Veterinary Integrative Sciences 2025; 23(2): e2025033-1-18. DOI: 10.12982/VIS.2025.033

Veterinary Integrative Sciences
ISSN; 2629-9968 (online)

Research article

# Prevalence of extended-spectrum beta-lactamase-producing *Escherichia Coli* in broiler farms: A systematic review and meta-analysis

**Phirum Or[1], Sukolrat Boonyayatra[2], Veerasak Punyapornwithaya[1,3], Nattakarn Awaiwanont[1,3,*]**

[1] *Veterinary Public Health and Food Safety Centre for Asia Pacific, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand*
[2] *Department of Veterinary Clinical Sciences, College of Veterinary Medicine, Long Island University, Brookville, NY 11548, USA*
[3] *Center of Excellence in Veterinary Public Health, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand*

## Abstract

Extended-spectrum beta-lactamase-producing *Escherichia coli* (ESBL *E. coli*) is a serious public health issue. ESBL *E. coli* in broiler production is known as a potential risk for human health. The aim of this study was to estimate the global pooled prevalence of ESBL *E. coli* in broiler farms. Literature searches were performed via PubMed, Web of Science, and Scopus. A random effect model was used to estimate the pooled prevalence. Heterogeneity was assessed by Cochrans's Q test and the I squared statistic ($I^2$). Subgroup analysis and meta-regression were conducted to investigate the source of heterogeneity. Sensitivity and publication bias analyses were performed. Overall, 872 and 18 additional studies were retrieved from databases and bibliography searches. Thirty-seven studies met the inclusion criteria. Pooled prevalence of ESBL *E. coli* in broiler farms was 26.6% (95% CI = 18.2 to 37.3). The analyzed data showed high heterogeneity (Q = 1958.87 and $I^2$ = 98.2%). The pooled prevalence of ESBL *E. coli* in broiler farms was almost identical between Asia; 33.0% (95% CI = 18.7 to 51.3) and Europe; 32.8% (95% CI = 15.0 to 57.4), while Africa showed the lowest prevalence at 12.4% (95% CI = 5.1 to 27.1). Prevalence of ESBL *E. coli* was found to be highest in fecal samples; 33.0% (95% CI = 21.5 to 46.8), followed by environmental samples; 28.3% (95% CI = 13.5 to 50.1), and other samples; 11.0% (95% CI = 5.0 to 22.8). Results from our study indicated a moderate prevalence of ESBL *E. coli* in broiler farms globally, and it has been fluctuating inconsistently in the last decade.

**Keywords**: Antimicrobial resistance, Broiler farm, *Escherichia coli,* Extended-spectrum beta-lactamase, Prevalence

***Corresponding author**: Nattakarn Awaiwanont, Veterinary Public Health and Food Safety Centre for Asia Pacific, and Center of Excellence in Veterinary Public Health, Faculty of Veterinary Medicine, Chiang Mai University, Chiang Mai 50100, Thailand. E-mail: nattakarn.a@cmu.ac.th

***Article history;*** *received manuscript: 14 May 2024,*
*revised manuscript: 13 June 2024,*
*accepted manuscript: 8 July 2024,*
*published online: 18 July 2024,*
***Academic editor;*** *Nguyen Trong Ngu*

# INTRODUCTION

Antimicrobial resistance (AMR) is a current and future threat to humanity. At present, AMR accounts for at least 700,000 deaths annually. The death toll could rise to as high as 10 million in 2050 if the rising rates of AMR could not be slowed down (De Kraker et al., 2016). Beta-lactam is a widely used class of antibiotic, both in the animal sector and the human sector. In the United States, beta-lactam accounts for 65% of all injectable antibiotic use, and nearly half of it consists of cephalosporin (Bush and Bradford, 2016). Cephalosporin has been categorized as "Veterinary Critically Important Antimicrobial Agents and Veterinary Highly Important Antimicrobial Agents" by the World Organization for Animal Health (WOAH) (OIE, 2020). The emergence of resistant enzymes such as extended-spectrum beta-lactamase (ESBL) has raised concern within the human medical and veterinary communities to revise its application of this antibiotic class. ESBL is known as plasmid-encoded enzymes that were found in Enterobacteriaceae, mostly in *Escherichia coli* (*E. coli)* and *Klebsiella pneumoniae*. This enzyme has the ability to hydrolyze various drugs of the beta-lactam class including penicillin, the second, third, and fourth generations of cephalosporin, and monobactams. However, carbapenems and cephamycins (e.g. aztreonam) are still effective against ESBL organisms (EFSA, 2011).

The emergence of ESBL-producing bacteria was recognized in the 1980s, with the emergence of ESBL-producing *Klebsiella pneumoniae* in the 1990s as a cause of nosocomial infections and the emergence of ESBL-producing *E. coli* in the 2000s as a cause of community-acquired infections (Chong et al., 2011; Chong et al., 2018). A recent meta-analysis on the prevalence of ESBL *E. coli* in healthy individuals reported a considerably high prevalence in South, Southeast, and East Asia, with an estimated rate of 50%. In contrast, Europe and North America showed considerably lower rates, both estimated at 10% (Karanika et al., 2016). Prevalence of ESBL *E. coli* among healthy individuals poses an ongoing worrisome on public health as the current second, third, and fourth generation cephalosporins are no longer an effective option for treatment of ESBL infected patients (Karanika et al., 2016). Food-producing animals are found to be a reservoir and risk factor for ESBL *E. coli*, especially in poultry production.

During 2000 to 2001, the initial findings of ESBL *E. coli* in poultry was reported in Spain. Since then, there have been frequent reports of ESBL *E. coli* in broiler farms and the broiler production chain (Dierikx et al., 2013). ESBL *E. coli* is also included in the monitoring program of antimicrobial resistance in food-producing animals as recommended by the Food and Agriculture Organization of the United Nations (FAO) and the European Food Safety Authority (EFSA) (EFSA, 2011; FAO, 2019). Several studies have suggested potential transmission of ESBL *E. coli* from poultry productions to humans that could pose a high risk to public health (Bui et al., 2018; Van Hoek et al., 2020; Aworh et al., 2020). Prevalence of ESBL *E. coli* in broiler farms has been reported from various places, however, a global level study on the prevalence of ESBL *E. coli* in broiler farms has not existed yet. Moreover, the indiscriminate and extensive use of antibiotics has contributed immensely to the rise of ESBL *E. coli* in broiler production. Therefore, our systematic review and meta-analysis aim to study the estimated pooled prevalence of ESBL *E. coli* in broiler farms and to assess the heterogeneity of the prevalence.

# MATERIALS AND METHODS

## Search strategy

This study was conducted based on Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines (Page et al., 2021). The research question was defined to include all primary research investigating the occurrence of ESBL-producing *E. coli* in broiler farms. The population, intervention, comparison of intervention, and outcome (PICO) framework was applied when designing research questions to ensure all relevant studies were covered.

