Meta-Analysis and Systematic Review: Analysis of Antibiotic Residues and Bacteria in Indonesia's Egg and Its Threat to Public Health

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ABSTRACT

Eggs are the most popular source of protein in Indonesia. The quality of eggs is prone to decline due toerrors in management and handling. Eggs can be damaged, one cause of which is microbial growth. Many studies also proved that some eggs sold on the market contain antibiotic residues. The purpose of this study is to determine the presence of antibiotics and bacterial residues on eggs circulating in Indonesia. This study also aims to conduct research on the health risks of eggs containing antibiotic and bacterial residues. This study used meta-analysis and a systematic review. The article search method employs PICO and snowballing techniques across three databases: Google Scholar, ScienceDirect, and PubMed. The articles used are research articles conducted in Indonesia and published between 2012 and 2022. Articles were selected and analyzed as many as 18 articles. This study showed that the findings of bacteria in eggs in Indonesia were OR 0.67 (95% CI 0.52 – 0.88) with a pooled value of OR nial e0.69 = 1.95. Meanwhile, for the OR value of antibiotic residues was 0.28 (95% CI 0.20 – 0.39) with pooled OR e0.28 was 1.32. However, the two results of the study show that there is a bias in the article of the two variables. Consumption of eggs containing antibiotic residues and bacteria can cause various health impacts. In this study, it was found that some eggs in Indonesia contain antibiotic and bacterial residues. Eggs containing antibiotic residues and bacteria can be a threat to public health.

Keyword : Antibiotic residue, Chicken eggs, *E.coli*, *Salmonella*, Total plate count

Introduction

East Java Province is the province with the highest Gross Regional Domestic Product (GDP) from the livestock industry in Indonesia. East Java Province is able to generate a GDP of Rp. 63.5 trillion or around 23.38% of the total national livestock GDP. Jember Regency is included in the top 10 most egg producers in East Java. Jember Regency is ranked 8th in the region that has a population of free-range and laying hens in East Java Province, with a total of 1.2 million laying hens.

The data goes hand in hand with the data on the average household consumption per capita in a week in 2021, which shows that there was an increase in the consumption of purebred chicken eggs by 4.10% and free-range chicken eggs increased by 11.11%. The trend of chicken egg consumption in Indonesia has always increased in the last 10 years. The upward trend reached its highest peak in 2022. Based on data from the Central Statistics Agency (BPS), the consumption of laying breed chicken eggs in Indonesia in 2022 reached 5.57 tons. Egg consumption data in 2022 is also mentioned to be higher than the consumption of other proteins such as the consumption of fresh fish and shrimp; purebred chicken/village meat; and beef/buffalo (Central Statistics Agency, 2022).

Behind the rich protein content in eggs, there are many shortcomings when eating eggs that do not meet the standards. Eggs are one of the food ingredients that are very easily contaminated. Eggs are a good medium for the growth of microorganisms that can cause foodborne diseases in the community [2]. Eggs can cause health problems when cooked undercooked or contaminated with diseases or bacteria in them (Laughter) *et al.*, 2020). *Salmonella* is a bacteria that is commonly found in eggs. According to a report by the US Food and Drug Administration (FDA), there have been an estimated 79,000 deaths due to the consumption of eggs containing *Salmonella* (Laughter) *et al.*, 2020). There has been a recent outbreak of gastroenteritis in Australia due to *Salmonella hessarek* contamination in eggs (Laughter) *et al.*, 2020). In the Indonesian National Standard (SNI) 3926:2008 concerning chicken eggs for consumption, it is determined that the microbiological qualities that must be considered in consumption eggs are the existence of Total Plate Count (TPC), Coliform, *Escherichia coli*, and *Salmonella sp*.

Material and Methods

This study uses a quantitative research approach with a meta-analysis method. This study uses an article that discusses bacterial contamination in eggs and antibiotic residues in eggs.

