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REVIEW ARTICLE
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Staphylococcus aureus as a foodborne pathogen in eggs and egg products in Indonesia: A review

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Abstract

Staphylococcus aureus causes foodborne disease in eggs. It is characteristic of pathogenicity and harmful to human health if contaminated eggs and products are contaminated from pre-production at the manufacturer until post-production. *S. aureus* is a Gram-positive bacterium normally present in the skin and mucosa of humans and other animals. Methicillin-resistant *S. aureus* (MRSA) is a strain of *S. aureus* that is resistant to several types of antibiotics, including tetracycline, amoxicillin, ampicillin, ciprofloxacin, ceftriaxone, beta-lactam, and azithromycin. Impure *S. aureus* infections in eggs and processed egg products have been reported in Indonesia for for 5 years. However, only a limited number of cases have been reported. Based on the Indonesian National Standard, *S. aureus* contamination in fresh poultry eggs is limited to $<1\times10^2$ colony forming unit/g, eggs processed from salty eggs as much as $<1 \times 10^1$ colonies/g, and food processed from base eggs, e.g., custard a must negative/gram. One Health is an approach to collaborative cross-recognized sector linkages between human health, animal health, and the environment, which should be managed holistically. It is expected that one health approach will be able to prevent and control the risk of *S. aureus* contamination in eggs and processed egg proucts. This review describes the incidence of *S. aureus* and MRSA in Indonesia compared with other countries. This review provides information on the One Health approach for preventing and controlling *S. aureus* contamination of eggs in Indonesia so that it can be adopted elsewhere.

Keywords: eggs and egg products, foodborne, Indonesia, methicillin-resistant *Staphylococcus aureus*.

Introduction

Guaranteeing the availability of food-origin-safe animals is essential to calm consumers. Contamination of humans with physical, chemical, and biological dangers can occur from pre-production at the manufacturer until post-production at important points where the product is distributed to consumers. A danger is the transmission of disease through food or foodborne diseases. The danger, of course, only threatens table eggs as a source of animal protein for the public at a time when contaminated eggs are a pathogen of microbes for humans. Based on data [1], the consumption rate of eggs per capita in Southeast Asia in 2020 was 20.94 kg/year, higher than that of world eggs per capita of 10.33 kg/year. The data also show that Malaysia is ranked first in South-east Asia with a consumption rate of 17.29 kg of eggs per capita, followed by Indonesia (15.72 kg/year) and Cambodia (1.15 kg/year). Thus, foodborne diseases threaten people's health, and food security becomes a factor that must be considered.

Several microorganism pathogens, including *Salmonella* spp., *Escherichia coli*, and *Staphylococcus aureus*, cause foodborne diseases in eggs [2–5]. *S. aureus* is not yet as famous bacteria as like other pathogens in fresh eggs. Thus, general outbreaks of foodborne diseases worldwide have become the attention of public health sector because of the need of cost significant prevention and control action in several countries [6, 7]. *S. aureus* is a responsible answer to various infections in humans and animals. Contaminated bacteria in food causes poisoning and food syndrome shock, which is toxic worldwide [8, 9]. In animals, *S. aureus* causes a disease that results in a significant loss of the economy of breeder dairy cow due to mastitis [7, 10]. *S. aureus* has virulence factors, including catalase, an enzyme that can break down H_2O_2 into H_2O and O_2; coagulase, an enzyme-like protein that can coagulate oxalate plasma or citrate plasma; hemolysin, a toxin that can form a zone of hemolysis around bacterial colonies; and leukocidin, a toxin that can kill white blood cells in some animals. Enterotoxins are enzymes resistant to alkaline conditions in the intestine, and exotoxins are toxins that cause fever, shock, skin rashes, and multi-system organ disorders in the body [11–13].

