Prevalence and Susceptibility Patterns Associated with Staphylococcus Aureus Presence in Marketed Milk and Milk Products.

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Abstract

Introduction: *Staphylococcus aureus* is a major foodborne pathogen that poses a serious threat to public health. Indiscriminate use of antibiotics increases evolution of antibiotic resistant strains. This study aimed to determine the presence of *Staphylococcus aureus* in milk and milk products and their antimicrobial susceptibility patterns.

Methods: A total of 334 samples were collected for analysis in the laboratories. To determine antimicrobial susceptibility patterns, selected antibiotics from different classes were used: Penicillin G, Erythromycin, Vancomycin, Chloramphenicol, Tetracycline, Gentamycin, Methicillin, and Ciprofloxacin.

Results: The presence of *S. aureus* in milk and milk products was found occurring in 21.56% of all the samples. In raw milk analyzed, 64.81% of samples were contaminated by *Staphylococcus aureus*, 20.54% in pasteurized milk, 10.71% in yogurt, and 3.57% in ice cream. All isolates were found to be 100% sensitive to Tetracycline, Ciprofloxacin, Erythromycin, and Methicillin. Infrequent sensitivity was found in Gentamicin and Vancomycin. Resistance to Penicillin G was occasionally observed across the different sources of milk and milk products. Resistance to Gentamicin (42%) and Vancomycin (11%) was seldom observed in isolates, hence occurring in yogurt samples only.

Conclusion and Recommendation: The research hypothesis was rejected based on the presence of pathogenic *Staphylococcus aureus* across the different samples analyzed. It is recommended that Tetracycline, Ciprofloxacin, Methicillin, and Erythromycin antibiotics should be used for the treatment of *Staphylococcus aureus* infections based on the susceptibility test outcome.

Introduction

*Staphylococcus aureus* (*S. aureus*) is a Gram-positive and spherical coccus of about (0.8-1.0 micron) in diameter appearing in grape-like clusters. *S. aureus* are aerobes and facultative anaerobes that thrive at an optimum temperature of 37º C while the temperature at which they are active ranges between 12–44º C. They have an optimum pH of 7.5. They have been found to grow well on ordinary lab media forming a golden yellow color in agar [1]. Pathogenic microorganisms are introduced in milk products when raw milk used to process them is contaminated or by cross-contamination [2].

In Kenya, 86% of milk is marketed raw and only 14% is processed [3]. Raw milk can be 20–50% cheaper than the formal and pasteurized milk on the market [3]. Unprocessed milk is also sold in desired quantities which give the low-income earners access since they can buy as little as they can afford [3]. Milk handling equipment is one of the most significant sources of microbial contamination in milk [2]. *S. aureus* produces enterotoxins that are virulent factors responsible for food poisoning in humans. In essence, enterotoxins are basic proteins that are resistant to heat, acid, and digestive enzymes. Enterotoxins produced cannot be destroyed by exposure to 100ºC for 30 minutes, therefore posing a serious challenge to their elimination from the contaminated food and other edibles [1]. Enterotoxins consumed incubate under favorable conditions and after 4–6 hours, symptoms of infection appear such
as nausea, dizziness, severe abdominal pains and cramps, loss of appetite, diarrhea, and vomiting up to 24 hours. This period of incubation is of great significance since it differentiates food poisoning caused by *S. aureus* to that caused by *Salmonella* infection which appears 24–48 hours after eating contaminated food.

The genetic plasticity of *S. aureus* has facilitated the emergence of persistent and multidrug-resistant strains that have a major impact on human and animal health [4]. *Staphylococcus aureus* can grow at low temperatures and therefore posing a serious threat. In Kenya, there exists limited information on the prevalence of *S. aureus* in raw milk while none has been documented on milk products. Susceptibility patterns of *S. aureus* isolated from milk and milk products have also not been well documented.