Data Collection

The data sources for this research come from Google Scholar (2013 – 2022), Pubmed (2013 – 2022), and Science Direct (2013 – 2022). The selection of keywords used in this study used the PICO (Population, Intervention, Comparison/Control, Outcome) technique. The keywords used in this study are "Bacteria", "*Salmonella sp*." "*E. coli*" "Total Plate Count" "Antibiotic Residue" "Chicken Eggs" "Indonesia". The combination of words used to search for articles about bacterial contamination in Indonesia is "Chicken Egg Bacteria" AND "Indonesia"; "*Salmonella sp* Chicken Eggs" AND "Indonesia"; "*E. coli*" Chicken Eggs" AND "Indonesian"; "Total Plate Count" AND "Chicken Eggs" AND "Indonesia". Meanwhile, the combination words for the search for articles on the existence of antibiotic residues on eggs in Indonesia are as follows: "Antibiotic Residues" AND "Chicken Eggs" AND "Indonesia". The keywords are written in Indonesian and English. The selected articles are then selected and selected again with inclusion criteria. This process is depicted in the PRISMA flow chart of this research in **Figure 1.**

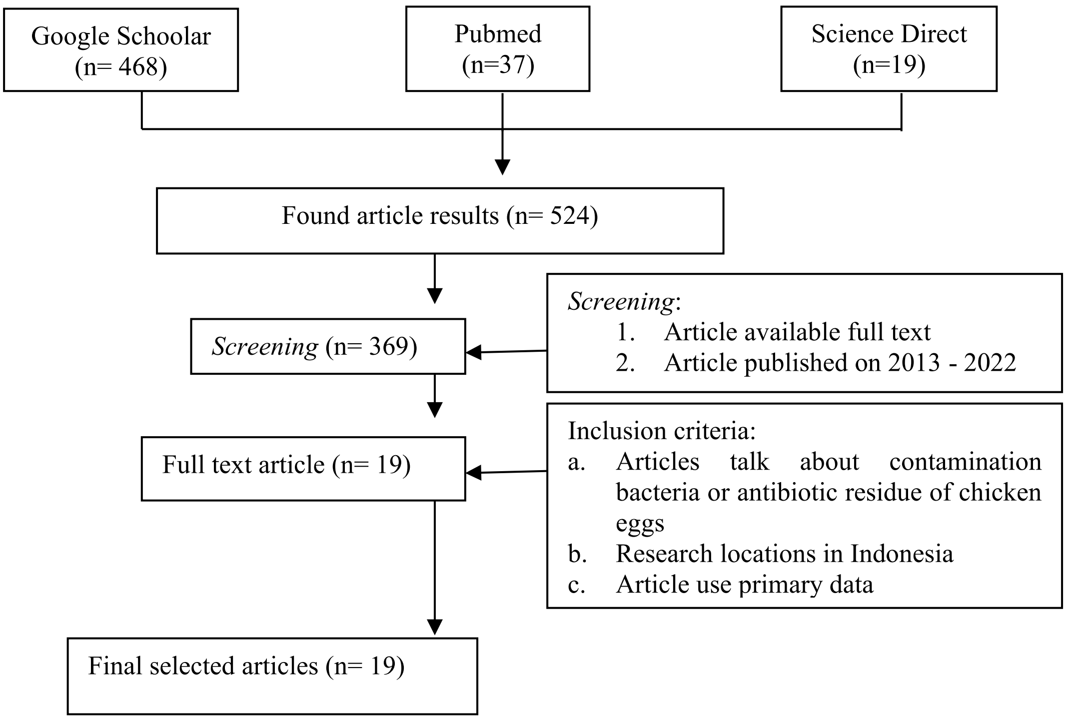

Figure 1. PRISMA Flow Chart Analysis of Antibiotic Residues and Bacteria in Indonesia's Eggs and Its Threat on Public Health