The systematic literature search was conducted in three databases (PubMed, Web of Science, and Scopus). The advanced search functions were used across all databases to locate literature. A broad list of search terms including related terms, alternative spelling, and synonyms were used and joined by Boolean operator ('OR' and 'AND') to minimize missing records. Within the same domain "OR" was used to join related key terms, whereas "AND" was used to join across domains. Therefore, the search term string: [broiler OR poultry OR chicken] AND [ESBL-producing *E. coli* OR Extended-spectrum β-lactamase-producing *Escherichia coli* OR Extended-spectrum beta-lactamase-producing *Escherichia coli* OR ESBL-producing *Escherichia coli* OR ESBL *E. coli* OR ESBL *Escherichia coli* OR ESBL-producing Enterobacteriaceae OR Extended-spectrum β-lactamase-producing Enterobacteriaceae] was used for systematic literature search. All record yields were limited to the English language only, with a publication year between January 2010 and October 2021.

## Inclusion and exclusion criteria

Records yielded from all databases were exported to Endnote, then duplicates were tracked and removed before the records were subjected to inclusion and exclusion assessment. The assessment of eligible studies was performed in two steps. The first step was the screening of relevant titles and abstracts. After title and abstract screening, the full texts of all relevant studies were screened for their eligibility. Studies were included if they were observational studies and reported the prevalence of ESBL-producing *E. coli* in broiler farms. On the other hand, studies were excluded if they were; 1) review articles, 2) experimental studies, 3) lack of targeted population, 4) lack of outcome of interest, 5) case reports or case series, and 6) articles with no clear information on the prevalence of ESBL-producing *E. coli* in broiler farms. At this step, two authors; PO and NA worked independently to screen for eligible studies. Disagreement on selecting some studies was discussed among both authors for consensus.

## Data extraction

Data were extracted and recorded into a Microsoft Excel spreadsheet by both authors, who screened the studies for eligibility. Discrepancies between the data obtained by these two authors were discussed with a third author for consensus to avoid bias. The extracted data consisted of; 1) author's surname, 2) year of publication, 3) year of isolation, 4) continents and countries where the study was conducted, 5) study design, 6) sample type, 7) number of samples, 8) number of *E. coli* isolates, 9) number of ESBL *E. coli* isolates, 10) detection method for ESBL *E. coli*, and 11) interpretation guideline for ESBL *E. coli*.

## Study quality assessment

Included studies were assessed for their quality using a checklist adapted from Ding et al. (2017). The checklist consisted of five questions which appraise five different aspects of the articles. The checklist contained questions as follows; 1) Was the research objective clearly described and stated?, 2) Was the sampling method described in detail?, 3) Were the period and location of the study clearly stated?, 4) Were the detection method and procedure for ESBL-producing *E. coli* clearly pointed out?, and 5) Were the samples clearly classified into different subgroups?. Each included study was appraised for their compliance with the checklist, and then a score was given to each aspect of the study (2 = yes, 1 = unsure, 0 = no). The individual score from each aspect was then summed up with a maximum score of 10.

## Statistical analyses

Meta-analysis for the prevalence of ESBL *E. coli* in broiler farms was computed using 'R Studio' statistical software (version 4.0.3). The in-built package "meta" was used to conduct meta-analysis. The prevalence of ESBL *E. coli* was calculated by dividing the total number of ESBL *E. coli* positives by the total number of samples.

## Pooled prevalence of ESBL *E. coli* in broiler farms

Pooled prevalence and its 95% confidence interval (95% CI) were computed using a random effect model. Cochran's *Q* test was used to estimate the heterogeneity of pooled prevalence. In addition, I squared statistic ($I^2$) was used to quantify the degree of heterogeneity between studies, with $I^2$ value of 25%, 50%, and 75% indicating low, moderate, and high degrees of heterogeneity, respectively (Higgins et al., 2003).

## Subgroup meta-analysis

Subgroup meta-analysis was performed to estimate the pooled prevalence among different categories. The pooled prevalence within each subgroup was calculated using a random effect model. The subgroup was divided into three characteristics included; 1) sample type, 2) continent where studies were conducted, and 3) year of publication (2010-2021). There were three groups of sample type; a) fecal sample (feces and cloacal swab), b) environmental swab (boot swab, air, dust, litter, flies, and equipment used in the broiler farms), and c) others (other clinical samples and other sample sources rather than fecal sample and environmental swab). There were five groups of continent including Asia, Europe, Africa, North America, and South America. The year of publication was categorized into nine groups including 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, and 2021.

## Meta-regression

Univariable and multivariable meta-regression was conducted to determine the association between ESBL *E. coli* in broiler farms and selected variables in the subgroup analysis. Association between variables and pooled prevalence in the multivariate meta-regression model was assumed when a *p*-value was less than 0.05 ($p < 0.05$).

## Sensitivity analysis

Sensitivity analysis was conducted to assess the robustness of the result. To achieve this, two methods were used in our meta-analyses. First, the result from the random effect model was compared with the result from the fixed effect model. Second, the leave-one-out analysis was used by removing a study with the highest and lowest prevalence one after another and recalculating the pooled prevalence.

## Publication bias

Funnel plot and Eggers's test were conducted to measure publication bias, where a $p < 0.05$ suggested publication bias of small study-effects (Egger et al., 1997).

# RESULTS

## Search results and selection of studies

A total of 872 studies were yielded from primary databases. In addition, 18 more studies were retrieved from various sources through bibliography search. After duplicates were removed, 547 studies were screened through titles and abstracts. In this step, 344 studies failed to meet inclusion criteria and were excluded. Furthermore, 203 studies were screened through full text, and 166 studies were excluded. Finally, 37 studies met the inclusion criteria and were included in the meta-analyses. The selection process and included studies are given in Figure 1.