**Materials And Methods**

**Sampling design**

Purposive sampling was employed in choosing supermarkets. Four supermarkets were selected in the Nairobi central business district based on the availability of all the required target samples in their storage facilities. Milk products from the supermarkets were randomly picked from the storage facilities taking into consideration the expiry date as indicated in the packet while applying the concept of Hazard Analysis and Critical Control Point (HACCP). Those with a shelf life of three days and below to expiry were excluded. Raw milk was randomly obtained from shops in the selected points of distribution between 6.00 am and 7.00 am to acquire milk directly from farmers. Blinding of the samples and concealment of supermarkets and shop outlets was done to avert bias and conflict of interest.

**Microbiological isolation in Blood agar and MacConkey agar**

MacConkey agar without crystal violet was preferred since it permits the growth of Gram-positive bacteria. Gram staining was done and microscopy was done on the selected colonies. The presence of *S. aureus* was determined from milk and milk product samples using standard confirmatory methods for the identification of *S. aureus*.

**Subculture of suspected isolates in Mannitol salt agar**

Mannitol salt agar was used as an indicator media for *S. aureus*. Isolates of *Staphylococcus* origin were sub-cultured in Mannitol Salt Agar (MSA) using the standard protocol for bacterial culture. After incubation at 37° C, golden yellow halo colonies that were big, spherical, raised, and smooth appearing in clusters were observed to grow fermenting Mannitol salt agar, and hence the characteristic yellow color caused by *S. aureus*.

**Isolation of Candida in Sabouraud’s dextrose agar**
The germ tube test was done as a confirmatory test for *Candida albicans*. A wet mount was examined microscopically for germ tubes, following the standard procedure for fungal isolation and staining technique. A positive result was indicated by a short hyphal extension arising laterally from a yeast cell with no constriction at the point of origin. A negative result had no hyphal extension arising from a yeast cell.

**Biochemical tests**

*Identification of S. aureus by catalase test*

For the Gram-positive cocci, the standard protocol for the catalase test was performed to distinguish catalase-negative *Streptococcus* sp from catalase-positive *Staphylococcus* sp. Isolates identified as catalase-positive were further identified by the coagulase test. Pathogenic *S. aureus* is both catalase and coagulase positive.

*Identification of S. aureus by coagulase test*

The standard protocol for evaluation of coagulation was done and appropriate observations made in line with the protocol. Clotting was evaluated at 30 min intervals for the first 4 hours of the test and then after 24 hours of incubation. The capacity of *S. aureus* to coagulate plasma is the principal characteristic of pathogenic *S. aureus* and is highly correlated to the capacity to produce enterotoxins harmful to the tissues of the infected host [5].

*Differentiation of Staphylococcus epidermidis from Staphylococcus saprophyticus*

*Staphylococcus epidermidis* was differentiated from *Staphylococcus saprophyticus* by novobiocin susceptibility test. *Staphylococcus epidermidis* is sensitive while *Staphylococcus saprophyticus* is resistant to novobiocin antibiotic. The zone diameter of inhibition was measured. Zone of inhibition < 12 mm was interpreted as resistant while \( \geq 16 \) mm was interpreted as sensitive.

*Microbiological identification of Escherichia coli by IMViC tests*

The indole test was performed by growing pure cultures on sterile Tryptophan broth for 24–48 hours per the identification protocol. A positive result was indicated by a red layer at the top of the tube. Methyl red test and Voges-Proskauer test were both done in Methyl red-Voges-Proskauer broth. A positive Methyl red test was identified by the development of a red color after the addition of methyl red reagent. In the Voges-Proskauer test, a positive result was indicated by the development of a red-brown color after the addition of Barritt's A and Barris B reagent. A citrate utilization test was performed on Simmons citrate agar. A positive citrate result was indicated by growth and a blue color change.

**Antimicrobial sensitivity test**

To establish antimicrobial sensitivity testing, the correctly identified *S. aureus* was thawed at room temperature, and the sample used for subculture. Panels of selected antibiotics commonly used in the
empirical treatment of *S. aureus* infections informed the choice of antibiotics used as follows: Penicillin G (10 µg) a penicillin, Erythromycin (15 µg) a macrolide, Vancomycin (5 µg) a glycopeptide, Chloramphenicol (30 µg), Tetracycline (30 µg) a tetracycline, Gentamycin (30 µg) an (aminoglycoside), Methicillin (10 µg) a penicillin and Ciprofloxacin (5 µg) a fluoroquinolone. Their effects on the growth of *S. aureus* were evaluated using the standard protocol for sensitivity testing.

