Detection of mecA gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from farms in Probolinggo, Indonesia [version 3; peer review: 2 approved]

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Abstract

Background: Staphylococcus aureus is commonly found in dairy cows and is a source of contamination in milk. S. aureus that are resistant to beta-lactam antibiotics (especially cefoxitin) are referred to as methicillin-resistant Staphylococcus aureus (MRSA). The spread of MRSA cannot be separated from sanitation management during milking; it can originate from milk collected from the udder or from the hands of farmers during the milking process. The purpose of this study was to examine the level of MRSA contamination in dairy cow’s milk and farmer’s hand.

Methods: A total of 109 samples of dairy cow's milk and 41 samples of farmer's hand swabs were collected at a dairy farm in Probolinggo, East Java, Indonesia. Samples were cultured and purified using mannitol salt agar (MSA). The profile of S. aureus resistance was
established by disk diffusion test using a disk of beta-lactam antibiotics, namely oxacillin and cefoxitin.

**Results:** The *S. aureus* isolates that were resistant to oxacillin and cefoxitin antibiotics were then tested for oxacillin resistance screening agar base (ORSAB) as a confirmation test for MRSA identity. *S. aureus* isolates suspected to be MRSA were then tested genotypically by polymerase chain reaction (PCR) method to detect the presence of the mecA gene. The results of the isolation and identification found 80 isolates (53.33%) of *S. aureus*. The results of the resistance test found that 42 isolates (15%) of *S. aureus* were resistant to oxacillin and 10 isolates (12.5%) were resistant to cefoxitin. The ORSAB test found as many as 20 isolates (47.62%) were positive for MRSA. In PCR testing to detect the presence of the mecA gene, three isolates (30%) were positive for the mecA gene.

**Conclusions:** This study shows that several *S. aureus* isolates were MRSA and had the gene encoding mecA in dairy farms.

**Keywords**
Staphylococcus aureus, MRSA, Milk, Swab's hand, Public health

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This article is included in the **Agriculture, Food and Nutrition** gateway.

This article is included in the **Pathogens** gateway.
Introduction

*Staphylococcus aureus* is a pathogenic bacteria that can cause public health problems, because these bacteria often contaminate products of animal origin, including milk or commonly known as milk-borne disease (MBD). This opportunistic bacterial pathogen that can be found in animals and humans. This bacterium can cause various diseases ranging from mild to systemic skin infections such as pneumonia, arthritis, and meningitis. In previous studies, *S. aureus* was mostly transmitted to humans through contaminated milk. *S. aureus* is commonly found on the skin and mucosa of livestock, especially dairy cows with subclinical or clinical mastitis, which is a source of contamination in milk. If these bacteria are resistant to beta-lactam antibiotics is referred to as methicillin-resistant *S. aureus* (MRSA). It has been noted in earlier investigations that MRSA can result in new health issues for both people and animals. The high rate of MRSA contamination in dairy farms due to excessive administration of antibiotics in the treatment of dairy cows and the spread of these bacteria cannot be separated from sanitation management during milking. Contamination can happen from milk that is collected from the udder as well as from the hands of farmers during the milking process. The Probolinggo Regency, specifically in Krucil District, is one of the largest milk-producing centers in Indonesia. Antibiotics have been widely used as treatment in cases of infection in dairy cattle in Probolinggo, especially in cases of mastitis, so contamination by MRSA in dairy farms in Probolinggo is possible.

*S. aureus* evolved into strain MRSA because it received the insertion of a large DNA element between 20-100 kb called staphylococcal cassette chromosome *mec* (SCC *mec*), that underlies the change in normal penicillin-binding protein (PBP), namely PBP2 to PBP2a. PBP2a is expressed by the gene encoding *mecA* contained in SCC *mec* which has a very low affinity for beta-lactams, so that event cultured on media containing high concentrations of beta-lactams, MRSA survives. Molecular detection of the *mecA* gene using polymerase chain reaction (PCR) is often carried out to confirm the presence of MRSA isolates, but cannot be done in all laboratories because of the ability and cost constraints. Constraints in the use of PCR can be replaced by examining MRSA using the disk diffusion method with the antibiotics oxacillin and cefoxitin, which is then continued with an examination using oxacillin resistance screening agar base (ORSAB).

The purpose of this study was to examine the level of MRSA contamination in dairy cow’s milk and farmer’s hand in Probolinggo, Indonesia, as well as to compare phenotypic detection methods using screening with oxacillin and cefoxitine diffusion disks, ORSAB, and confirming genotypes using PCR to detect *mecA*-coding genes. The sensitivity and specificity of the test show the effectiveness and ease of application of the MRSA detection method.