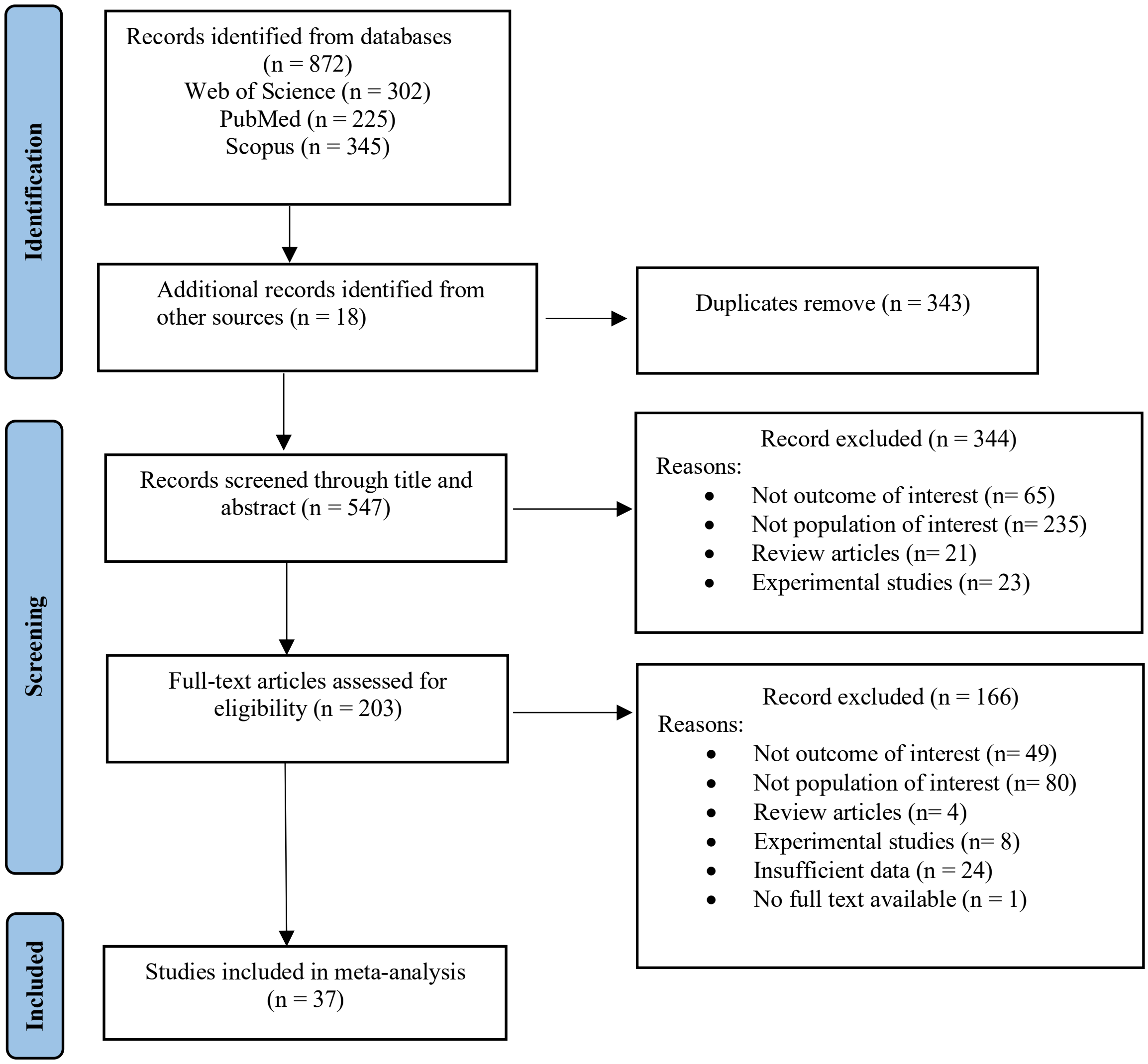


**Figure 1** PRISMA flow diagram that indicated the selection process of the included studies.

## Characteristics of included studies

Mean score of study quality assessment was 9.48/10 (SD = 0.9). Most studies (15/37, 40.5%) included in the meta-analysis were conducted in Asia followed by Europe (11/37, 29.7%). More than half of the included studies (22/37, 59.4%) were published during 2019-2021. We found that the most used ESBL *E.*

*coli* detection method in the included studies was the double disk-synergy test (16/37, 43.2%), followed by the combination disk method (14/37, 37.8%). In Asia, the prevalence of ESBL *E. coli* in broiler farms was reported in nine countries including India, Thailand, the Philippines, Vietnam, Pakistan, China, Lebanon, Bangladesh, and Nepal. In Europe, there were published reports on the prevalence of ESBL *E. coli* in broiler farms in eight countries including Spain, Turkey, Italy, the Netherland, Slovenia, Slovakia, Belgium, and Germany. In Africa, four countries, including Ghana, Tunisia, Nigeria, and Egypt, were found to have the reported prevalence of ESBL *E. coli* in broiler farms. Studies that reported prevalence in South America consisted of reports from two countries including Brazil and Columbia. In North America, we found only one study reported the prevalence of ESBL *E. coli* in broiler farms in Cuba. More details on study characteristics are given in Table 1.

**Table 1** Characteristics of the included studies.

| Authors and year of publication | Country | Sample type | No. of ESBL positive samples/ total no. of samples (%prevalence) | Methodology | Interpretation guideline |
|---|---|---|---|---|---|
| Abreu et al., 2014 | Spain | Cloacal swab | 237/260 (91.1%) | Double-disk synergy test | CLSI |
| Apostolakos et al., 2019 | Italy | Cloacal swab | 227/580 (39.1%) | Double-disk synergy test | CLSI |
| Baez et al., 2021 | Cuba | Cloacal swab | 40/100 (40.0%) | Combination disk method | EUCAST |
| Bhave et al., 2019 | India | Feces | 10/176 (5.7%) | Combination disk method | CLSI |
| Blaak et al., 2015 | Netherland | Feces, rinse water, air, dust, flies, surface water, soil, run-off gullies, feces of other animals | 195/276 (70.6%) | Combination disk method | CLSI |
| Boonyasiri et al., 2014 | Thailand | Cloacal swab | 30/80 (37.5%) | Double-disk synergy test | EUCAST |
| Cardozo et al., 2021 | Brazil | Cloacal swab | 17/100 (17.0%) | Combination disk method | EUCAST |
| Carissa et al., 2013 | Nigeria | Feces | 9/96 (9.4%) | Double-disk synergy test | CLSI |
| Castellanos et al., 2017 | Colombia | Feces, drag swab, cloacal swab | 13/45 (28.9%) | PCR | CLSI |
| Dierikx et al., 2013 | Netherland | Cloacal swab | 209/600 (34.8%) | Combination disk method | EUCAST |
| Doregiraee et al., 2017 | Iran | Cloacal swab | 27/471 (5.7%) | Combination disk method | CLSI |
| Drugdova et al., 2013 | Slovakia | Feces | 14/83 (16.9%) | PCR | CLSI |
| Falgenhauer et al., 2019 | Ghana | Feces | 45/140 (32.1%) | Combination disk method | EUCAST |
| Ferreira et al., 2014 | Brazil | Cloacal swab | 19/200 (9.5%) | Double-disk synergy test | CLSI |
| Gazal et al., 2021 | Brazil | Feces, boot swab, water, feed | 67/576 (11.6%) | Double-disk synergy test | CLSI |
| Gundran et al., 2019 | Philippines | Cloacal swab, boot swab | 69/156 (44.2%) | Combination disk method | CLSI |
| Hassen et al., 2020 | Tunisia | Feces | 60/286 (21.0%) | Double-disk synergy test | CLSI |
| Hinenoya et al., 2018 | Vietnam | Cloacal swab, bedding | 15/17 (88.2%) | Combination disk method | CLSI |
| Ilyas et al., 2021 | Pakistan | Cecal sample | 156/250 (62.4%) | Double-disk synergy test | CLSI |
| Jouini et al., 2021 | Tunisia | Feces | 11/80 (13.7%) | Double-disk synergy test | CLSI |
| De Koster et al., 2021 | Belgium, Netherland | Feces | 666/779 (85.5%) | Combination disk method | EUCAST |