**Results**

**Subculture of suspected isolates in Blood agar and Mannitol salt agar**

Pathogenic *S. aureus* showed β-hemolysis in blood agar after incubation while *S. epidermidis* exhibited γ-hemolysis. In Mannitol salt agar, the presence of growth and change of pH in the media (red to yellow) was regarded as confirmative identification of the salt-tolerant *Staphylococci*.

**Microbial contamination of milk and milk products**

Besides the targeted *S. aureus*, other bacteria and a fungus were isolated from milk and milk products in this study. These were *Staphylococcus epidermidis, Staphylococcus saprophyticus, Bacillus* species (sp), and *Escherichia coli* bacteria while the fungus was *Candida* as shown in (Table 1), P = 0.00001. There was a significant difference in contamination set at P < 0.05.

**Table 1**

Microbiological contamination of milk and milk products.$^a$

| Organism          | Pasteurized milk (n = 112) | Fermented milk (n = 112) | Ice-cream (n = 56) | Raw milk (n = 54) |
|-------------------|----------------------------|--------------------------|-------------------|-------------------|
| *Staphylococcus*  | 62 (55.4%)                 | 28 (25%)                 | 18 (32.1%)        | 49 (87.5%)        |
| *Epidermidis*     |                            |                          |                   |                   |
| *Staphylococcus*  | 23 (20.5%)                 | 12 (10.7%)               | 2 (3.6%)          | 35 (64.81%)       |
| *Aureus*          |                            |                          |                   |                   |
| *Staphylococcus*  | 31 (27.7%)                 | 18 (16.7%)               | 7 (12.5%)         | 15 (26.8%)        |
| *Saprophyticus*   |                            |                          |                   |                   |
| *Bacillus sp*     | 70 (62.5%)                 | 68 (60.7%)               | 11 (19.6%)        | 18 (32.1%)        |
| *Candida*         | 0 (0.0%)                   | 0 (0.0%)                 | 0 (0.0%)          | 2 (3.6%)          |
| *E. coli*         | 0 (0.0%)                   | 0 (0.0%)                 | 0 (0.0%)          | 45 (80.4%)        |
Other bacterial contaminants were also isolated from raw milk and milk products in varying levels.

**Biochemical tests on Staphylococcus species isolated**

Biochemical tests of microorganisms found to be of *Staphylococcus* origin were done and the results showed that *Staphylococcus aureus* coagulated rabbit plasma forming sticky clots in the test tubes. They were also catalase-positive in 3% hydrogen peroxide as opposed to the other *Staphylococcus* sp.

**Levels of contamination by pathogenic S. aureus**

The levels of total bacteria count recorded in milk and milk product samples were compared to World Health Organization (WHO) and the Kenya Bureau of Standards (KEBS) recommended safety levels of $3.0 \times 10^4$ and $2.0 \times 10^6$ colony forming units (CFU/ml) in milk. In all the samples, the total bacteria count (TBC) values of contaminated samples were higher than WHO recommended safety levels showing that the samples were of unacceptable levels of contamination and therefore not safe for consumption (Table 2). There was a significant difference in contamination compared with the acceptable level by WHO ($P = 0.0001$)

**Table 2**

Total Bacterial Counts in milk and milk products.\(^{b}\)

| Source                                | Average TBC Values (CFU/ml) |
|----------------------------------------|----------------------------|
| Raw milk (Direct from farmers)         | $3.2 \times 10^6$          |
| Raw milk (From shop outlets)           | $3.8 \times 10^6$          |
| Pasteurized milk                       | $4.2 \times 10^7$          |
| Fermented milk                         | $4.8 \times 10^7$          |
| Ice-cream                              | $3.3 \times 10^7$          |
| WHO acceptable level of contamination  | $3.0 \times 10^4$          |
| Kenya Bureau of Standards maximum limits | $2.0 \times 10^6$        |

\(^{b}\) Values indicated with similar letters are not significantly different ($P > 0.05$). Values indicated with different letters are significantly different ($P < 0.05$).

