cows and associated risk factors in and around Areka town, Southern of Ethiopia. Glob. J. Ind. Microbiol., 1 (1): 017-022.

32. Gordon J J, Harter D H and Phair J P (1985) Meningitis due to Staphylococcus aureus. The American Journal of Medicine, 78(6): 965–970.

33. Graham P L, Lin S X and Larson E L (2006) A U.S. population-based survey of Staphylococcus aureus colonization. Ann Intern Med., 144: 318–325.

34. Hageman J C, Uyeki T M, Francis J S, Jernigan D B, Wheeler J G, Bridges C B, Barenkamp S J, Sievert D M, Srinivasan A, Doherty M C, McDougal L K, Killgore G E, Lopatin U A, Coffman R, MacDonald J K, McAllister S K, Fosheim G E, Patel J B and McDonald L C (2006) Severe Community-acquired Pneumonia Due to Staphylococcus aureus. Emerg Infect Dis., 12(6):894.

35. Husein A, Haftu B, Hunde A and Tesfaye A (2013) Prevalence of camel (Camelus dromedaries) mastitis in Jijiga Town, Ethiopia. African Journal of Agricultural Research, 8(24): 3113-3120.

36. Hussain S, Shams R, Ahmad K, Perveen R and Riaz B (2005) Prevalence of methicillin resistant Staphylococcus aureus (MRSA) in surgical site infections in a tertiary care hospital. Journal Pathol, 3(2):81–85.

37. Jaber N N (2011) Isolation and biotyping of Staphylococcus aureus from white cheese in basrah local markets. Bas.J.Vet.Res., 10(2): 55-66.

38. Kahsay A, Mihret A, Abebe T and Andualem T (2014) Isolation and antimicrobial susceptibility pattern of Staphylococcus aureus in patients with surgical site infection at Debre Markos Referral Hospital, Amhara Region, Ethiopia. Archives of Public Health, 72:16.

39. Katsande S, Matope G, Ndengu M and Pfukenyi D M (2013) Prevalence of mastitis in dairy cows from smallholder farms in Zimbabwe. Journal of Veterinary Research, 80(1).

40. Kejela T and Bacha K (2013) Prevalence and antibiotic susceptibility pattern of methicillin resistant Staphylococcus aureus (MRSA) among primary school children and prisoners in Jimma Town, Southwest Ethiopia. Annals of Clinical Microbiology and Antimicrobials, 12:11.

41. Koop G, Rietman J F and Pieterse M C (2010) Staphylococcus aureus mastitis in Texel sheep associated with sucking twins. Veterinary record, 167:868-869.

42. Le Loir Y, Baron F and Gautier M (2003) Staphylococcus aureus and food poisoning. Genetics and Molecular Research, 2(1):63–76.

43. Li J P, Zhou H J, Yuan L, He T and Hu S H (2009) Prevalence, genetic diversity, and antimicrobial susceptibility profiles of Staphylococcus aureus isolated from bovine mastitis in Zhejiang Province, China. J Zhejiang Univ Sci B., 10(10): 753–760.

44. Megersa B, Manedo A, Abera M, Regassa A and Abunna F (2012) Mastitis in Lactating Cows at Hawassa Town: Prevalence, Risk Factors, Major Bacterial Causes and Treatment Response to Routinely Used Antibiotics. American-Eurasian Journal of Scientific Research, 7 (2): 86-91.

45. Mekibir B, Furgasa M, Abunna F, Megersa B and Regassa A (2010) Bovine Mastitis: Prevalence, Risk Factors and Major Pathogens in Dairy Farms of Holeta Town, Central Ethiopia. Veterinary World, 3(9):397-403.

46. Mekuria A, Asrat D, Woldeamanuel Y and Tefera G (2013) Identification and antimicrobial susceptibility of Staphylococcus aureus isolated from milk samples of dairy cows and nasal swabs of farm workers in selected dairy farms around Addis Ababa, Ethiopia. African journal of microbiology research, 7(27): 3501-3510.

47. Moges N, Asfaw Y, Belihu K and Tadesse A (2011) Antimicrobial Susceptibility of Mastitis Pathogens from Smallholder Dairy Herds in and Around Gondar, Ethiopia. Journal of Animal and Veterinary Advances Year, 10 (12): 1616-1622.