Methods

Sampling

Milk samples were taken from the udders of female cows who were in lactation period, while the samples of farmer’s hand swabs were taken from farmers who were milking. The sample size in this study refers to the formula used by Regasa *et al.* in the study of the milk safety assessment of *Staphylococcus aureus* as follows:

\[
 n = \frac{Z^2 \times P(1-P)}{d^2}
\]

\[
 n = \frac{1.96^2 \times 0.048(1-0.048)}{0.04^2} = \frac{3.8416 \times 0.045696}{0.0016} = \frac{0.1755457536}{0.0016} = 109.72 \sim 109 \text{ dairy cow’s}
\]

Note:

\[
 n = \text{Sample size}
\]

\[
 Z = \text{Z value at 95% confidence level (1.96)}
\]
\[ P = \text{Expected prevalence is 4.8%}^{17} \]
\[ d = \text{Desired absolute precision (4%)} \]

Based on these calculations, 109 milk samples was obtained with the selection of dairy cooperatives purposively based on the amount of milk production in an area and the willingness of dairy cooperatives to participate in the study. Meanwhile, the number of farmer hand swab samples was adjusted to the number of dairy cows owned by each farmer in the dairy cooperative area, of which 41 cattle were obtained from 109 cows.

A total of 109 samples of dairy cow’s milk and 41 samples of farmer’s hand swabs were collected at a dairy farm in the Probolinggo region, East Java, Indonesia from July to September 2021. Dairy cow’s milk samples were taken from each cow in the third press as much as 30 ml which was then stored in a 60 ml sample bottle; the farmer’s hand swab samples were taken from each farmer after the milking process using a sterile cotton swab which was then stored on Amies medium.

**Bacteria isolation and identification**

As much as 1 ml of each milk sample was put into a 20 ml test tube filled with 9 ml of Mannitol Salt Broth (MSB) medium while for hand swab samples, the Amies medium was vortexed until it became liquid and then 1 ml was added into a 20 ml test tube which has been filled with 9 ml of MSB media. The test tube containing MSB which had been mixed with the sample was incubated in an incubator (Isuzu Model 2-2195, Jica) at 37°C for 24 hours. The samples were cultured and purified using Mannitol Salt Agar (MSA) (Oxoid CM0085) and then incubated at 37°C for 24 hours.

Microscopic examination of bacteria was done through Gram staining to visualise Gram-positive bacteria in the form of cocci and clusters. The biochemical examination was carried out using a catalase test and a coagulase test. The catalase test was carried out by dripping 3% hydrogen peroxide (H\(_2\)O\(_2\)) on bacterial colonies that had been placed on the surface of the glass. The coagulase test was carried out by dripping 200 \(\mu\)l of rabbit plasma into a coagulase test tube containing bacterial colonies, which was then incubated at 37°C for 24 hours.

**Oxacillin and cefoxitin disk diffusion methods**

The test was carried out following the Clinical and Laboratory Standards Institute (CLSI) 2020 guidelines: *S. aureus* was tested for susceptibility to the antibiotics oxacillin 1 \(\mu\)g and cefoxitin 30 \(\mu\)g (Oxoid) on Muller Hinton Agar (MHA) plates (Oxoid, CM0337). The identified isolates were purified on mannitol salt agar (HiMedia Pvt. Ltd., M118) and incubated at 37°C for 24 hours. Using a sterile cotton swab (AKD 10903610549), standardized isolates (0.5 McFarland standard) were evenly streaked on the surface of the MHA medium (Oxoid, CM0337). The oxacillin (1 \(\mu\)g) and cefoxitin (30 \(\mu\)g) antibiotic disks were placed side by side with a distance of 50 mm on MHA that had been inoculated with isolates, and then incubated at 37°C for 24 hours to measure the inhibition zone.

**Oxacillin resistance screen agar test**

*S. aureus* isolates resistant to oxacillin 1 \(\mu\)g and cefoxitin 30 \(\mu\)g (Oxoid) were confirmed by ORSAB (HiMedia M1415) using *S. aureus* isolates from the MHA media; plus Oxacillin Resistance Selective Supplement (Supplement, HiMedia Pvt. Ltd., FD191).

**Detection of the mecA gene**

All *S. aureus* isolates that were resistant to cefoxitin 30 \(\mu\)g and positive on ORSAB examination were then subjected to a PCR test to detect the presence of the *mecA* gene. The DNA extraction process was carried out according to the QIAamp DNA Mini Kit protocol (51304 & 51306), where previously the isolates were purified on MSA (HiMedia Pvt. Ltd, M118) and inoculated on MHA (Oxoid, CM0337). The primer used was *mecA* F: 5’-AAA ATC GAT GAT GTA AAT TGT TGG C-3’ and *mecA* R: 5’-AGT TCT GCA GTA CCG GTG TTT G-3’. The PCR master mix used GoTaq Green Master Mix (Promega, 9PIM712) which is a ready-to-use solution mixture containing Taq DNA polymerase, dNTPs, MgCl\(_2\), and a reaction buffer. DNA was amplified using a Thermal Cycler T100 machine (Bio-Rad, 186-1096) for 40 cycles in 25 \(\mu\)l of the reaction mixture with the following steps: denaturation at 94°C for 30 seconds, annealing at 55°C for 30 seconds, and extension at 72°C for 1 min with a final extension at 72°C for 5 min. A total of 10 \(\mu\)l of PCR product were analyzed by 2% agarose gel electrophoresis, and the gel was visualized under ultraviolet light. A positive test indicated a PCR product in the 533-base pair (bp) band.
Result
The results of the isolation and identification tests yielded 80 (53.33%) *S. aureus* isolates from 150 samples taken at a dairy farm in Probolinggo, East Java, Indonesia. The 80 isolates that were positive for *S. aureus* consisted of 54 isolates from dairy cow’s milk samples and 26 isolates from farmer’s hand swab samples as shown in Table 1. *S. aureus* had phenotypic colony characteristics on MSA medium, namely a change in color in the medium from red to golden-yellow indicating mannitol fermentation, while the colonies had various pigments including white, golden, and yellow as shown in Figure 1. The Gram staining test showed the Gram-positive colonies in the form of cocci and clusters as shown in Figure 2, which were then confirmed by the catalase test and coagulase test as shown in Figures 3 and 4.