**Sensitivity profiles obtained from samples of milk and milk products.**

*Staphylococcus aureus* isolated from pasteurized milk in packets
Zones of inhibition of the growth of *S. aureus* in pasteurized milk when exposed to 8 different types of antibiotics showed that there was significantly higher inhibition by Gentamycin (mean inhibition zone 26.9 mm), Erythromycin (Ery) (mean 26.7 mm) and Penicillin (mean 26.4 mm) than the other antibiotics. Out of the 23 *S. aureus* isolates, 5 isolates were sensitive to Gentamycin (Gen) and 1 isolate was sensitive to Penicillin (Pen). All the 19 isolates were sensitive to Tetracycline (Ten), Ciprofloxacin (Chl), Erythromycin, and Methicillin (Met). 13 of the *S. aureus* isolates were resistant to Penicillin and none of the isolates was resistant to the other seven antibiotics, *P* = 0.0001 (Table 3).

### Table 3

| Antibiotic | Chl  | Gen  | Van  | Pen  | Tet  | Cip  | Ery  | Met  |
|------------|------|------|------|------|------|------|------|------|
|            | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) |
| Mean       | 25.4c| 26.9d| 14.3a| 26.4d| 20.0b| 13.5a| 26.7d| 13.3a|
| SE         | 0.35 | 0.31 | 0.23 | 0.37 | 0.31 | 0.25 | 0.21 | 0.38 |

 Values indicated with similar letters are not significantly different (*P* > 0.05). Values indicated with different letters are significantly different (*P* < 0.05).

Staphylococcus aureus isolated from fermented milk

Zones of inhibition of *S. aureus* isolated from fermented milk when exposed to 8 different antibiotics showed that there was significantly higher inhibition by Ciprofloxacin (mean inhibition zone 27.5 mm), Tetracycline (mean 26.3 mm), Erythromycin (mean 26.3 mm) and Chloramphenicol (mean 26.0 mm) than the other antibiotics (Table 4). Out of the 12 *S. aureus* isolates, 5 isolates were sensitive to Gentamycin. All 12 isolates were sensitive to Tetracycline, Ciprofloxacin, Erythromycin, and Methicillin. There was no resistant isolate of *S. aureus* from fermented milk to any of the antimicrobial agents they were exposed to, *P* = 0.0001.

### Table 4

| Antibiotic | Chl  | Gen  | Van  | Pen  | Tet  | Cip  | Ery  | Met  |
|------------|------|------|------|------|------|------|------|------|
|            | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) | (Mm) |
| Mean       | 26.0d| 15.3b| 13.0a| 13.8a| 26.3d| 27.5d| 26.3d| 19.7c|
| SE         | 0.59 | 0.38 | 0.33 | 0.44 | 0.38 | 0.42 | 0.41 | 0.50 |

 Values indicated with similar letters are not significantly different (*P* > 0.05). Values indicated with different letters are significantly different (*P* < 0.05).
Staphylococcus aureus isolated from ice-cream

Out of two *S. aureus* isolates, one isolate was sensitive to Gentamycin, both of the 2 isolates were sensitive to Tetracycline, Ciprofloxacin, Erythromycin, and Methicillin. Only one isolate was resistant to Penicillin G (Table 5).

**Table 5**

Sensitivity of *S. aureus* obtained from ice-cream (Zone diameter measurements in (Mm)).

| *S. aureus* Isolate | C 30 (Mm) profile | CN 30 (Mm) profile | VA 5 (Mm) profile | P 10 (Mm) profile | TE 30 (Mm) profile | Cip 5 (Mm) profile | E 15 (Mm) profile | ME 10 (Mm) profile |
|---------------------|-------------------|-------------------|------------------|------------------|-------------------|-------------------|-------------------|-------------------|
| 501                 | 25 I              | 16 S              | 13 I             | 15 I             | 26 S              | 27 S              | 27 S              | 20 S              |
| 502                 | 26 I              | 14 I              | 12 I             | 12 R             | 25 S              | 26 S              | 25 S              | 21 S              |