S. aureus is a cocci-shaped Gram-positive bacteria with normal skin and mucosa flora in humans and animals. Bacteria are resistant to various antibiotics, as demonstrated in a 90-day study of infected humans [14]. In addition to the life of animals, bacteria can contaminate various original ingredients, including milk, meat, and eggs. The foodborne disease of eggs becomes interesting for research focusing more on remembering products. It is easily obtained and consumed by many circles all over the world. Numerous studies have been conducted on related contamination of eggs caused by *Salmonella* spp. and *E. coli* [15, 16]; however, *S. aureus* infection in eggs in Indonesia has yet to be studied intact and is only limited in prevalence. This review aimed to describe the incidence of *S. aureus* and methicillin-resistant *Staphylococcus aureus* (MRSA) in Indonesia compared with that in several other countries, as well as One Health approach to the prevention and control of *S. aureus* contamination of eggs in Indonesia.

S. aureus Contamination in Eggs and Egg Products in Indonesia

S. aureus contamination of eggs and processed egg products within 5 years is rarely reported in Indonesia. Based on the data collected, only bacteria can be found in the fresh produce obtained from places selling and processing eggs, such as egg duck salt and egg omelet, distributed in Sumatra and Java (Table-1) [17–20]. Tested eggs are obtained only from merchants, who provide information directly from poultry eggs. The Indonesian government regulates and limits *S. aureus* contamination in eggs, and their safe products consumed are egg salty $<1\times10^1$ colonies/g of food processed made from base egg, for example, custard a must negative/gram [3] and fresh poultry eggs $<1\times10^2$ colony-forming unit/g [21] (Figure-1).

S. aureus contamination is also found in fresh eggs and produce processed over 10 years. The data in Table 2 [22–35] show that bacteria were found on farms, traditional markets, supermarkets, and shops selling material food. The number of *S. aureus* found in shell eggs is generally higher than in white and yolk eggs. More *Staphylococcus* bacteria are often found on the surface of eggs because of their ability to adapt to endure, live, and thrive in the environment so that they can easily be found in nature free of dust, feces, and soil in the cage [36].

There are several possible sources of *S. aureus* contamination before reaching consumers at several locations of the supply chain of table eggs (chicken farms, wholesalers, retailers, and food processing industries) (Figure 2). In farms, people (in particularly, workers), egg trays reused and not disinfected, manure, and chickens can be sources of contamination. *Staphylococcus* is the most common bacterium that contaminates eggshells during the formation and laying process [37, 38]. *S. aureus* contamination of eggs can occur horizontally when passing through the cloaca; this is reinforced by research [39] which found *S. aureus* in 28% of broiler cloacal swab samples and 50% of laying hens in Bogor Regency, Indonesia. Shells contaminated with many microorganisms will increase the risk of microbial penetration into eggs. Vertical (transovarian) contamination of eggs occurs when the albumen and membranes are directly contaminated by bacterial infection of the reproductive organs [40]. *E. coli* O157:H7 facilitates the penetration of *S. aureus* into consumer chicken eggs when both bacteria contaminate the eggshell [41].

Some of the suspected sources of contamination of eggs include litter, egg crates/racks, feces, egg packing and storage equipment, clothing and hands of cage workers, dust, and the environment [34]. In contact with dirty surfaces such as feces, bacteria can contaminate the shell in a short time and penetrate inside the egg. People and egg trays can be a source of contamination in grocers and retailers. Human handling of food products and infection of livestock and workers have been described as an important mechanism of egg contamination with *S. aureus* [29].

S. aureus and Methicillin-Resistant *S. aureus* (MRSA)

Contamination of eggs with microbes and their effects on human health has become an important problem worldwide. Several microbes, including *Salmonella* spp., *Staphylococcus* spp., *Streptococcus* spp., *Pseudomonas* spp., *Campylobacter jejuni*, *Listeria*

Table-1: Reports of *S. aureus* contamination in eggs and processed egg products in Indonesia.