The disk diffusion method on MHA medium showed that 42 isolates exhibited resistance to oxacillin preparations, with a percentage of 52.5% (28 isolates came from dairy cow’s milk samples and 14 isolates came from farmer’s hand swab sample); on the other hand, 10 isolates showed resistance to cefoxitin, with a percentage of 12.5% (five isolates came from dairy cow’s milk samples and five isolates came from farmer’s hand swab samples) as shown in Table 2 and Figure 5.

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Sample code</th>
<th>Sample size</th>
<th>Gram positive</th>
<th>Catalase positive</th>
<th>Coagulase positive</th>
<th>Positive <em>S. aureus</em> (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>AS</td>
<td>109</td>
<td>109 (100%)</td>
<td>109 (100%)</td>
<td>54 (49.54%)</td>
<td>54 (49.54%)</td>
</tr>
<tr>
<td>Swab hand</td>
<td>AT</td>
<td>41</td>
<td>41 (100%)</td>
<td>41 (100%)</td>
<td>26 (63.41%)</td>
<td>26 (63.41%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>150</strong></td>
<td></td>
<td></td>
<td></td>
<td><strong>80 (53.33%)</strong></td>
</tr>
</tbody>
</table>

Figure 1. The results of positive yellow mannitol fermentation and *Staphylococcus aureus* colonies appear mucoid white on mannitol salt agar (MSA) medium (HiMedia Pvt. Ltd, M118).
Figure 2. Microscopic picture of Gram stain test on presumptive *Staphylococcus aureus* isolates using a 1000× magnification microscope.

Figure 3. Catalase test results positive for *Staphylococcus aureus* isolates.
No *S. aureus* isolate was found to simply be resistant to cefoxitin, according to the disc diffusion test results, and all isolates that were found to be resistant to cefoxitin were also found to be resistant to oxacillin, as shown in Table 3.

Confirmation of the phenotype test that for resistance to oxacillin and cefoxitin was followed by ORSAB test, with a blue culture coloration indicating positive results while a white coloration indicated negative results. The ORSAB test showed that of the 42 isolates of *S. aureus* that were resistant to oxacillin, 20 isolates (47.62%) were confirmed MRSA by the disk diffusion method, as shown in Table 4.

*S. aureus* isolates suspected to be MRSA (Phenotypically resistant to cefoxitin and positive for ORSAB) were then tested genotypically using PCR to detect the presence of the gene encoding *mecA*. A total of 10 isolates suspected to be MRSA were tested, from which three isolates (30% of the total isolates tested by PCR) were detected positive for the *mecA* gene, as shown in Figure 6. The results of the PCR test showed that isolates suspected to be MRSA were found to have the *mecA* gene, which is resistant to the antibiotics cefoxitin and oxacillin, as shown in Table 3.

![Figure 4. Coagulase test results positive for *Staphylococcus aureus* isolates.](image)

**Table 2. Oxacillin and cefoxitin disk diffusion test of *Staphylococcus aureus***

<table>
<thead>
<tr>
<th>Sample type</th>
<th><em>Staphylococcus aureus</em> isolate (n=80)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>OX disk diffusion</td>
</tr>
<tr>
<td></td>
<td>Resistant (%)</td>
</tr>
<tr>
<td>Milk</td>
<td>28 (35%)</td>
</tr>
<tr>
<td>Swab hand</td>
<td>14 (17.5%)</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>42 (52.5%)</strong></td>
</tr>
</tbody>
</table>
Figure 5. Oxacillin (OX) and cefoxitin (FOX) resistant to disk diffusion test in Mueller Hinton Agar (MHA) (Oxoid, CM0337); OX = oxacillin, FOX = cefoxitin.

Table 3. Positive MRSA confirmed by oxacillin and cefoxitin disk diffusion, ORSAB and meca gene detection.

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Sample code</th>
<th>Resistance to disk diffusion test</th>
<th>ORSAB Test</th>
<th>meca detection using PCR</th>
<th>Number positive of MRSA isolates by meca detection (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>AT 21</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td>2 (20%)</td>
</tr>
<tr>
<td></td>
<td>AT 28</td>
<td>+ + +</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AT 29</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AT 33</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AT 41</td>
<td>+ + +</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Swab hand</td>
<td>AS 67</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td>1 (10%)</td>
</tr>
<tr>
<td></td>
<td>AS 77</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AS 80</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AS 102</td>
<td>+ + +</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>AS 109</td>
<td>+ + +</td>
<td>+</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3 (30%)</td>
</tr>
</tbody>
</table>

Table 4. Total number confirmed MRSA by oxacillin resistance screening agar base (ORSAB).