*Resistant (R), Sensitive (S), Intermediate (I), C30 (Chl), CN30 (Gen), VA5 (Van), P10 (Pen), TE30 (Tet), Cip5 (Cip) E15 (Ery), ME10 (Met)*

Staphylococcus aureus isolated from raw milk

Zones of inhibition of the growth of *S. aureus* in raw milk when exposed to 8 different types of antimicrobial agents showed that there was significantly higher inhibition by Tet (mean inhibition zone 28.26 mm), Cip (mean inhibition 26.77 mm), Chl (mean inhibition 25.97 mm), Gen (mean inhibition 26.26 mm) and Ery (mean inhibition 27.03 mm) than Met (mean inhibition 22.66 mm), Pen (mean inhibition 15.60 mm) and Van (mean inhibition 14.09 mm), \( P = 0.0001 \) (Table 6).

**Table 6**

Mean zones of inhibition of *S. aureus* to antibiotics in raw milk.

| Antibiotic | Chl (Mm) | Gen (Mm) | Van (Mm) | Pen (Mm) | Tet (Mm) | Cip (Mm) | Ery (Mm) | Met (Mm) |
|------------|----------|----------|----------|----------|----------|----------|----------|----------|
| Mean       | 25.97d   | 26.26d   | 14.09a   | 15.60b   | 28.26d   | 26.77d   | 27.03d   | 22.66c   |
| SE         | 0.22     | 0.18     | 0.19     | 0.26     | 0.30     | 0.36     | 0.27     | 0.26     |

*Values indicated with similar letters are not significantly different (\( P > 0.05 \)). Values indicated with different letters are significantly different (\( P < 0.05 \))*

**Table 7**

Susceptible isolates expressed in percentage (%).
### Table 8

Intermediate isolates expressed in percentage (%).

| Source of S. aureus isolate | Chl | Gen | Van | Pen | Tet | Cip | Ery | Met |
|-----------------------------|-----|-----|-----|-----|-----|-----|-----|-----|
| Fresh whole milk            | 0.00| 22.0| 0.00| 4.00| 100.0| 100.0| 100.0| 100.0|
| Yoghurt                     | 0.00| 58.0| 0.00| 0.00| 100.0| 100.0| 100.0| 100.0|
| Ice-cream                   | 0.00| 50.0| 0.00| 0.00| 100.0| 100.0| 100.0| 100.0|
| Raw milk                    | 0.00| 100.0| 11.43| 29.0| 100.0| 100.0| 100.0| 100.0|

9 All isolates were 100% sensitive to tetracycline, ciprofloxacin, erythromycin and methicillin: C30 – Chloramphenicol, CN 30 – Gentamycin, VA 5 – Vancomycin, P10 – Penicillin G, TE – Tetracycline, Cip 5 – Ciprofloxacin, E15 – Erythromycin, ME 10 – Methicillin

### Table 9

Resistant isolates expressed in percentage (%).

| Source of S. aureus Isolate | Chl   | Gen   | Van   | Pen   | Tet   | Cip   | Ery   | Met   |
|-----------------------------|-------|-------|-------|-------|-------|-------|-------|-------|
| Fresh                       | 100.00| 78.26 | 100.00| 39.00 | 0.00  | 0.00  | 0.00  | 0.00  |
| Whole milk                  |       |       |       |       |       |       |       |       |
| Yogurt                      | 100.00| 0.00  | 89.00 | 63.00 | 0.00  | 0.00  | 0.00  | 0.00  |
| Ice-cream                   | 100.00| 50.00 | 100.00| 50.00 | 0.00  | 0.00  | 0.00  | 0.00  |
| Raw milk                    | 100.00| 42.00 | 100.00| 67.00 | 0.00  | 0.00  | 0.00  | 0.00  |