48. Moon J S, Lee A R, Kang H M, Lee E S, Joo Y S, Park Y H, Kim M N and Koo H C (2007) Antibiogram and coagulase diversity in staphylococcal enterotoxin-producing Staphylococcus aureus from bovine mastitis. Journal of Dairy Science, 90(4):1716-1724.

49. Mork T, Tollersrud T, Kvitle B, Jorgensen H J and Waage S (2005) Comparison of Staphylococcus aureus genotypes recovered from cases of bovine, ovine, and caprine mastitis. J Clin Microbiol, 43:3979–3984.

50. Okwu M U, Mitsan O and Okeke O P (2014) Prevalence and antimicrobial susceptibility profiles of community-acquired methicillin-resistant Staphylococcus aureus (CA-MRSA) isolates among healthy individuals in Okada, South-South, Nigeria. US Open Pharmaceutical, Biological & Chemical Sciences Journal, 1(1): 1 – 9.
51. Peake S L, Peter J V, Chan L, Wise R P, Butcher A R and Grove D I (2006) First Report of Septicemia Caused by an Obligately Anaerobic Staphylococcus aureus Infection in a Human. J Clin Microbiol., 44(6): 2311–2313.

52. Rahimi E (2013) Enterotoxigenicity of Staphylococcus aureus isolated from traditional and commercial dairy products marketed in Iran. Brazilian Journal of Microbiology, 44(2): 393-399.

53. Rasheed B Y (2011) Isolation and identification of bacteria causing arthritis in chickens. Iraqi Journal of Veterinary Sciences, 25(2): 93-95.

54. Rathore P and Kataria A K (2012) Antimicrobial susceptibility profiling of Staphylococcus aureus of camel (Camelus dromedarius) skin origin. ABAH Bioflux., 4(2): 47-50.

55. Regassa A, Golicha G, Tesfaye D, Abunna F and Megersa B (2013) Prevalence, risk factors, and major bacterial causes of camel mastitis in Borana Zone, Oromia Regional State, Ethiopia. Tropical Animal Health and Production, 45 (7):1589.

56. Ribeiro M G, Lara G H B, Bicudo S D, Souza A V G, Salerno T, Siqueira A K and Geraldo J S (2007) An unusual gangrenous goat mastitis caused by Staphylococcus aureus, Clostridium perfringens and Escherichia coli co-infection. Arq. Bras. Med. Vet. Zootec., 59(3):810-812.

57. Rubinstein E, Kollef M H and Nathwani D (2008) Pneumonia Caused by Methicillin- Resistant Staphylococcus aureus. Clin Infect Dis., 46 (5): 378-385.

58. Sarkar P, Mohanta D, De S and Debnath C (2014) Staphylococcus aureus in dairy animals and farm workers in a closed herd in Karnal, North India: Assessment of prevalence rate and COA variations. International Journal of Innovative Research in Science, Engineering and Technology, 3(4).

59. Scott P R and Murphy S (1997) Outbreak of staphylococcal dermatitis in housed lactating Suffolk ewes. Veterinary Record, 140:631–632.

60. Shareef A M, Mansour R S and Ibrahim K K (2009) Staphylococcus aureus in commercial breeder layer flocks. Iraqi Journal of Veterinary Sciences, 23:63-68.

61. Sharmaa I and Brintya A (2014) Isolation and Identification of Staphylococcus aureus from Bovine Mastitis Milk and Their Drug Resistance Patterns in Silchar Town Dairy Farms, N.E India. Online International Interdisciplinary Research Journal, 4: 256-259.

62. Shearer J K and Harris B (1992) Mastitis in Dairy Goats. http://mysrf.org/pdf/pdf_dairy/goat_handbook/dg5.pdf

63. Shitandi A, Anakalo G, Galgalo T and Mwangi M (2004) Prevalence of bovine mastitis amongst small holder dairy herds in Kenya. Israel journal of veterinary medicine, 59:1-2.