<table>
<thead>
<tr>
<th>Sample type</th>
<th>Sample code</th>
<th>Number of isolates tested ORSAB (n=42)</th>
<th>Positive ORSAB test</th>
</tr>
</thead>
<tbody>
<tr>
<td>Milk</td>
<td>AS</td>
<td>28 (66.67%)</td>
<td>15 (35.71%)</td>
</tr>
<tr>
<td>Hand swab</td>
<td>AT</td>
<td>14 (33.33%)</td>
<td>5 (11.9%)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>42 (100%)</td>
<td>20 (47.62%)</td>
</tr>
</tbody>
</table>
Discussion

MBD is quite a common public health problem, because it not only has an impact on human health, also has an impact on the health of dairy cows, especially in the milk production and quality sector. Several previous studies have reported that the incidence of contaminated milk by *S. aureus* resistant to antibiotics is found in both developed and developing countries. Improper and unhygienic handling of milk, especially during the milking process, plays an important role in the occurrence of milk contamination. Unhygienic farmer hands when milking can also potentially transmit pathogenic bacteria in milk, including *S. aureus*. *S. aureus* is a pathogenic bacterium that can cause various infectious diseases ranging from skin infections to systemic infections that can lead to death. In this study, of 150 milk samples, 80 samples (53.33%) were found to have *S. aureus* contamination; this percentage is higher than the research conducted by Wang *et al.* who isolated 90 (46.15%) *S. aureus* from 195 milk samples, and from another study conducted by Jahan *et al.* who isolated 12 (25.53%) *S. aureus* from 47 milk samples. This study employed a purposive sampling design that was carried out to detect the presence of *S. aureus* strains in dairy farms that have low milking hygiene, which can increase bacterial contamination in cow’s milk. In line with this, the research conducted by Khiabanian *et al.* showed that the difference in the number of isolates found could be influenced by differences in study design such as population and geographic distribution of the sample, infection control practices, and the type of antibiotic used, as seen in Figure 6.

The problem of the incidence of *S. aureus* infection continues to grow with the emergence of MRSA, which is resistant to all beta-lactam antibiotics, including monobactams and cephalosporins, which are a group of antibiotics often used to treat Staphylococcus infections. MRSA infection causes treatment problems and facilitates its spread, so prompt and early diagnosis is needed to identify MRSA accurately. In this study, 42 samples (52.5%) of *S. aureus* were found to be resistant to oxacillin disks, and 10 samples (12.5%) to cefoxitin disks. Miragaia stated that the phenotypic detection of MRSA using disk diffusion still has not shown accurate results, and meCA genotyping using PCR is still the main recommendation even though it cannot be done routinely. However, even so, identification of MRSA with disk diffusion is still widely used because it can be done quickly and at a lower cost. Diffusion disks using oxacillin and cefoxitin have...
the same sensitivity level of 100%, and specificities of 74.07% for oxacillin and 92.59% for cefoxitin. However, several previous studies reported that the use of the cefoxitin disk diffusion method had a better sensitivity level than that of oxacillin in detecting MRSA, because the oxacillin disk diffusion method still has a high false positive rate. Vyas et al. stated that false positives could be influenced by beta-lactamase hyperproduction, resulting in the phenotypic expression of oxacillin resistance but without a genotypic resistance mechanism.

In this study, all isolates detected were resistant to the cefoxitin and oxacillin disks. All isolates detected to be resistant to oxacillin and cefoxitin were confirmed by ORSAB assay, in line with a report by Pourmand et al. which stated that the ORSAB test has a specificity of 100%. In this study, 20 of the 42 isolates (47.62%) were found to be positive for MRSA. The sensitivity level confirmed the resistance strain being tested while the specificity was to the minimum inhibitory concentration (MIC). Cefoxitin-resistant and ORSAB-positive S. aureus isolates were tested genotypically using PCR to detect the presence of the gene encoding mecA; these isolates also had positive results in all phenotypic methods (resistance to cefoxitin and oxacillin in the disk diffusion method and positive results in the ORSAB test). These results are similar to those from research conducted by Ramandinianto et al. The antibiotic cefoxitin is a good inducer for the expression of the mecA gene because it can increase the expression of PBP2a, which is encoded by the mecA gene. This also agrees with Reichmann and Pinho and Anand et al.

From this study, it can be concluded that the occurrence of MRSA contamination in milk can be caused by various factors including the unhygienic hands of farmers when milking. MRSA contamination poses a serious public health risk, which increases the potential for the spread of difficult-to-treat staphylococci. Therefore, microbiology laboratory examinations are very important to isolate and identify MRSA isolates quickly, accurately, and cost-effectively from food samples of animal origin. Genotypic detection using PCR to detect the presence of the gene encoding mecA is a molecularly accurate MRSA test; however, in laboratories that cannot perform molecular testing, the cefoxitin disk diffusion method can be used to detect MRSA. This is based on the ability of the cefoxitin disk diffusion test in detecting the expression of the mecA gene which can be a more effective and efficient MRSA screening method.

**Conclusions**

This study shows that several S. aureus isolates are Methicillin-Resistant S. aureus (MRSA) and have the gene encoding mecA in dairy farms. The spread of S. aureus that is MRSA can be a threat to public health. Thus, prevention and control measures are needed to suppress the spread of S. aureus infection on a dairy farm in Probolinggo, East Java, Indonesia.