Data Analysis

The analysis in this study uses an intervention review on the Review Manager Version 5.0 application. Articles collected from the database are then entered into the application in the Studies and References section. Eligible articles will be entered into the data and analysis menu and included in the included studies option. After that, the selected articles had their data analyzed to compare contaminated and uncontaminated eggs. Data interpretation using the Effect Size of contaminated eggs and uncontaminated eggs, which is described as the difference in the standardized average (Standardized Mean Difference or SMD) and the Confidence Interval (CI) of 95%. According to Cohen (1992), SMD interpretation is said to be weak when SMD = 0.2, medium SMD = 0.5, and high when SMD = 0.8. The heterogeneity method (I^2) was used to calculate the influence of heterogeneity on the results of the meta-analysis. Heterogeneity (I^2) is considered low if 25% - 50%, moderate if 50% - 75%, and high if > 75%. Random effect models are used when heterogeneity > 50%, while fixed effect models are used when < 50%.

The data will be displayed as tables and forest charts. The data displayed in the form of a box, shows the Effect Size (ES) of each article studied. The horizontal line on the forest plot shows the estimated Confidence Interval (CI) of each article. The diamond image shows the effect size value of the article being researched in the meta analysis.

Results and Discussion

Bacterial Contamination in Eggs

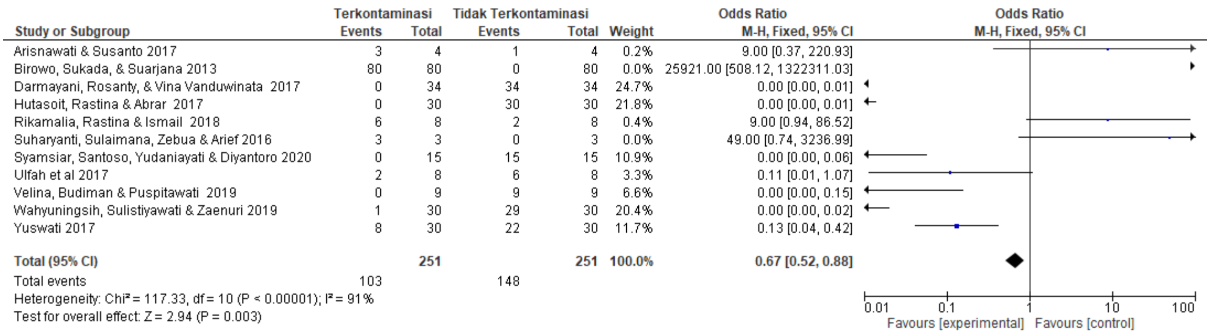

Figure 1. Results of Meta-Analysis of Microbacteria in Eggs

The heterogeneity test in the article used in this analysis is high, i.e. $I^2 = 91\%$. This means that this analysis is a random effect model. The effect sized pooled in this study was shown in the total Standard Mean Difference (SMD) score for bacterial analysis in eggs was 0.67 (95%) CI ([0.52 – 0.88], P < 0.00001). This means that bacteria contaminate eggs in Indonesia quite a lot. In the Indonesian National Standard 3926:2008 concerning chicken eggs for consumption, it is determined that the microbiological quality that must be considered in consumption eggs is the presence of Total Plate Count (TPC), Coliform, *Escherichia coli*, and *Salmonella sp*. According to CDC data, *Salmonella* generally contaminates chicken eggshells. This contamination occurs when eggs come into contact with chicken feces after being laid. *Salmonella* can enter eggs through chickens while still in the chickens before skin formation [4]. Eggs are infected through three routes: transovarian, transoviductal, and eggshell. Transovaria is an infection that occurs when the egg is still attached to the ovary. Transovarian sperm occurs when the egg is being prepared and passes through the oviduct. Finally, through the egg shell when it has passed through the cloaca [5]. Most studies found positive *Salmonella* content in their studies. A total of 8 out of 11 articles found stated that there was a detection of *Salmonella* in eggs circulating in Indonesia. This is due to environmental conditions that do not meet standards. In general, there is no washing process for eggs on farms. There are still many chicken stains and blood spots on the eggshells sold in the market [2]. The dangerous contamination of *Salmonella* in eggs does not stop when they are contaminated, but also when hands hold eggs in the supermarket, then touch other ingredients and cause cross-contamination.