| Authors and year of publication | Country | Sample type | No. of ESBL positive samples/ total no. of samples (%prevalence) | Methodology | Interpretation guideline |
|---|---|---|---|---|---|
| Kwoji et al., 2019 | Nigeria | Cloacal swab | 12/48 (25.0%) | Combination disk method | CLSI |
| Laube et al., 2013 | Germany | Feces, litter, boot swab, dust and environmental sample | 152/420 (36.2%) | PCR | CLST |
| Li et al., 2016 | China | Feces | 142/160 (88.7%) | Combination disk method | CLSI |
| Mikhayel et al., 2021 | Lebanon | Cloacal swab | 60/280 (21.4%) | Double-disk synergy test | EUCAST |
| Moawad et al., 2018 | Egypt | Cloacal swab | 7/576 (1.2%) | Vitek 2 system | EUCAST |
| Niero et al., 2018 | Italy | Swab at lesion site | 7/98 (7.1%) | PCR | CLSI |
| Ur Rahman et al., 2019 | Pakistan | Drinking water, farm floor, feeding and drinking equipment | 14/100 (14.0%) | Double-disk synergy test | CLSI |
| Rodroo et al., 2021 | Thailand | Boot swab, feed, water | 28/144 (19.4%) | Combination disk method | CLSI |
| Rojs et al., 2019 | Slovenia | Feces, air, internal organ | 6/33 (18.2%) | Combination disk method | EUCAST |
| Rousham et al., 2021 | Bangladesh | Feces | 26/40 (65.0%) | ESBL selective media | CLSI |
| Sayin et al., 2020 | Turkey | Synovial fluid | 8/152 (5.3%) | Vitek 2 system | CLSI |
| Shafiq et al., 2021 | China | Feces | 103/210 (49.0%) | Double-disk synergy test | CLSI |
| Shoaib et al., 2016 | Pakistan | Broiler liver | 8/150 (5.3%) | Double-disk synergy test | CLSI |
| Sola-Gines et al., 2015 | Spain | Flies from broiler farm | 42/682 (6.1%) | Double-disk synergy test | EUCAST |
| Subramanya et al., 2020 | Nepal | Cloacal swab | 15/47 (31.9%) | Double-disk synergy test | CLSI |
| Wibisono et al., 2021 | Indonesia | Cloacal swab | 46/160 (28.7%) | Double-disk synergy test | CLSI |

## Pooled prevalence of ESBL *E. coli* in broiler farms

Pooled prevalence of ESBL *E. coli* in broiler farms calculated by a random effect model was estimated at 26.6% (95% CI = 18.2 to 37.3). The overall estimation indicated high heterogeneity (Q value = 1958.87 and $I^2$ = 98.2%). The total number of samples being observed was 8,651 and the total number of ESBL *E. coli* positive was 2,812. The forest plot indicated the overall pooled prevalence of ESBL *E. coli* is given in Figure 2.

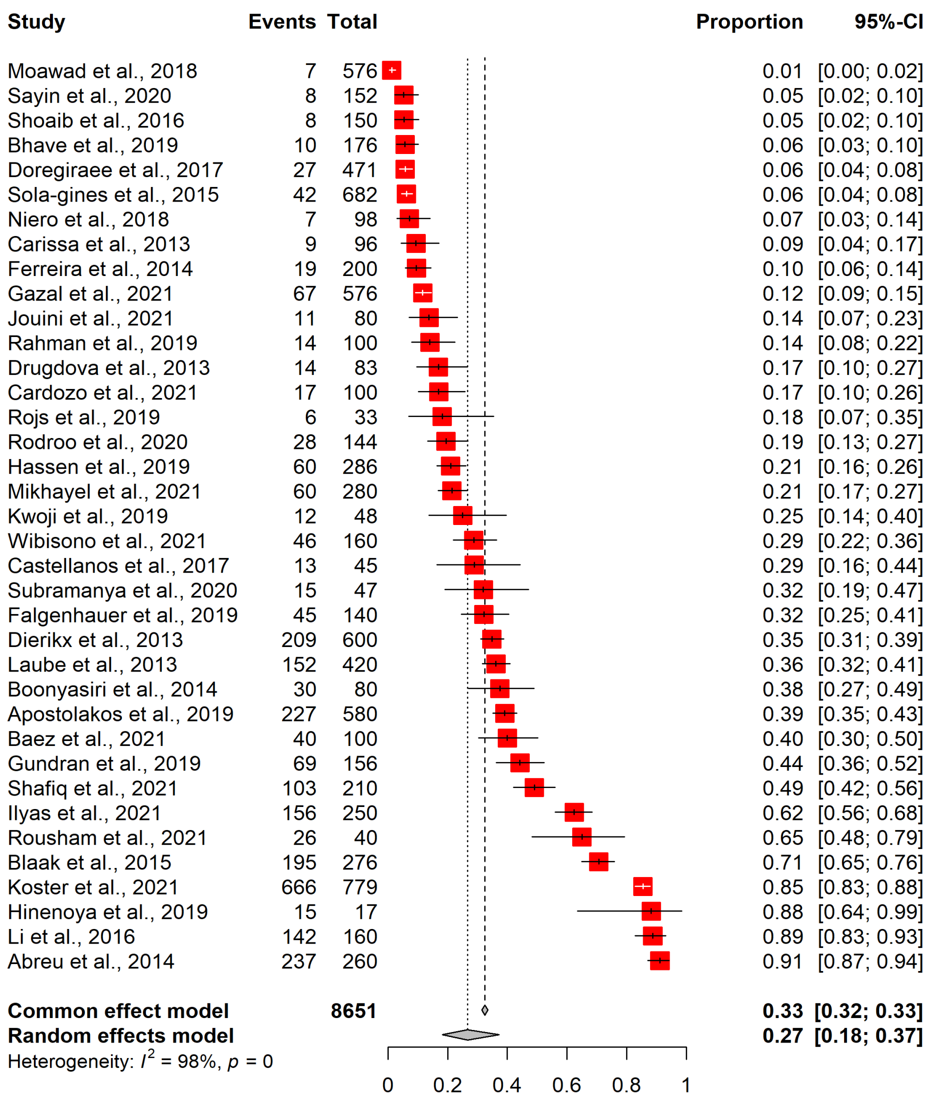


**Figure 2** Forest plot indicated the global pooled prevalence of ESBL *E. coli* in broiler farms.

## Subgroup analysis

In the continent subgroup, Asia and Europe had almost the same pooled prevalence estimated, 33.0% (95% CI = 18.7 to 51.3) and 32.8% (95% CI = 15.0 to 57.4), respectively. Africa had the lowest pooled prevalence, estimated at 12.4% (95% CI = 5.1 to 27.1). Global distribution of ESBL *E. coli* in broiler farms is shown in Figure 3. In the subgroup of sample type, the highest estimated pooled prevalence of 33.0% (95% CI = 21.5 to 46.8) was found in fecal samples, while the lowest estimated pooled prevalence of 11.0% (95% CI = 5.0 to 22.8) was found in other samples. Pooled prevalence of ESBL *E. coli* within subgroups is given in Table 2.