**Data availability**

**Underlying data**

Figshare: Detection of mecA gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from the farmer in Probolinggo, Indonesia, [https://doi.org/10.6084/m9.figshare.19784005](https://doi.org/10.6084/m9.figshare.19784005).

This project contains the following underlying data:

- CMT data and code sample (Argopuro).xlsx
- Results of Isolation and Identification (Argopuro).xlsx
- Bacterial resistance test results (Argopuro).xlsx
- MRSA confirmatory test results (Argopuro).xlsx

**Extended data**

Figshare: Detection of mecA gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from the farmer in Probolinggo, Indonesia, [https://doi.org/10.6084/m9.figshare.19784005](https://doi.org/10.6084/m9.figshare.19784005).

This project contains the following extended data:

- Table and Figure.docx

Data are available under the terms of the Creative Commons Attribution 4.0 International license (CC-BY 4.0).
Acknowledgements

The authors wish to express their sincere gratitude to Faculty of Veterinary Medicine, Universitas Airlangga. This article was supported in part by the Penelitian Hibah Mandat funding from Universitas Airlangga, Indonesia in the fiscal year 2022, with grant number: 220/UN3.15/PIT/2022.

References

Open Peer Review

Current Peer Review Status: ✔ ✔

Version 3

Reviewer Report 20 September 2022

https://doi.org/10.5256/f1000research.138608.r150894

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Department of Infectious Diseases and Public Health, Jockey Club College of Veterinary Medicine and Life Sciences, City University of Hong Kong, Hong Kong, China

Thank you for the revised version of the manuscript. I think the authors did a great job in addressing all the comments related to the initial review.

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Antibiotic resistance, Public health, Bioinformatics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

Version 2

Reviewer Report 13 September 2022

https://doi.org/10.5256/f1000research.138347.r150170

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✔ Ikechukwu Benjamin Moses

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2 Division of Infectious Diseases, Escola Paulista de Medicina, Federal University of Sao Paulo, Sao
My concerns have been addressed by the authors.

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Antimicrobial resistance surveillance in veterinary and human medicine, and the development of alternative therapeutic approaches.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard.

---

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**General comments:**
The article entitled “Detection of mecA gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from farms in Probolinggo, Indonesia” was well-written. The study design and objectives of the manuscript were good and address a critical public health issue, especially with regards to foodborne illnesses and the spread of clinically-relevant bacterial pathogens (MRSA) in livestock and their by-products. However, the authors need to make a few grammatical and technical corrections which I have already suggested in my attached comments. The research findings are in very good tandem with the research aim and objectives. If the authors are able to make the few corrections I suggested, it can be indexed.

**Abstract:**
The abstract is good and well-structured but needs a few corrections:

- **Sentence 1:** “S. aureus that are resistant to beta-lactam antibiotics are referred to as methicillin-resistant Staphylococcus aureus (MRSA).”

**Comment 1:** Authors should rephrase/restructure the above sentence in the abstract section because beta-lactam antibiotics include penicillin, ampicillin, etc. So, if for example,
an isolate is resistant to penicillin or even ampicillin, it can’t be referred to as methicillin-resistant. The disc diffusion method using cefoxitin disc (30 µg) is more reliable in identifying methicillin-resistant *S. aureus* (MRSA). So, I suggest that authors should re-write this sentence as “*S. aureus* that are resistant to beta-lactam antibiotics (especially cefoxitin) are referred to as methicillin-resistant *Staphylococcus aureus* (MRSA).

*Sentence 2:* “The purpose of this study was to examine the level of MRSA contamination in dairy cow’s milk and farmer’s hand swabs.”

**Comment 2:** Authors should delete the word “swabs” in the sentence because what is being actually assessed are the hands of the farmers. The swab is just a tool used to collect the sample.

**Comment 3:** The keyword "Swab's hand" should be changed to "hand swabs" in the list of keywords.

**Introduction:**
The introduction was generally very good. I will suggest that the authors make a change in the last paragraph of this section:

**Last paragraph of introduction:** The purpose of this study was to examine the level of MRSA contamination in dairy cow’s milk and farmer’s hand swab in Probolinggo, Indonesia, as well as to compare phenotypic detection methods using screening with oxacillin and cefoxitin diffusion disks, ORSAB, and confirming genotypes using PCR to detect mecA-coding genes.

**Comment:** I think the authors should remove the word “swab” as what is being actually assessed are the farmers’ hands, just like I mentioned in my earlier suggestion in the abstract section.

**Methods:**
The methodology was well-detailed except for some important technical corrections which I have suggested:

**Oxacillin and cefoxitin disk diffusion methods**
The test was carried out following the Clinical and Laboratory Standards Institute (CLSI) 2020 guidelines: *S. aureus* was tested for susceptibility to the antibiotics oxacillin 30 µg and cefoxitin 30 µg (Oxoid) on Muller Hinton Agar (MHA) plates (Oxoid, CM0337). The identified isolates were purified on mannitol salt agar (HiMedia Pvt. Ltd., M118), incubated at 37°C for 24 hours as a 0.5 McFarland suspension, and then taken using a sterile cotton swab of size S (AKD 10903610549). They were then wiped evenly on the surface of the MHA medium (Oxoid, CM0337). **Disk.** The oxacillin 30 µg and cefoxitin 30 µg antibiotic disks were placed side by side with a distance of 5 cm on MHA that had been inoculated with isolates, and then incubated at 37°C for 24 hours to measure the inhibition zone.