The egg storage process affects the presence of bacteria in the egg. In general, eggs at traders are stored in the open at room temperature. However, this can cause the growth of bacteria on the eggs [6]. The study was conducted on eggs stored in supermarkets with a time span of 3 – 8 days that were positive for *E. coli* bacteria [7]. However, the study has some biases. The study also noted that *E. coli* contamination could come from contaminated hands of officers or self-service visitors. This is supported by the fact that most employees still do not have enough knowledge in hygiene and sanitation of egg handling. The statement regarding the effect of long storage on contamination is supported in research conducted in Bogor. The eggs, which were allegedly stored for a long time, were found to contain a large amount of *E. coli* and exceeded the set SNI, which was above 5 logs [8]. The combination of storage time and room temperature is a risk factor for bacterial contamination of eggs. At room temperature with 80-90% humidity, it can be stored for 14 days. The shelf life will be longer when the temperature is cooler up to 30 days [9]. This is supported by experimental research conducted by researcher[10]. Eggs, which are stored for 21 days at cold temperatures, do not contain bacterial contamination. In the study, it was added that this was influenced by the quality of the shells from the eggs. The shell has an important role in the process of bacterial penetration in the egg[10].

Infections in hens primarily cause bacterial contamination of eggs. Eggs are infected through three routes, namely transovarian, transoviduct, and eggshell. Transovaria is an infection that occurs when the egg is still attached to the ovary. Transovarian sperm occurs when sperm are produced during egg preparation and pass through the oviduct. Finally, through the egg shell when it has passed through the cloaca [5]. This contamination of eggs is through vertical or transovarial means. This pollution is caused by the mother's intake of the mother chicken's food. Bacteria can enter through chicken feed and drinking water that has been contaminated with dust, soil and feces. Bacteria that enter the mother chicken's body will multiply and cause an inflammatory reaction. These bacteria will generally be in the macrophages and digestion of chickens. The bacteria will then penetrate the mucosa, enter the lymphatic and reach the blood vessels where they can spread to the reproductive ovarian [10].

Contamination of Antibiotic Residues on Eggs

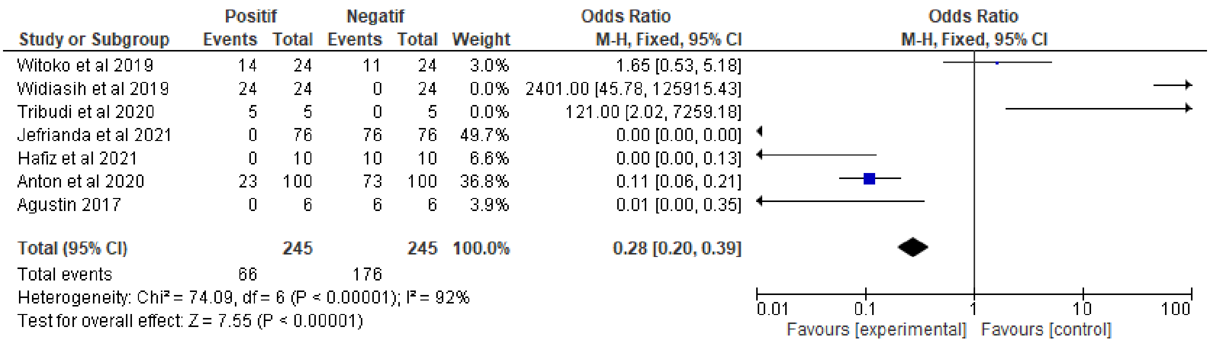

Figure 2. Results of Meta-Analysis on Egg Residue

Based on the hetergonity test, the articles in the study were heterogeneous. This is shown in the test results that show the number I^{2} = 92%, which means that the heterogeneity of the articles in this analysis is high. Therefore, this analysis uses a random effect model. Based on figure 2, the value of effect sized pooled in the analysis of antibiotic residues in Indonesia is shown at an SMD score of 0.28 (95%) CI ([0.20 – 0.39], p < 0.00001). Based on this data, it can be concluded that antibiotic residue contamination in Indonesia is quite low. This result is likely supported by the stipulation of the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 144/PERMENTAN/PK.350/5/2017 concerning the Classification of Veterinary Drugs which prohibits the use of antibiotics in animal feed. The results of this study are not in line with research conducted in Chile, which estimates that 66% of farmers in developing countries still use antibiotic mixtures in chicken feed.