Case No.	Year	Prevalence	Type of sample	Location	Province	Reference
1	2018	75% of table eggs samples sold in contain *S. aureus* $>1\times10^2$ colony forming unit/mL in the shell and contents	Table eggs consumption	Supermarkets in Banda Aceh	Aceh	[17]
2	2018	33.3% samples of salted eggs were positive for *S. aureus*	Salted duck eggs	Household industry in Purbalingga	Central Java	[18]
3	2018	100% of raw salted egg samples came from traders in containing *S. aureus* $>1\times10^1$ colony forming unit/mL in ashes, shells and contents	Salted duck eggs	Traditional markets in Aceh Besar	Aceh	[19]
4	2020	Sliced omelet contains 983 colonies/g of *S. aureus*	Sliced omelet	Bandung	West Java	[20]

S. aureus=*Staphylococcus aureus*

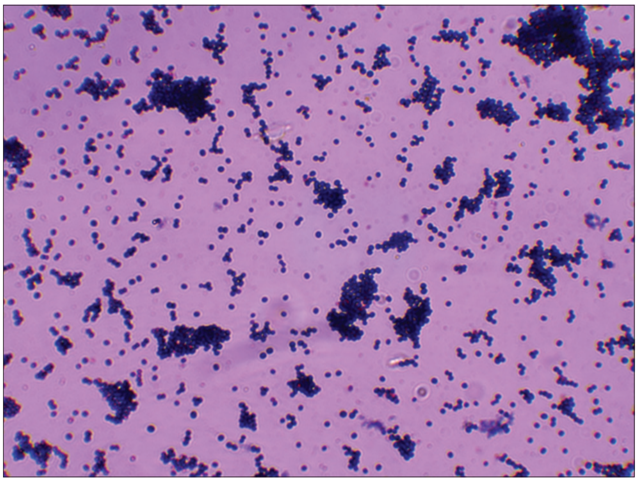

Figure-1: *Staphylococcus aureus* in table eggs found in South Sulawesi Indonesia under 100× magnifications.

monocytogenes, and *E. coli*, frequently contaminate table eggs and production processes [4, 42]. Among microbes, *S. aureus* produces a bacterial toxin that causes food poisoning in humans contaminated by bacteria. Enterotoxins stimulate the digestive system in humans and trigger poisoning symptoms such as nausea, vomiting, diarrhea, pain, stomach, and fever over a period of 1–6 h [29]. *S. aureus* is also resistant to several antibiotics, including tetracycline, amoxicillin, ampicillin, ciprofloxacin, ceftriaxone, beta-lactam, and azithromycin [27, 29]. This is what is challenging *S. aureus* in the world of poultry at present. The development of multiresistant antibiotics makes it difficult to treat disease in poultry.

Antibiotics have been used for more than half a century in poultry feed to improve performance, reduce the number of pathogenic microorganisms, and increase the number of useful microorganisms in the avian intestinal tract [43]. However, antibiotics as growth promoters in feed cattle have forbidden the consumption of animals resistant to antibiotics [44, 45]. In a related matter, the Indonesian government has also published Regulation of the Minister of Agriculture of the Republic of Indonesia Number 14 of 2017, confirming the prohibition of antibiotics as growth promoters in feed.

As many as 27% of chicken eggs originating from traditional markets and supermarkets in East Jakarta, Indonesia, contain residues of the antibiotic kanamycin, an aminoglycoside [44]. Similar results were also found in the provinces of Bali, Nusa Tenggara Barat, and Nusa Tenggara Timur, where penicillin, tetracycline, aminoglycosides, and macrolides were found in 0.3%–9.15% of samples of egg chickens, ducks, and quails obtained from traditional markets and supermarkets [46].