**Comment 1:** Authors should correct the concentration of oxacillin antibiotic disc to 1 µg because oxacillin disc concentration from Oxoid, UK is 1 µg while that of cefoxitin is correct at the 30 µg indicated. I think this might have been an oversight during the writing of the manuscript.
**Comment 2:** Authors should take note of the **bolded sections** in the sentence and make corrections as I indicated below for the sentence to be more comprehensive and understandable. Also, 5cm is the same as 50mm, so it is preferable to indicate that the distance between the oxacillin and cefoxitin antibiotics was 50 mm instead of 5 cm since distance units in the CLSI charts are in mm. As I mentioned earlier, the sentence in the last section should be written as: “The identified isolates were purified on mannitol salt agar (HiMedia Pvt. Ltd., M118) and incubated at 37°C for 24 hours. **Using a sterile cotton swab** (AKD 10903610549), **standardized isolates (0.5 McFarland standard) were evenly streaked** on the surface of the MHA medium (Oxoid, CM0337). The oxacillin (**1 μg**) and cefoxitin (**30 μg**) antibiotic disks were placed side by side with a distance of 50 mm on MHA that had been inoculated with isolates, and then incubated at 37°C for 24 hours to measure the inhibition zone.”

**Comment 3:** The concentration of all the oxacillin discs in the manuscript should be changed to **1 μg**.

**Results:**
The results are very clear and understandable. Data were properly interpreted and comprehensive. However, I suggested some important changes and corrections:

- **Comment 1:** The colour of *S. aureus* on mannitol salt agar (MSA) is golden-yellow. I will suggest authors use this all through the manuscript.

- **Sentence:** “Based on the results of the disk diffusion test, no *S. aureus* isolate was to only be resistant to cefoxitin: all *S. aureus* isolates that were detected to be resistant to cefoxitin were also identified as resistant to oxacillin as shown in Table 3.”

**Comment 2:** I suggest that authors should rephrase this sentence to be more understandable.

**Comment 3:** I suggest that the authors delete the column “**mecA detection using PCR**” in **Table 3** as it is empty and serves no function since the last column is already indicating the total isolates that harboured the mecA gene.

**Discussion:**
The discussion is good but needs some critical changes in some confusing sentences which I have suggested below:

- **Sentence:** ..contamination; this percentage is higher than the research conducted by Wang et al.27 which isolated 195 milk samples, of which 90 samples (46.15%) were contaminated with *S. aureus*, and from another study conducted by Jahan et al.28 who isolated 47 milk samples, of which 12 (25.53%) were contaminated with *S. aureus*.

**Comment 1:** There is a mix-up in the sentence above. The sentence is stating that milk samples were isolated while what was actually isolated was the *S. aureus* from the milk samples. I will suggest that authors should re-write this section as “..contamination; this percentage is higher than the research conducted by Wang et al.27 **who isolated 90 (46.15%) *S. aureus* from 195 milk samples, and from another study conducted by Jahan et al.28 who isolated 12 (25.53%) *S. aureus* from 47 milk samples”. 

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Sentence: ...mecA PCR results with a positive band at 533 bp. Marker line: 100-bp molecular-weight markers; Line K-: Staphylococcus aureus ATCC 25923 (Negative Control); Line AT28, AT41, and AS109: positive result for mecAgene detection; Line AT21, AT29, AT33, AS67, AS77, AS80, and AS102: negative result for mecAgene.

Comment 2: I think the authors should delete this sentence since Figure 3 already has text under the gel picture depicting what was positive for mecA, including the targeted fragment size and what was negative.

Is the work clearly and accurately presented and does it cite the current literature?
Yes

Is the study design appropriate and is the work technically sound?
Partly

Are sufficient details of methods and analysis provided to allow replication by others?
Yes

If applicable, is the statistical analysis and its interpretation appropriate?
Not applicable

Are all the source data underlying the results available to ensure full reproducibility?
Yes

Are the conclusions drawn adequately supported by the results?
Yes

Competing Interests: No competing interests were disclosed.

Reviewer Expertise: Antimicrobial resistance surveillance in veterinary and human medicine, and the development of alternative therapeutic approaches.

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 06 Sep 2022
Aswin Rafif Khairullah, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya, Indonesia

Respected reviewer Moses, thanks a lot for your able input. We have followed all your kind suggestions accordingly. Kindly find our response:

Thanks for your valuable comments and suggestions on the manuscript entitled: “Detection of mecA gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from farms in Probolinggo, Indonesia”
We welcome feedback. We have made modifications to the study on the following points:

**Abstract section:**
Authors should rephrase/restructure the above sentence in the abstract section because beta-lactam antibiotics include penicillin, ampicillin, etc. So, if for example, an isolate is resistant to penicillin or even ampicillin, it can’t be referred to as methicillin-resistant. The disc diffusion method using cefoxitin disc (30 µg) is more reliable in identifying methicillin-resistant S. aureus (MRSA). So, I suggest that authors should re-write this sentence as “S. aureus that are resistant to beta-lactam antibiotics (especially cefoxitin) are referred to as methicillin-resistant Staphylococcus aureus (MRSA).