Most of the samples studied did not find residue in chicken eggs, likely because the drug discontinuation period had been reached and the use of antibiotics was appropriate [11]. Eggs taken as samples on the second day after antibiotic administration at a dose of 1 gr/liter were proven to cause no antibiotic residue in the eggs [12]. However, another study says that with the administration of oxytetracycline, it will disappear on day 14 on the inside of the egg and on day 7 on the eggshell[15].

Threats to Public Health

The emergence and global dissemination of antimicrobial resistance (AMR) in foodborne pathogens such as *Salmonella spp*. and *Escherichia coli* originating from poultry products pose a significant and multifaceted threat to public health. The widespread use of antibiotics in poultry production, often for growth promotion and prophylaxis, has been identified as a primary driver in the selection and proliferation of resistant bacterial strains [13]. This reservoir of resistance within the food chain directly compromises the efficacy of essential antimicrobial therapies in human medicine. As documented in the WHO GLASS report (2022), median resistance rates for critical bloodstream infection indicators are alarmingly high in countries with less robust surveillance, with third-generation cephalosporin-resistant *E. coli* at 41.8% and methicillin-resistant *Staphylococcus aureus* (MRSA) at 34.7%. This escalating resistance directly translates into a greater risk of treatment failure for common and life-threatening infections, forcing clinicians to rely on more expensive, last-resort antibiotics such as carbapenems, which in turn perpetuates the cycle of resistance and increases healthcare costs and patient morbidity [14].

The direct transmission of these resistant pathogens and their resistance genes from poultry products to humans represents a critical pathway for the spread of AMR. Numerous studies have documented the contamination of retail poultry meat and eggs with multidrug-resistant (MDR) bacteria. For instance, a global review by Castro-Vargas et al. (2020) found a median *Salmonella* prevalence of 30% in raw chicken meat, with a staggering 97.8% of the reviewed studies reporting MDR isolates. Similarly, Kapena et al. (2020) reported a 34.26% *E. coli* contamination rate on retail eggshells in Zambia, with isolates exhibiting extremely high resistance to critical antibiotics such as colistin sulfate (94.6%) and tetracycline (83.8%). In the context of duck meat in Bogor, Indonesia, Loisa et al. reported *Salmonella* isolates resistant to erythromycin (66.7%) and chloramphenicol (33.3%) [15,16]. Consuming such contaminated products, or even direct contact with them, can lead to colonization of the human gut by resistant bacteria. As highlighted by Agyare et al. (2018), once these pathogens enter the human system, they can transfer their resistance determinants horizontally to the endogenous intestinal flora, thereby compromising future treatment options for a wide range of bacterial infections and turning previously manageable illnesses into serious health threats[16].

Furthermore, the convergence of high AMR rates and foodborne transmission has led to the emergence of *Salmonella* strains with extensive drug resistance (XDR) profiles, a development of grave international concern. XDR *Salmonella typhi* strains that are resistant to five first-line antimicrobial classes, including chloramphenicol, ampicillin, cotrimoxazole, fluoroquinolones, and third-generation cephalosporins. The management of XDR typhoid fever requires expensive, broad-spectrum antibiotics such as carbapenems or azithromycin, which may not be readily available in low- and middle-income countries (LMICs) [17]. This scenario not only escalates the economic burden on already strained healthcare systems but also significantly increases the risk of severe complications, prolonged illness, and death, particularly in vulnerable populations such as children, the elderly, and immunocompromised individuals [18]. The problem is further compounded by the fact that a substantial proportion of isolates from poultry production settings exhibit MDR phenotypes, as demonstrated by researcher, who found that 62.5% of *Salmonella* isolates from broiler chickens were MDR, with high resistance to tetracycline (87.5%) and chloramphenicol (75%).