Research results [25] showed that 86.8% of egg chicken race-positive consumption contaminated with *S. aureus* was positive for *mec*A, which is a coding gene for MRSA. In addition, there is a similarity in existing MRSA genetics in egg chicken race consumption with human infection. MRSA is a *S. aureus* isolate that has acquired the coding gene resistance antibiotics

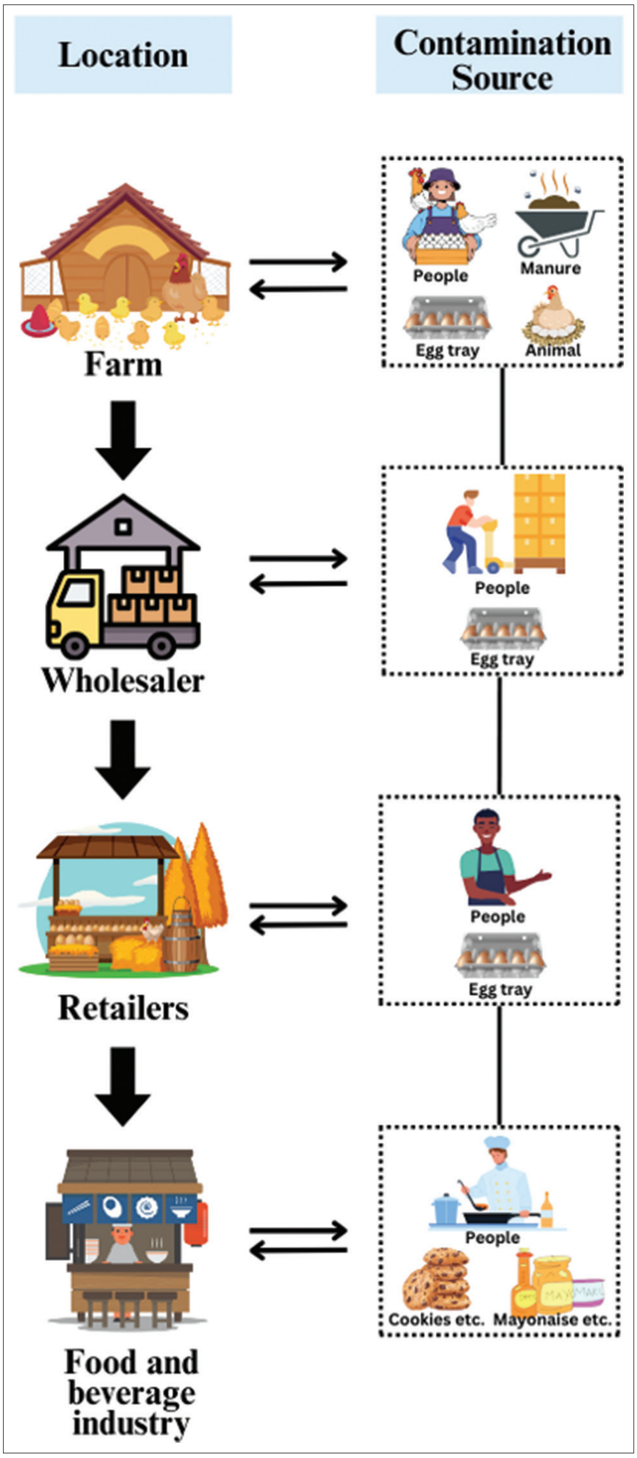

Figure-2: Contamination Source of *Staphylococcus aureus* in supply chain.

to all penicillins, including methicillin. Resistance to antibiotics is one characteristic of the bacteria that make it resistant naturally. It can be obtained through mutations in its DNA alone or DNA acquisition that delivers resistance from another source [47]. Based on the results of the study [39], part big *S. aureus* isolates obtained from a cloacal swab farm chicken meat and egg laying in Bogor are resistant to tetracycline, ampicillin, oxytetracycline, erythromycin, and acid nalidixic. This study aimed to identify resistance genes, including *bla*TEM, *gyr*A, and *tet*A, found in

Table-2: Reports of *S. aureus* contamination in eggs and processed egg products in several countries.