**Response:** We have revised and rephrased/restructured this sentence: "S. aureus that are resistant to beta-lactam antibiotics are referred to as methicillin-resistant *Staphylococcus aureus* (MRSA)."

Authors should delete the word “swabs” in the sentence because what is being actually assessed are the hands of the farmers. The swab is just a tool used to collect the sample.

**Response:** We have deleted the word “swabs” in the sentence.

**Introduction section**
I think authors should remove the word “swab” as what is being actually assessed are the farmers’ hands just like I mentioned in my earlier suggestion in the abstract section.

**Response:** We have removed the word swabs accordingly as you suggested to us.

**Methodology section**
Authors should correct the concentration of oxacillin antibiotic disc to 1 µg because oxacillin disc concentration from Oxoid, UK is 1 µg while that of cefoxitin is correct at the 30 µg indicated. I think this might have been an oversight during the writing of the manuscript.

**Response:** According to your suggestion we have corrected the concentration of oxacillin antibiotic disc to 1 µg.

Authors should take note of the **bolded sections** in the sentence and make corrections as I indicated below for the sentence to be more comprehensive and understandable. Also, 5cm is the same as 50mm. So, it is preferable to indicate that the distance between the oxacillin and cefoxitin antibiotics were 50 mm instead of 5 cm since distance units in the CLSI charts are in mm. Like I mentioned earlier, the sentence in the last section should be written as: “The identified isolates were purified on mannitol salt agar (HiMedia Pvt. Ltd., M118) and incubated at 37°C for 24 hours. **Using a sterile cotton swab** (AKD 10903610549), **standardized isolates (0.5 McFarland standard) were evenly streaked** on the surface of the MHA medium (Oxoid, CM0337). The oxacillin (1 µg) and cefoxitin (30 µg) antibiotic disks were placed side by side with a distance of 50 mm on MHA that had been inoculated with isolates, and then incubated at 37°C for 24 hours to measure the inhibition zone.”
Response: We have corrected the whole section accordingly as you suggested. The concentration of all the oxacillin discs in the manuscript should be changed to 1μg.

Results section
The colour of *S. aureus* on mannitol salt agar (MSA) is golden-yellow. I will suggest authors use this all through the manuscript.

Response: We have corrected this sentence throughout the manuscript.

I suggest that authors should rephrase this sentence to be more understandable.

Response: We have rephrased the whole sentence of table three so that it is understandable.

I suggest that authors delete the column of “mecA detection using PCR” in Table 3 as it is empty and serves no function since the last column is already indicating the total isolates that harboured mecA gene.

Response: We have followed your suggestions and made changes in Table 3.

Discussion section
There is a mix up in the sentence above. The sentence is stating that milk samples were isolated while what was actually isolated were the *S. aureus* from the milk samples. I will suggest that authors should re-write this section as “..contamination; this percentage is higher than the research conducted by Wang *et al.*27 who isolated 90 (46.15 %) *S. aureus* from 195 milk samples, and from another study conducted by Jahan *et al.*28 who isolated 12 (25.53%) *S. aureus* from 47 milk samples”.

Response: We have corrected your recommended sentence accordingly in the whole section of the manuscript.

I think Authors should delete this sentence since Figure 3 already has a writing under the gel picture depicting what was positive for mecA, including the targeted fragment size and what as negative.

Response: We have deleted this sentence.

Competing Interests: no
Introduction:
1. "*Staphylococcus aureus* is a pathogenic bacteria...", "*S. aureus* is an opportunistic bacterial pathogen..." - The two lines are almost similar and seem redundant. However, using pathogenic bacteria on the first line is unnecessary.

2. "In previous studies, *S. aureus* mainly was transmitted to humans through contaminated milk..." - In this line, you should add at least three references.

3. "These bacteria can quickly evolve into antibiotic-resistant strains due to inappropriate antibiotic administration" - Please delete the line or re-write it. It's challenging to make such a bold statement regarding drug administration.

4. "*S. aureus* that is resistant to beta-lactam antibiotics is referred to as methicillin-resistant *S. aureus* (MRSA)" - Why this line again? Please check the coherence of the lines.

5. "In previous studies, it was reported that the presence of MRSA can cause new health problems..." - Please re-write the introduction section to improve the flow of the introduction - sorry.

Methods:
1. How was the sample size calculated?

2. Please describe the sampling strategy.

3. What was the condition of the cows? i.e., lactation, age, antibiotic administration, housing type, mastitis condition, etc.

4. How do you select the dairy animals from the herd?

5. Why were hand swabs taken after milking? Before milking seems more accurate. Before milk collection, what process did you follow for the aseptic milk collection?

6. I don't find any importance in microscopic examination here.

7. What was the positive isolate used as a standard?

8. For MRSA, you can do only Cefoxitin disk diffusion for the confirmation. Oxacillin MIC is recommended according to CLSI (13th edition, CLSI, M02, Page 30).

Results:
1. "The Gram staining test showed the Gram-positive colonies in the form of cocci and clusters, which were then confirmed by the catalase test and coagulase test" - Change the line and add both biochemical test results (+/-).

2. You did not include the correlation between the isolates recovered from milk or hand swab.

3. "...milk can be caused by various factors including the unhygienic hands of farmers when milking..." - You did not take the swab before milking, how do you argue about it?

