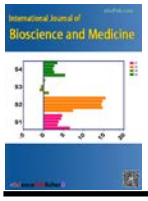
Review Article **IJBM (2017) 1:5**



International Journal of Bioscience and Medicine
(ISSN:2575-7814)

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

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How to cite this article:
Fitsum Tessema. Review on the Prevalence and Drug Resistance Patterns of Staphylococcus aureus in Food Producing Animals, Their Products and Humans. International Journal of Bioscience and Medicine, 2017; 1:5.

eSciencePublisher
eSciPub LLC, Houston, TX USA.
Website: http://escipub.com/

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). *S. 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 (Ebrahimi *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
	Dermatitis	Batha *et al*., 2011; Scott and Murphy, 1997;
	Abortion	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
	Arthritis	Rasheed, 2011
	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; *Kahsay et al*., 2014). Staphylococcal food poisoning is an intoxication that is caused by the ingestion of food containing pre formed Staphylococcal enterotoxine (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
	11.1	Traditional cheese	Biochemical tests	Rahimi, 2013
Iraq	52.04	Tracheal Swab from layers breed	Coagulase test and APIStaph Ident 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	Udegbunam *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

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
Borena	12.8	Camel milk	Biochemical tests	Regassa *et al*., 2013
Gondar	16.5	Bovine milk	Biochemical tests	Moges *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 referal 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 Oxacilin (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%), Cephalexin (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, Levofloxacin, 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; Enrofluxacin, 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

(58.3%) and Amoxicillin (36.1%). 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%), Trimethoprime-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 Ciprofloxacine. 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.

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