Case No.	Year	Prevalence	Type of sample	Location	Country	Reference
1	2012	61% of salad samples sold were contaminated with *S. aureus*	Salad	Hyderabad	India	[22]
2	2014	*Staphylococcus* spp. was found at 25% in liquid pasteurized egg white, 37.5% in pasteurized egg yolk with sugar (33%), and 37.5% in pasteurized whole egg	Liquid pasteurized egg white, pasteurized egg yolk with sugar, and pasteurized whole egg	Brno	Czech Republic	[23]
3	2015	18.40% of the table eggs shells came from the market, and 28.40% of laying hen farms were contaminated with *Staphylococcus* spp.	Table eggs consumption	Pathum Thani	Thailand	[24]
4	2018	21.3% of table eggs from retail stores were contaminated with *S. aureus*	Table eggs consumption	Haripur	Pakistan	[25]
5	2018	*S. aureus* contaminates table eggs obtained from packaged eggs in the market, groups, native chicken eggs, eggs from farms immediately after cleaning, and eggs from farms before cleaning	Table eggs consumption	Irbid	Jordan	[26]
6	2018	24.29% of table eggs came from retailers contaminated with *Staphylococcus* spp.	Table eggs consumption	Dhaka	Bangladesh	[27]
7	2019	7.61% of the table eggs came from nine farms contaminated with *S. aureus*	Table eggs consumption	Lublin	Polandia	[28]
8	2019	25.86% of the shells and contents of table eggs by farms and traders were contaminated with *S. aureus*	Table eggs consumption	Enugu	Nigeria	[29]
9	2020	13.3% of table eggs came from farms, markets, supermarkets, and food stores contaminated with *S. aureus*	Table eggs consumption	Beni Suef	Mesir	[30]
10	2020	27.8% of the shells and contents of table eggs from farms and markets were contaminated with *S. aureus*	Table eggs consumption	Eastern Ethiopia	Ethiopia	[31]
11	2022	1% in egg shells originating from modern markets, 6% in egg contents originating from modern markets, and 1% in egg contents originating from traditional markets, with a total sample of 1770 contaminated with *S. aureus*	Table eggs consumption	Rabat	Maroko	[32]
12	2022	90% of the shells and 75% of the contents of table eggs originating from a poultry farm and small-scale vendors are contaminated with *S. aureus*	Table eggs consumption	Southern Ethiopia	Ethiopia	[33]
13	2022	19% in shells of table eggs originating from laying hen farms are contaminated with *S. aureus*	Table eggs consumption	Algiers	Aljazair	[34]
14	2023	30.41% in commercially available foods (egg products, sweets, and sauces) from diverse sale outlets are contaminated with *S. aureus*	Table eggs consumption	Algiers	Aljazair	[35]

S. aureus=Staphylococcus aureus

animal husbandry, whereas *erm*B was only found on farm chicken broilers.

One Health Approach to Prevention and Control of *S. aureus* in Eggs in Indonesia

S. aureus potentially causes various human diseases, from mild symptoms to severe. Developing bacteria resistant to various antibiotics can prolong the disease and increase the cost of maintaining health. Therefore, it is important to take measures to ensure the safety of eggs for humans to consume and to prevent the spread of resistant bacteria to antibiotics. One Health is a collaborative approach to human, animal, and environmental health [48]. One Health approach can be used to prevent *S. aureus* contamination in eggs from various corner views, including steps to prevent *S. aureus* infection in humans and animals and reduce polluted environments [49]. Several review publications have discussed One Health approach as a strategy for overcoming various problems in the livestock, health, food, and other sectors so that it can be adopted to reduce *S. aureus* bacterial contamination in poultry farms in Indonesia (Table-3) [50–55].

Application of the concept of One Health in humans through good personal hygiene practices during the production, handling, and storage of eggs, for example,

Table-3: Publication of One Health approach strategies.