**Discussion and Conclusions:**

1. I think the authors did a great job describing the findings.

**References**


**Is the work clearly and accurately presented and does it cite the current literature?**

Yes

**Is the study design appropriate and is the work technically sound?**

Partly

**Are sufficient details of methods and analysis provided to allow replication by others?**

Yes

**If applicable, is the statistical analysis and its interpretation appropriate?**

Yes

**Are all the source data underlying the results available to ensure full reproducibility?**

Yes

**Are the conclusions drawn adequately supported by the results?**

Yes

**Competing Interests:** No competing interests were disclosed.

**Reviewer Expertise:** Antibiotic resistance, Public health, Bioinformatics

I confirm that I have read this submission and believe that I have an appropriate level of expertise to confirm that it is of an acceptable scientific standard, however I have significant reservations, as outlined above.

Author Response 13 Sep 2022

Aswin Rafif Khairullah, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya,
Indonesia

Thanks for your valuable comments and suggestions on the manuscript entitled: “Detection of meca gene and methicillin-resistant Staphylococcus aureus (MRSA) isolated from milk and risk factors from farms in Probolinggo, Indonesia”

Abstract section:
No need for 'Swab's hand' as a keyword.

Response: We have removed the "swab hand's" description in the keywords.

Introduction section
"Staphylococcus aureus is a pathogenic bacteria...", "S. aureus is an opportunistic bacterial pathogen..." - The two lines are almost similar and seem redundant. However, using pathogenic bacteria on the first line is unnecessary.

Response: We have removed the description of S. aureus in the second sentence so that there is no repetition of the word.

"Staphylococcus aureus is a pathogenic bacteria...", "S. aureus is an opportunistic bacterial pathogen..." - The two lines are almost similar and seem redundant. However, using pathogenic bacteria on the first line is unnecessary.

Response: We have removed the description of S. aureus in the second sentence so that there is no repetition of the word.

"In previous studies, S. aureus mainly was transmitted to humans through contaminated milk..." - In this line, you should add at least three references.

Response: We have added two more references to the sentence so that there are three references in the sentence.

"These bacteria can quickly evolve into antibiotic-resistant strains due to inappropriate antibiotic administration" - Please delete the line or re-write it. It's challenging to make such a bold statement regarding drug administration.

Response: We have deleted the sentence.

"S. aureus that is resistant to beta-lactam antibiotics is referred to as methicillin-resistant S. aureus (MRSA)" - Why this line again? Please check the coherence of the lines.

Response: We have corrected the sentence to make it clearer.

"In previous studies, it was reported that the presence of MRSA can cause new health problems..." - Please re-write the introduction section to improve the flow of the introduction.
**Response:** We have corrected the sentence to make it clearer.

**Methodology section**

How was the sample size calculated?

**Response:** We have added the sample calculation formula to the methodology.

Please describe the sampling strategy.

**Response:** Based on these calculations, a sample was obtained with the selection of dairy cooperatives purposively based on the amount of milk production in an area and the willingness of dairy cooperatives to participate in the study.

What was the condition of the cows? i.e., lactation, age, antibiotic administration, housing type, mastitis condition, etc.

**Response:** Milk samples were taken from the udders of female cows who were in the lactation period.

How do you select the dairy animals from the herd?

**Response:** The condition of most dairy farms in Indonesia is not in a herd, but a few dairy cows are kept in cages.

Why were hand swabs taken after milking? Before milking seems more accurate. Before milk collection, what process did you follow for the aseptic milk collection?

**Response:** Because after the milking process there is cross-contamination of MRSA transmission from cows to humans and humans to cows. We have sterilized the sample bottles that we will use to take samples and milk samples taken directly from the cow's nipples.

I don't find any importance in microscopic examination here.

**Response:** We have added a description of the microscopic examination in Table 1 along with a picture of the results of Gram staining observed through a microscope.

What was the positive isolate used as a standard?

**Response:** Isolates were tested positive for *Staphylococcus aureus* when they had yellow colonies on Mannitol Salt Agar (MSA) media accompanied by positive results on Gram-positive staining and biochemical tests (catalase test and coagulase test).

For MRSA, you can do only Cefoxitin disk diffusion for the confirmation. Oxacillin MIC is recommended according to CLSI (13th edition, CLSI, M02, Page 301).

**Response:** Because cefoxitin has a higher sensitivity and specificity than oxacillin in
detecting MRSA.

**Results section**
"The Gram staining test showed the Gram-positive colonies in the form of cocci and clusters, which were then confirmed by the catalase test and coagulase test" - Change the line and add both biochemical test results (+/-).

**Response:** We have added the description of the Gram stain examination, catalase test, and coagulase test in Table 1 along with pictures.

You did not include the correlation between the isolates recovered from milk or hand swab.

**Response:** Because in this study we focused on observing risk factors for MRSA transmission originating from dairy cows.

"...milk can be caused by various factors including the unhygienic hands of farmers when milking..." - You did not take the swab before milking, how do you argue about it?

**Response:** Because we had difficulty in sampling on the farms, especially when sampling farmers' hand swabs due to the large number of milk samples we took. Besides that, it was very difficult to get samples of farmers' hand swabs before milking on several farms at the same time.

**Competing Interests:** No competing interests were disclosed.