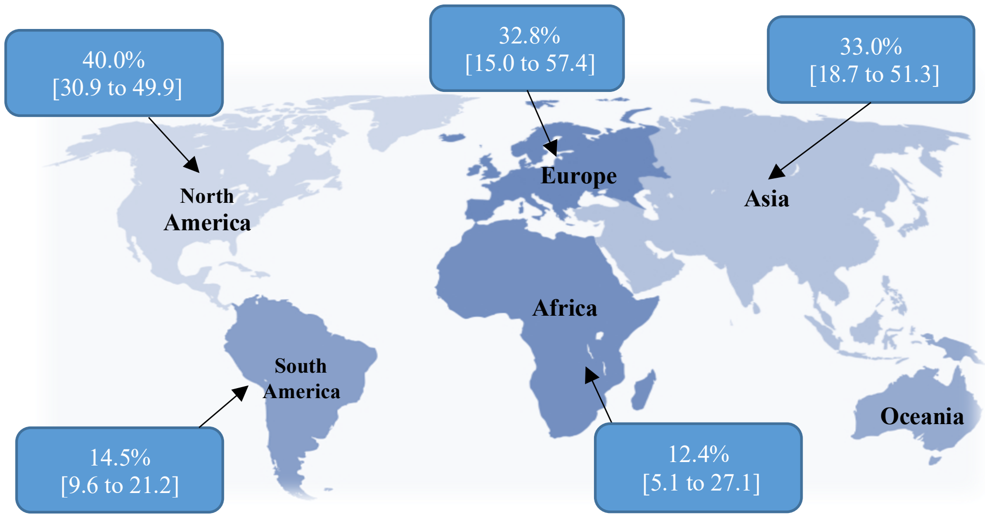


**Figure 3** Distribution of the pooled prevalence of ESBL *E. coli* in broiler farms across different continents.

**Table 2** The overall pooled prevalence of ESBL *E. coli* in broiler farms and subgroup meta-analysis using a random effects model.

| No. | Categories | No. of studies | Pooled prevalence (95% CI) | $I^2$ (%) | Q | *p*-value | *p*-value for subgroup difference |
|---|---|---|---|---|---|---|---|
| 1 | ESBL *E. coli* in broiler farm | 37 | 26.6 (18.2 to 37.3) | 98.2 | 1958.87 | *P* = 0 | |
| | | | **Sample types** | | | | *P* < 0.01 |
| 1 | Fecal sample | 29 | 33.0 (21.5 to 46.8) | 98.2 | 1543.20 | *P* < 0.01 | |
| 2 | Environmental sample | 7 | 28.3 (13.5 to 50.1) | 97.8 | 267.96 | *P* < 0.01 | |
| 3 | Others | 5 | 11.0 (5.0 to 22.8) | 95.5 | 89.08 | *P* < 0.01 | |
| | | | **Continent** | | | | *P* < 0.01 |
| 1 | Asia | 15 | 33.0 (18.7 to 51.3) | 97.2 | 500.69 | *P* < 0.01 | |
| 2 | Africa | 6 | 12.4 (5.1 to 27.1) | 94.0 | 83.90 | *P* < 0.01 | |
| 3 | Europe | 11 | 32.8 (15.0 to 57.4) | 99.0 | 995.91 | *P* < 0.01 | |
| 4 | North America | 1 | 40.0 (30.8 to 49.9) | - | - | - | |
| 5 | South America | 4 | 14.5 (9.6 to 21.2) | 78.2 | 13.75 | *P* < 0.01 | |
| | | | **Year-Wise** | | | | *P* = 0.01 |
| 1 | 2013 | 4 | 22.9 (12.9 to 37.3) | 90.6 | 31.85 | *P* < 0.01 | |
| 2 | 2014 | 3 | 46.4 (9.1 to 88.2) | 99.0 | 206.32 | *P* < 0.01 | |
| 3 | 2015 | 2 | 28.4 (3.1 to 82.9) | 99.7 | 302.87 | *P* < 0.01 | |
| 4 | 2016 | 2 | 39.9 (2.0 to 95.6) | 99.2 | 125.47 | *P* < 0.01 | |
| 5 | 2017 | 2 | 12.9 (3.8 to 35.6) | 95.9 | 24.46 | *P* < 0.01 | |
| 6 | 2018 | 2 | 2.8 (0.8 to 9.3) | 91.1 | 11.26 | *P* < 0.01 | |
| 7 | 2019 | 9 | 27.9 (15.5 to 44.9) | 92.7 | 110.26 | *P* < 0.01 | |
| 8 | 2020 | 3 | 15.5 (6.4 to 33.0) | 90.2 | 20.38 | *P* < 0.01 | |
| 9 | 2021 | 10 | 37.3 (22.2 to 55.4) | 98.8 | 736.32 | *P* < 0.01 | |

## Meta-regression

In the univariable meta-regression, the association between ESBL *E. coli* in broiler farms to studies reported in Asia (Coef. 95% CI = 1.36 (0.0002 to 2.71), $p$ = 0.050), and studies that were published in 2018 (Coef. 95% CI = -2.29 (-4.57 to -0.01), $p$ = 0.049) were found (Table 3). In the multivariable meta-regression, the association with ESBL *E. coli* was found in studies reported from Europe and in studies isolated from other types of sample subgroups, as indicated by a $p < 0.05$ (Table 4).

**Table 3** Summary results of univariable meta-regression for the prevalence of ESBL *E. coli* in broiler farms.

| Variables | Coef. (95% CI) | Standard error | *p*-value |
|---|---|---|---|
| **Sample type** | | | |
| Environmental sample (ref) | - | - | - |
| Fecal sample | 0.16 (-1.09 to 1.41) | 0.64 | 0.802 |
| Others | -1.24 (-2.98 to 0.50) | 0.89 | 0.162 |
| **Continent** | | | |
| Africa (ref) | - | - | - |
| Asia | 1.36 (0.0002 to 2.71) | 0.69 | 0.050 |
| Europe | 1.41 (-0.0071 to 2.83) | 0.72 | 0.051 |
| North America | 1.55 (-1.49 to 4.59) | 1.55 | 0.318 |
| South America | 0.35 (-1.37 to 2.06) | 0.87 | 0.692 |
| **Year-wise** | | | |
| 2013 (ref) | - | - | - |
| 2014 | -1.12 (-0.85 to 3.08) | 1.00 | 0.265 |
| 2015 | 0.34 (-1.88 to 2.56) | 1.13 | 0.764 |
| 2016 | 0.89 (-1.36 to 3.14) | 1.15 | 0.439 |
| 2017 | -0.63 (-2.87 to 1.62) | 1.14 | 0.584 |
| 2018 | -2.29 (-4.57 to -0.01) | 1.16 | 0.049 |
| 2019 | 0.32 (-1.23 to 1.88) | 0.79 | 0.684 |
| 2020 | -0.44 (-2.43 to 1.54) | 1.01 | 0.659 |
| 2021 | 0.74 (-0.78 to 2.27) | 0.78 | 0.340 |