64. Shittu A O, Okon K, Adesida S, Oyedara O, Witte W, Strommenger B, Layer F and Nubel U (2011) Antibiotic resistance and molecular epidemiology of Staphylococcus aureus in Nigeria. BMC Microbiology, 11:92.

65. Siegrist J (2011) Staphylococcus aureus in the focus. Microbiology focus, 3(4): 2-5.

66. Smith E M, Green L E, Medley G F, Bird H E and Dowson C G (2005) Multilocus sequence typing of Staphylococcus aureus isolated from high-somatic-cell count cows and the environment of an organic dairy farm in the United Kingdom. J. Clin. Microbiol., 43:4731-4736.

67. Stewart C M (2003) Staphylococcus aureus and staphylococcal enterotoxins. Ch 12 In: Hocking AD (ed) Foodborne microorganisms of public health significance. 6th ed, Australian Institute of Food Science and Technology (NSW Branch), Sydney, p. 359–380.

68. Suleiman I A, Raslan, A R A and Mohamed M E M (2012) Isolation of Staphylococcus aureus from Milk and Human with Reference to its Survival on Surfaces. World Journal of Dairy and Food Sciences, 7 (2): 142-145.

69. Suleiman A, Zarria L T, Grema H A and Ahmadu P (2013) Antimicrobial resistant coagulase positive Staphylococcus aureus from chickens in Maiduguri, Nigeria. Sokoto Journal of Veterinary Sciences, 11(1): 51-55.

70. Sung J M, Lloyd D H and Lindsay J A (2008) Staphylococcus aureus host specificity: comparative genomics of human versus animal isolates by multi-strain microarray. Microbiology, 154:1949–1959.

71. Taddesse Z, Tiruneh M and Gizachew M (2014) Staphylococcus aureus and its Antimicrobial Susceptibility Pattern in Patients, Nasal carriage of Health Personnel, and objects at Dessie referral hospital, Northern Ethiopia. Global Journal of Medical Research: Microbiology and Pathology, 14(2): 29-35.

72. Tessema F (2016) Prevalence and Drug Resistance Patterns of Staphylococcus aureus in Lactating Dairy Cow’s Milk in Wolayta Sodo, Ethiopia. EC Veterinary Science, 2(5): 226-230.
73. Tessema F, Abunna F, Duguma R., Beyene T, Bihonegn A, Worku T, Adugna B and Almazu M (2016) Drug resistance pattern of *Staphylococcus* in poultry in central and southern Ethiopia. Global Journal of Science Frontier Research (D): Agriculture and Veterinary, 16(2): 30-36.

74. Thaker H C, Brahmbhatt M N and Nayak J B (2013) Isolation and identification of *Staphylococcus aureus* from milk and milk products and their drug resistance patterns in Anand, Gujarat. Veterinary World, 6(1):10-13.

75. Turutoglu H, Tasci F and Ercelik S (2005) Detection of *Staphylococcus aureus* in milk by tube coagulase test. Bull Vet Inst Pulawy, 49: 419-422.

76. Udegbunam S O, Udegbunam R I and Anyanwu M U (2014) Occurrence of Staphylococcal Ocular Infections of Food Producing Animals in Nsukka Southeast, Nigeria. Veterinary Medicine International.

77. Uwaezuoke J C and Aririatu L E (2004) A Survey of Antibiotic Resistant *Staphylococcus aureus* Strains from Clinical Sources in Owerri. J. Appl. Sci. Environ. Mgt., 8 (1): 67 – 69.

78. Wertheim H F, Melles D C, Vos M C, Van Leeuwen W and Van Belkum A (2005) The role of nasal carriage in *Staphylococcus aureus* infections. Lancet Infectious Disease, 5: 751–762.

79. Yohannis M and Molla W (2013) Prevalence, risk factors and major bacterial causes of bovine mastitis in and around Wolalta Sodo, Southern Ethiopia. African Journal of Microbiology Research, 7(48): 5400-5405.

80. Zeryehun T, Aya T and Bayecha R (2013) Study on prevalence, bacterial pathogens and associated risk factors of bovine mastitis in small holder dairy farms in and around Addis Ababa, Ethiopia. Journal of Animal and Plant Science. 23(1):50-55.