h None of the isolates was found intermediate to tetracycline, ciprofloxacin, erythromycin and methicillin: C30 – Chloramphenicol, CN 30 – Gentamycin, VA 5 – Vancomycin, P10 – Penicillin G, TE – Tetracycline, Cip 5 – Ciprofloxacin, E15 – Erythromycin, ME 10 – Methicillin
| Source of S. aureus isolates | Antimicrobial agents |
|----------------------------|----------------------|
|                            | C30 | CN30 | VA5 | P10 | TE30 | Cip5 | E15 | ME10 |
| Fresh Whole milk           | 0.00| 0.00 | 0.00| 57.00| 0.00 | 0.00 | 0.00| 0.00 |
| Yogurt                     | 0.00| 42.00| 11.00| 37.00| 0.00 | 0.00 | 0.00| 0.00 |
| Ice cream                  | 0.00| 0.00 | 0.00| 50.00| 0.00 | 0.00 | 0.00| 0.00 |
| Raw milk                   | 0.00| 0.00 | 0.00| 4.00 | 0.00 | 0.00 | 0.00| 0.00 |

i None of the isolates was found resistant to tetracycline, ciprofloxacin, erythromycin and methicillin. However, resistance occurred occasionally to penicillin, vancomycin and gentamicin: C30 – Chloramphenicol, CN 30 – Gentamycin, VA 5 – Vancomycin, P10 – Penicillin G, TE – Tetracycline, Cip 5 – Ciprofloxacin, E15 – Erythromycin, ME 10 – Methicillin

Discussion

Other than S. aureus, other microorganisms were also isolated in this study: *Staphylococcus epidermidis, Staphylococcus saprophyticus*, *Bacillus* sp, and *Escherichia coli* bacteria while a fungus was *Candida* as shown in (Table 1). These organisms have also been cited by [6] from Tanzania who reported the isolation of *Bacillus* sp, *Proteus* sp, *Escherichia coli*, *Staphylococcus* sp, *Enterobacteria* sp, *Corynebacterium* and *Micrococcus* sp.

This study revealed a higher prevalence rate of *S. aureus* in raw milk 64.81% compared to the other milk products investigated. Microbial contamination in milk could be associated with unhygienic milking and poor handling practices that could be promoting poor milk. In Pasteurized milk, 20.54% of *S. aureus* isolates were detected and 10.71% and 3.57% in yogurt and ice-cream respectively. Most of the bacterial contaminants must have been significantly eliminated during the process of pasteurization. However, the presence of *S. aureus* in pasteurized milk in other cases indicates the process was not satisfactorily done. Its presence could also be due to exogenous contamination after pasteurization [7]. *Staphylococcus aureus* could also find access to pasteurized milk during the cooling and packaging of the products into their various packets for branding and distribution to the outlets [8].

Fermented milk is characterized by acid production, flavor additives, and cultured bacteria. This environment could have therefore been competitively harsh for *S. aureus* to survive and thrive well and hence the possible cause of few isolates isolated compared to raw milk and pasteurized milk. Low temperatures below 5°C inhibit growth and multiplication of *S. aureus* according to [9], and this could be the reason why its presence in ice-cream was notably very low compared to all other findings of this study. Contamination of the various milk and milk products as was found in this study revealed that the levels of contamination were significantly different as well as the number of samples contaminated. The microbial counts were significantly lower in farmers’ raw milk and highest in fermented milk. An implication that farmers milk was of better quality but the quality deteriorated along the supply chain due to the proliferation of the microorganisms initially present in milk or/and due to cross-contamination. It is
demonstrated (Table 2) that the results on the level of contamination increased after a send-off from the farm level by farmers. The quality of milk significantly decreases after send-off by farmers [10].

From the findings of this study, *S. aureus* investigated were largely sensitive to the antimicrobial agents used. There was, however, occasional resistance to penicillin G. All *S. aureus* isolates investigated from the different sources (Pasteurized milk, yogurt, Ice cream, and raw milk) were found to be 100% sensitive to Tetracycline, Ciprofloxacin, Erythromycin, and Methicillin. None of the isolates was found sensitive to Chloramphenicol while in Vancomycin 11.00% of the isolates were found sensitive in raw milk (Table 7). Resistance to Vancomycin was found in isolates obtained from yogurt (11%). This difference in activity by Vancomycin was thought to be brought about by the ability of *S. aureus* to acquire more resistance due to selective pressure.