## Sensitivity analysis and publication bias

Compared to the results obtained from the random effects model, the pooled prevalence of ESBL *E. coli* in broiler farms was found to be higher, at 32.5% (95% CI = 31.5 to 33.5) when computed by the fixed-effects model. However, the pooled prevalences determined by fixed and random effect models are comparable. The leave-one-out analysis showed a slight change in the pooled prevalence being estimated. The pooled prevalence was estimated at 28.5% (95% CI = 19.9 to 38.9) when the study with the lowest prevalence was excluded from the meta-analysis. On the other hand, the pooled prevalence was estimated at 24.8% (95% CI = 17.1 to 34.6) when the study with the highest prevalence was removed. Thus, removing the studies with the highest and lowest prevalence did not influence the overall pooled prevalence of ESBL *E. coli* in broiler farms. Sensitivity analysis to assess the robustness of the pooled prevalence is given in Table 5.

The existence of publication bias due to the small study effect was suggested by a funnel plot as shown in Figure 4 and Egger's test which indicated a statistically significant coefficient bias (-5.29±2.54, $p$ = 0.0449).

**Table 4** Summary results of multivariable meta-regression for the prevalence of ESBL *E. coli* in broiler farms.

| Variables | Coef. (95% CI) | Standard error | *p*-value |
|---|---|---|---|
| **Sample type** | | | |
| Environmental sample (ref) | - | - | - |
| Fecal sample | 0.34 (-0.83 to 1.51) | 0.60 | 0.570 |
| Others | -1.78 (-3.55 to -0.01) | 0.90 | 0.048 |
| **Continent** | | | |
| Africa (ref) | - | - | - |
| Asia | 0.95 (-0.28 to 2.19) | 0.63 | 0.130 |
| Europe | 2.35 (0.97 to 3.73) | 0.70 | 0.0008 |
| North America | 0.85 (-1.65 to 3.34) | 1.27 | 0.506 |
| South America | -0.09 (-1.74 to 1.57) | 0.84 | 0.917 |
| **Year-wise** | | | |
| 2013 (ref) | - | - | - |
| 2014 | 1.28 (-0.53 to 3.09) | 0.92 | 0.167 |
| 2015 | 0.15 (-1.75 to 2.05) | 0.97 | 0.876 |
| 2016 | 2.22 (-0.05 to 4.49) | 1.16 | 0.055 |
| 2017 | 0.15 (-2.03 to 2.33) | 1.11 | 0.894 |
| 2018 | -1.17 (-3.19 to 0.85) | 1.03 | 0.256 |
| 2019 | 1.04 (-0.38 to 2.46) | 0.72 | 0.150 |
| 2020 | 0.19 (-1.64 to 2.02) | 0.93 | 0.838 |
| 2021 | 1.24 (-0.28 to 2.76) | 0.78 | 0.11 |

**Table 5** Sensitivity analysis to assess robustness of the pooled prevalence.

| Categories | No. of studies or subgroups | Prevalence (95% CI) |
|---|---|---|
| **Model** | | |
| Fixed effects | 37 | 32.5 (31.5 to 33.5) |
| Random effects | 37 | 26.6 (18.2 to 37.3) |
| **Leave-one-out analysis** | | |
| The lowest prevalence[a] | 36 | 28.5 (19.9 to 38.9) |
| The highest prevalence[b] | 36 | 24.8 (17.1 to 34.6) |

[a]Excluded study of Moawad et al. (2018) from the meta-analysis.
[b]Excluded study of Abreu et al. (2014) from the meta-analysis.

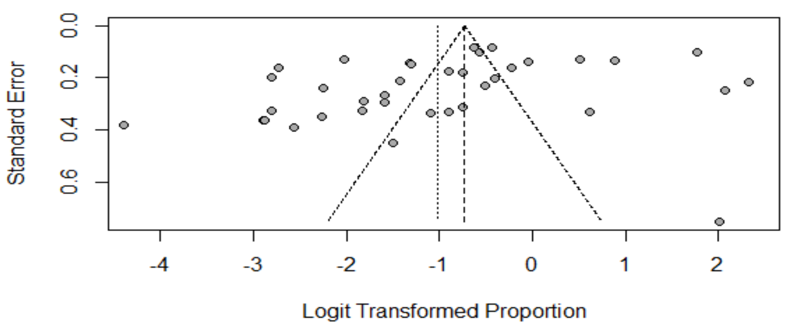


**Figure 4** Funnel plot to measure publication bias of the included studies.

# DISCUSSION

Antibiotic agents have been extensively used in broiler production for the purposes of growth promotion, prophylaxis (antibiotic is given to exposed herd of healthy animals), metaphylaxis (antibiotic is given to herd of healthy animals for disease prevention), and individual treatment (Page and Gautier, 2012; Roth et al., 2019). Broiler farming is depicted as a pyramidal hierarchy with the narrow top of the pyramid representing the breeding company. Studies revealed that there are only a few breeding companies worldwide, and two companies have a market share of more than 85% of the European market (EFSA, 2011). Our results revealed a moderate pooled prevalence of ESBL *E. coli* in broiler farms worldwide, with an estimated rate of 26.6% (95% CI = 18.2 to 37.3) using a random effects model. The pooled prevalence demonstrated a high level of heterogeneity, with Q = 1958.9 and $I^2$ = 98.2%. There are many risk factors that could potentially lead to the presence of ESBL *E. coli* in broiler farms. ESBL *E. coli* may introduce to the broiler farms via stocking of new chicks, exposure to contaminated air, water or feed, insect or rodent vectors, human-to-animals, and animal-to-animal transmission.