Year	One Health Approach Strategy Objectives	Reference
2018	One health concept is a strategy for the effective use of antimicrobials in humans for treatment and in animals to increase growth and prevent disease, thereby preventing the occurrence of antimicrobial resistance.	[50]
2019	One health concept is a strategy to reduce detrimental livestock cultivation practices such as the use of antimicrobials for non-therapeutic purposes, animal welfare deviations, and waste that is not managed properly.	[51]
2020	One health concept is a strategy to achieve global food security, conserve natural resources, and improve health through maintaining food safety.	[52]
2021	One health concept as a strategy to control the transmission and eradicate bird flu in the form of coordination, collaboration, and cooperation in animal and human surveillance, as well as disease management involving various health professionals in each sector, must be implemented and expanded simultaneously.	[53]
2022	One health concept is a mitigation strategy that promotes health, development, and environmental protection against microbial contamination in poultry facilities, with an emphasis on animal bedding.	[54]
2023	One health concept as a strategy in exposure assessment for dealing with fungal contamination in poultry farms	[55]

regularly washing hands with soap and water, covering up wounds or infected skin with clean bandages, and avoiding contact with wounds or other people's bandages can help prevent *S. aureus* infection [56, 57]. The application to animals, for example, is through the consistent use of biosecurity farms. Application 3 zone biosecurity on farms chicken laying eggs in Indonesia has been proclaimed by the Indonesian government through Regulation of the Minister of Agriculture Number 28 of 2016 concerning Biosecurity Livestock and Regulation of the Minister of Agriculture Number 29 of 2016 concerning Free Territory Zoning Disease Animals. Regulation: This is a set procedure for controlling and preventing diseases in animals in Indonesia, with application draft 3 zone biosecurity. In 2018, the Indonesian government launched the "National Biosecurity Movement" program to increase the public's awareness of the importance of biosecurity in preventing the deployment of diseased animals. This program includes education about good biosecurity practices and supervision of cross-breeding, application insulation, and sanitation inside the farm to prevent the deployment of *S. aureus* infection in livestock and its products.

Application of the last concept of One Health in reducing contamination environment to prevent *S. aureus* contamination in egg consumption, for example, cleaning and sanitizing surface source contact contamination with egg regularly, as well as practice storage at or below 4°C and proper handling to prevent cross contamination [27]. This draft can be applied on farms as well as at shops/markets/supermarkets [29, 58, 59]. Support from the government as the main pillar in the implementation of One Health in the prevention of disease infection is urgently needed, mainly in making decisions in a society that has to be based on knowledge and considering cross-sectoral and multi-professional cross-sectoral links between different institutions (public, private, and research) [60, 61]. Applying the One Health approach to combat foodborne diseases effectively minimizes the risk of *S. aureus* contamination in table eggs.

Conclusion

S. aureus is a bacterium found in fresh eggs and egg products. In general, the number of *S. aureus* found on shells is higher than the number of eggs present. *S. aureus* can also produce toxins that cause food poisoning in humans contaminated by bacteria. Bacteria are also resistant to several types of antibiotics, such as tetracycline, amoxicillin, ampicillin, ciprofloxacin, ceftriaxone, beta-lactam, and azithromycin, which make it challenging to treat the disease in poultry or humans. MRSA is a strain of *S. aureus* which is resistant to several types of antibiotics, including beta-lactams, methicillin, oxacillin, and penicillin. Using eggs and processed egg products to combat foodborne diseases can be minimized through a collaborative One health approach between humans, animals, and the environment.

Authors' Contributions

AHT, RM, WH, and FM: Designed the study. AHT: Collected the literature and analyzed it and drafted the manuscript. RM, WH, and FM: Guidance and edited and revised the manuscript. All authors have read, reviewed, and approved the final manuscript.

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Competing Interests

The authors declare that they have no competing interests.

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