Resistance to Penicillin G was variant across the four different sources; Pasteurized milk, yogurt, ice-cream, and raw milk as 57%, 37%, 50%, and 4% respectively (Table 9). Resistance to Penicillin G antibiotics as presented in the current study could have been caused by the bacterial enzymes which destroy the antibiotic before it can act on the pathogen [11]. This mechanism is mostly used by microorganisms for defense against antimicrobial agents. Besides, frequent use of Penicillin G in the treatment of both herds of cattle and humans is also among the possible cause of the emergence of more resistant strains of *S. aureus* and hence posing a serious challenge to public health. Resistance to Penicillin G (100.00%) and Gentamicin (10.00%) was observed by [12] while [13] observed that all *S. aureus* isolates were susceptible to Ciprofloxacin, Gentamicin, and Vancomycin. Isolates were also resistant to Penicillin (56%) and Tetracycline (22%).

Resistance to gentamicin was found occurring in isolates obtained from yogurt (42%). Resistance to gentamicin (aminoglycosides) is due to the evolving mechanism of *S. aureus* strains to inhibit the aminoglycoside action which occurs via protonated amine and/or hydroxyl interactions with the ribosomal RNA of the bacterial 30 s ribosomal subunit. These mechanisms of aminoglycoside resistance and genetic disorder exhibited by strains are either: aminoglycoside modifying enzymes, ribosomal mutations, or active efflux of the drug out of the bacteria [14]. Occasional resistance by *S. aureus* to antibiotics could be associated with earlier exposure of these drugs to isolates which may have enhanced the development of resistance. Likewise, failure to follow physicians’ instructions resulting in the frequent use of antibiotics can result in the emergence of multi-drug resistant strains. Also, the irresponsible use of antibiotics in animal husbandry could bring about increased antibiotic resistance by *S. aureus*. These wrong practices can result in the mutation of the organismal genes and therefore becoming more resistant to drugs commonly used in empirical treatment.

**Conclusions**

The presence of *S. aureus* in milk and milk products was found occurring in 21.56% of the total samples. The research hypothesis was rejected based on the significant difference in the levels of contamination of milk and milk products by *S. aureus*. Isolates from the different sources were found to be occasionally
resistant to Penicillin G and seldom resistant to Gentamycin and Vancomycin. The isolates were 100% sensitive to Tetracycline, Ciprofloxacin, Methicillin, and Erythromycin and occasionally intermediate to Chloramphenicol.

RECOMMENDATIONS

1. All processing procedures should be followed to the latter especially the pasteurization process so that the recommended temperatures are reached without compromise.
2. It is recommended that Tetracycline, Ciprofloxacin, Methicillin, and Erythromycin antibiotics should continue to be used for the treatment of *S. aureus*.
3. Education and public awareness regarding milk and milk product hygiene should be strengthened.
4. Finally, further research and study on hygiene practices in Kenya regarding milk and milk products and innovation of cost-effective ways of storage and preservation affordable to low-income earners should be done.

Abbreviations

HACCP
Hazard Analysis and Critical Control Point (HACCP), MSA:Mannitol Salt Agar, WHO:World Health Organization, KEBS:Kenya Bureau of Standards, CFU:colony forming units, TBC:total bacteria count, R:Resistant, S:Sensitive, I:Intermediate, C30:Chloramphenicol, CN 30:Gentamycin, VA 5:Vancomycin, P10:Penicillin G, TE:Tetracycline, Cip 5:Ciprofloxacin, E15:Erythromycin, ME 10:Methicillin, RNA:ribonucleic acid, sp:species

Declarations

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Authors’ contributions

MMJ: conception of the research idea, study design, data collection, analysis and interpretation, and manuscript write-up. ZK: data analysis and manuscript write-up. RC: supervision, study design and interpretation of results. MJM: data collection, laboratory practices and interpretation. NKA: supervision, study design and interpretation of results. BLR: supervision, data analysis and manuscript write-up. All authors read and approved the final manuscript

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The datasets used in this study are available from the corresponding author upon reasonable request.

Ethics approval and consent to participate

The study was granted ethical approval by the Kenyatta University ethical committee.

Consent for publication

Not applicable.

Competing interests

The authors declare that they have no competing interests.

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