Subgroup analyses showed a significant difference ($p < 0.01$) of ESBL *E. coli* in the continents and sample type subgroup. In a subgroup of continent, the pooled prevalence of ESBL *E. coli* in broiler farms was highest in Asia (33.0%) and lowest in Africa (12.4%). Studies from Asia revealed an extensive use of beta-lactam in broiler production which is a factor contributing to the increased prevalence of ESBL *E. coli* in broiler production (Brower et al., 2017; Coyne et al., 2019). In addition, a study conducted in Chiang Mai and Lamphun provinces in Thailand reported that 96.2% of ESBL *E. coli* isolates were confirmed as multidrug resistant (MDR). Additionally, 7.5% of these MDR isolates were found to be resistant to as many as nine different classes of antimicrobials (Rodroo et al., 2021). This emphasizes the significant impact of ESBL *E. coli* on public health. Moreover, a shift from conventional to commercial farming practices is also attributed to the increase of ESBL *E. coli* in broiler farms (Li et al., 2016; Hinenoya et al., 2018). Our results showed that the prevalence of ESBL *E. coli* in European broiler farms was similar to those in Asia. ESBL *E. coli* has been reported in broiler farms and chicken meat in European countries due to several attributable factors such as heavy use of cephalosporins, lack of monitoring of biosecurity practices, and animals' trade (Liebana et al., 2013; Paivarinta et al., 2016). The European Food Safety Authority (EFSA) has a recommendation that applies to all EU members, which aims to minimize the public health risk of ESBL *E. coli* posed by poultry farming. The guideline calls for the prudent use of the third and fourth generation cephalosporins in poultry farms. The off-label use of these antibiotics is discouraged. The use of third and fourth generation cephalosporins are reserved for animals that have responded poorly to narrow-spectrum antimicrobials. Most importantly, the guideline emphasized biosecurity practices within poultry farms to prevent vertical transmission from the top of the poultry production pyramid (EFSA, 2011). Even though the prevalence of ESBL *E. coli* in Africa was the lowest in our studies, the risk of ESBL *E. coli* remains high. Absence of strict regulations, extensive use of antibiotics in broiler farms, and over-the-counter availability of antibiotics have been reported as associated factors that contributed to the presence of ESBL *E. coli* in African broiler farms (Carissa et al., 2013). In addition, the pooled prevalence of ESBL *E. coli* in broiler farms has fluctuated inconsistently throughout the decade. However, the prevalence has remained below 50%. To the best of our knowledge, we could not find any evidence to support this fluctuation.

We conducted a two-step meta-regression, where univariable meta-regression acts as a screening test and multiple meta-regression takes into account other variables when assessing the association, to investigate the association between ESBL *E. coli* in broiler farms and other variables that might influence the prevalence. The results from the univariable meta-regression reveal an association between ESBL *E. coli* in broiler farms and studies conducted in Asia ($p$ = 0.05), as well as studies published in 2018 ($p$ = 0.049). However, the multiple meta-regression reveals an association between ESBL *E. coli* in broiler farms and studies conducted in Europe ($p$ = 0.0008), as well as others sample type ($p$ = 0.048).

Publication bias analysis by Eggers's test suggested a publication bias of small study-effect. This indicated that studies with small sample sizes included in this study are a major source of publication bias. However, all studies included in the meta-analysis were of good quality, with an average score of 9.48/10 (SD = 0.9). The result from the sensitivity analysis, which involved comparing the pooled prevalence between the fixed and random effects models and the use of leave-one-out analysis, demonstrated that our meta-analyses were both robust and stable.

Our study contains some limitations. Firstly, the systematic literature searches were limited to only three databases. Secondly, all records were limited to studies that were published in English, as a result, we may rule out relevant studies that were published in other languages. Thirdly, subgroups were not well distributed across some characteristics due to the fact that few studies being eligible for analysis. Fourthly, the prevalence of ESBL *E. coli* was limited to samples taken from broiler farms, thus, studies conducted at broiler slaughterhouses were not included. Lastly, publication years may not always accurately reflect the time of sample collection. These could affect the result of the subgroup analysis.

# CONCLUSIONS

Our study revealed a moderate prevalence of ESBL *E. coli* from broiler farms over a decade. The estimated pooled prevalence was 26.6% (95% CI = 18.2 to 37.3). This suggests a potential burden of ESBL *E. coli* in public health and broiler production. The use of antibiotics in broiler production requires monitoring to ensure their prudent use within the industry. Regulations regarding the use of antibiotics in broiler production need to be established, especially in areas where such regulations are currently absent. Collective actions among policymakers, broiler producers, veterinarians, and consumers are necessary to achieve sustainable and less antibiotic use in broiler production. Further research on alternatives to antibiotic use in broiler production is encouraged to make it more available and accessible to a broader scale of broiler production.

# ACKNOWLEDGEMENTS

The authors would like to extend deepest gratitude to the Veterinary Public Health and Food Safety Centre for Asia Pacific (VPHCAP), Chiang Mai University, SEAOHUN Scholarship Program and USAID. This study was funded by the Center of Excellence in Veterinary Public Health, Faculty of Veterinary Medicine, Chiang Mai University and the SEAOHUN Scholarship Program with the generous support of the American people through US Agency for international Development (USAID) One Health Workforce – Next Generation (OHW-NG) Award 7200AA19CA00018. The contents and associated materials are the responsibility of the authors and do not necessarily reflect the views of USAID or the US Government.

# AUTHOR CONTRIBUTIONS

NA and SB designed and conceptualized the study. NA, PO and SB performed systematic review and meta-analysis. NA and PO prepared and revised the manuscript. VP revised statistical analysis.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## REFERENCES

Abreu, R., Castro, B., Espigares, E., Rodriguez-Alvarez, C., Lecuona, M., Moreno, E., Espigares, M., Arias, A., 2014. Prevalence of CTX-M-type extended-spectrum beta-lactamases in *Escherichia coli* strains isolated in poultry farms. Foodborne. Pathog. Dis. 11(11), 868-873.

Apostolakos, I., Mughini-Gras, L., Fasolato, L., Piccirillo, A., 2019. Assessing the occurrence and transfer dynamics of ESBL/pAmpC-producing *Escherichia coli* across the broiler production pyramid. PLoS One. 14(5), e0217174.

Aworh, M.K., Kwaga, J., Okolocha, E., Harden, L., Hull, D., Hendriksen, R.S., Thakur, S., 2020. Extended-spectrum beta-lactamase-producing *Escherichia coli* among humans, chickens, and poultry environments in Abuja, Nigeria. One Health Outlook. 2, 11.

Baez, M., Espinosa, I., Collaud, A., Miranda, I., Montano, D.L.N., Feria, A.L., Hernandez-Fillor, R., 2021. Genetic features of extended-spectrum β-lactamase-producing *Escherichia coli* from poultry in Mayabeque Province, Cuba. Antibiotics. 10*,* 1-14.

Bhave, S., Kolhe, R., Mahadevaswamy, R., Bhong, C., Jadhav, S., Nalband, S., Gandhale, D., Muglikar, D., 2019. Phylogrouping and antimicrobial resistance analysis of extraintestinal pathogenic *Escherichia coli* isolated from poultry species. Turk. J. Vet. Anim. Sci. 43*,* 117-126.

Blaak, H., Van Hoek, A.H.A.M., Hamidjaja, R.A., Van Der Plaats, R.Q.J., Kerkhof-De Heer, L., De Roda Husman, A.M., Schets, F., 2015. Distribution, numbers, and diversity of ESBL-producing *E. coli* in the poultry farm environment. PLoS One. 10(8), e0135402.

Boonyasiri, A., Tangkoskul, T., Seenama, C., Saiyarin, J., Tiengrim, S., Thamlikitkul, V., 2014. Prevalence of antibiotic-resistant bacteria in healthy adults, foods, food animals, and the environment in selected areas in Thailand. Pathog. Glob. Health. 108(5), 235-245.