The regional burden of this public health crisis is particularly pronounced in South Asia and parts of Southeast Asia, where the confluence of intensive poultry farming, inadequate regulation of antibiotic use, and close human-animal-environment interfaces amplifies the risk. A 10-year meta-analysis of *Salmonella* in South Asia by researcher revealed an overall pooled AMR prevalence of 70%, with a concerning temporal increase from 53% in 2010-2013 to 77% in 2018-2021. The study identified high rates of resistance to nalidixic acid (74.25%) and tetracycline (37.64%). Within Indonesia specifically, a literature review by researcher underscored the gravity of the situation, reporting average *E. coli* resistance rates of 60.85% to β-lactams and 56.25% to aminoglycosides on chicken farms, with similarly high rates observed in animal-derived food products. The incidence of resistance was particularly high in regions such as West Java and Bali. Studies on other avian species reinforce these findings; other researcher reported that bacteria from cloacal swabs of healthy quail in Yogyakarta showed 90% resistance to erythromycin and 50% to penicillin, with one bird carrying resistance to seven out of nine tested antibiotics. Such widespread resistance in seemingly healthy animals highlights the silent and pervasive nature of the AMR reservoir within the food production environment. Collectively, these findings underscore an urgent need for integrated surveillance systems, strict enforcement of antibiotic-use regulations in agriculture, and the promotion of alternative farming practices to mitigate the escalating public health threat posed by antimicrobial-resistant pathogens originating from poultry.

The use of antibiotics in large quantities and outside their intended purpose will endanger public health [19]. Antibiotics can be used as feed additives for livestock to maintain animal health. This is because antibiotic residues can be consumed by humans with foods of animal origin (meat, milk, eggs, fish, honey, etc.). Probable daily intake for drinking water and food consumption based on total concentrations of all antibiotics detected is 310, 200 and 130 ng/kg-body weight for preschoolers, adolescents and adults, with maximum consumption of up to 1400, 970, and 530 ng/kg-bw/day [20]. The health effects of antibiotic residues are generally observed over a long period of time [21]. Types of antibiotics such as *penicillin, oxacillin, cefoxitin, fluxacillin,* and *amoxicillin-clavulanate* may cause hepatitis (especially cholestatic) [22].

Therefore, it is imperative that consumers exercise discretion when selecting eggs for consumption. While such practices may not yet be widespread in Indonesian society, choosing eggs bearing cage-free or organic certification is a more favorable option. Organically labeled eggs are generally antibiotic-free, as the administration of antibiotics would preclude organic status [23]. Moreover, eggs derived from cage-free hens tend to exhibit lower antibiotic residues [24]. Lastly, the selection of eggs with clean shells is recommended, as such eggs present a lower risk of bacterial contamination. Furthermore, the avoidance of egg washing combined with refrigerated storage has been shown to prolong the storage period and mitigate the risk of bacterial contamination [25].

Conclusion

Bacterial contamination in eggs in Indonesia remains relatively high; however, antibiotic residue contamination is still comparatively low. Although currently classified as low, the potential for this type of contamination remains significant due to the persistent lack of stringent regulations governing antibiotic use in Indonesian poultry farms. This situation poses a potential public health risk, whether stemming from the direct threat of pathogenic bacteria, the development of antimicrobial resistance, or the presence of residual antibiotics in consumed eggs. Therefore, regulations concerning Good Manufacturing Practices must be strictly enforced and widely disseminated among layer chicken farmers. Such measures are essential to improve and maintain egg quality by safeguarding it from all forms of contamination, thereby ensuring the protection and preservation of public health standards across Indonesia.

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