Brower, C.H., Mandal, S., Hayer, S., Sran, M., Zehra, A., Patel, S.J., Kaur, R., Chatterjee, L., Mishra, S., Das, B.R., Singh, P., Singh, R., Gill, J.P.S., Laxminarayan, R., 2017. The Prevalence of Extended-Spectrum Beta-Lactamase-Producing multidrug-resistant *Escherichia Coli* in poultry chickens and variation according to farming practices in Punjab, India. Environ. Health. Perspect. 125(7), 077015.

Bui, T.K.N., Bui, T.M.H., Ueda, S., Le, D.T., Yamamoto, Y., Hirai, I., 2018. Potential transmission opportunity of CTX-M-producing *Escherichia coli* on a large-scale chicken farm in Vietnam. J. Glob. Antimicrob. Resist. 13, 1-6.

Bush, K., Bradford, P.A., 2016. β-Lactams and β-Lactamase Inhibitors: an overview. Cold. Spring. Harb. Perspect. Med. 6(8), a025247.

Cardozo, M.V., Liakopoulos, A., Brouwer, M., Kant, A., Pizauro, L.J.L., Borzi, M.M., Mevius, D., de Ávila, F.A., 2021. Occurrence and molecular characteristics of extended-spectrum beta-lactamase-producing Enterobacterales recovered from chicken, chicken meat, and human infections in Sao Paulo State, Brazil. Front. Microbiol. 12, 628738.

Carissa, D., Edward, N., Michael, A., Chika, E., Charles, E., 2013. Extended-spectrum beta-lactamase-producing *Escherichia coli* strains of poultry origin in Owerri, Nigeria. World. J. Med. Sci. 8(4), 349-354.

Castellanos, L.R., Donado-Godoy, P., León, M., Clavijo, V., Arevalo, A., Bernal, J.F., Timmerman, A.J., Mevius, D.J., Wagenaar, J.A., Hordijk, J., 2017. High heterogeneity of *Escherichia coli* sequence types harbouring ESBL/AmpC genes on IncI1 plasmids in the Colombian poultry chain. PLoS One. 12(1), e0170777.

Chong, Y., Ito, Y., Kamimura, T., 2011. Genetic evolution and clinical impact in extended-spectrum β-lactamase-producing *Escherichia coli* and *Klebsiella pneumoniae*. Infect. Genet. Evol. 11(7), 1499-1504.

Chong, Y., Shimoda, S., Shimono, N., 2018. Current epidemiology, genetic evolution and clinical impact of extended-spectrum β-lactamase-producing *Escherichia coli* and *Klebsiella pneumoniae*. Infect. Genet. Evol. 61, 185-188.

Coyne, L., Arief, R., Benigno, C., Giang, V.N., Huong, L.Q., Jeamsripong, S., Kalpravidh, W., McGrane, J., Padungtod, P., Patrick, I., Schoonman, L., Setyawan, E., Harja Sukarno, A., Srisamran, J., Ngoc, P.T., Rushton, J., 2019. Characterizing antimicrobial use in the livestock sector in three South East Asian countries (Indonesia, Thailand, and Vietnam). Antibiotics (Basel). 8(1), 33.

De Koster, S., Ringenier, M., Lammens, C., Stegeman, A., Tobias, T., Velkers, F., Vernooij, H., Kluytmans-van den Bergh, M., Kluytmans, J., Dewulf. J., Goossens H., 2021. ESBL-producing, carbapenem- and ciprofloxacin-resistant *Escherichia coli* in Belgian and Dutch broiler and pig farms: a cross-sectional and cross-border study. Antibiotics. 10(8), 945.

De Kraker, M.E.A., Stewardson, A.J., Harbarth, S., 2016. Will 10 million people die a year due to antimicrobial resistance by 2050?. PLoS Med. 13(11), e1002184.

Dierikx, C.M., Van Der Goot, J.A., Smith, H.E., Kant, A., Mevius, D.J., 2013. Presence of ESBL/AmpC-producing *Escherichia coli* in the broiler production pyramid: a descriptive study. PLoS One. 8(11). e79005.

Ding, H., Gao, Y. M., Deng, Y., Lamberton, P.H., Lu, D.B., 2017. A systematic review and meta-analysis of the seroprevalence of *Toxoplasma gondii* in cats in mainland China. Parasit Vectors. 10(1), 27.

Doregiraee, F., Alebouyeh, M., Nayeri Fasaei, B., Charkhkar, S., Tajeddin, E., Zali, M.R., 2018. Changes in antimicrobial resistance patterns and dominance of extended spectrum β-lactamase genes among faecal *Escherichia coli* isolates from broilers and workers during two rearing periods. Ital. J. Anim. Sci. 17(3), 815-824.

Drugdova, Z., Kmet, V., 2013. Prevalence of beta-lactam and fluoroquinolone resistance, and virulence factors in *Escherichia coli* isolated from chickens in Slovakia. Biologia. 68(1), 11-17.

EFSA Panel on Biological Hazards (BIOHAZ), 2011. Scientific opinion on the public health risks of bacterial strains producing extended-spectrum β-lactamases and/or AmpC β-lactamases in food and food-producing animals. EFSA J. 9(8), 2322.

Egger, M., Smith, G.D., Schneider, M., Minder, C., 1997. Bias in meta-analysis detected by a simple, graphical test. BMJ. 315(7109), 629-634.

Falgenhauer, L., Imirzalioglu, C., Oppong, K., Akenten, C.W., Hogan, B., Krumkamp, R., Poppert, S., Levermann, V., Schwengers, O., Sarpong, N., Owusu-Dabo, E., May, J., Eibach, D., 2019. Detection and characterization of ESBL-producing *Escherichia coli* from humans and poultry in Ghana. Front. Microbiol. 10, 3358.

Food and Agriculture Organization of the United Nations, 2019. Monitoring and surveillance of antimicrobial resistance in bacteria from healthy food animals intended for consumption. In: Regional antimicrobial resistance monitoring and surveillance guidelines: Volume 1. Available online: https://openknowledge.fao.org/server/api/core/bitstreams/f31e70b6-b9e0-41b6-916a-1cb0c3654c4d/content.

Ferreira, J.C., Penha Filho, R.A.C., Andrade, L.N., Berchieri, A., Darini, A.L.C., 2014. Detection of chromosomal blaCTX-M-2 in diverse *Escherichia coli* isolates from healthy broiler chickens. Clin. Microbiol. Infect. 20(10), 623-626.

Gazal, L.E.D.S., Medeiros, L.P., Dibo, M., Nishio, E.K., Koga, V.L., Gonçalves, B.C., Grassotti, T.T., de Camargo, T.C.L., Pinheiro, J.J., Vespero, E.C., de Brito, K.C.T., de Brito, B.G., Nakazato, G., Kobayashi, R.K.T., 2021. Detection of ESBL/AmpC-producing and fosfomycin-resistant *Escherichia coli* from different sources in poultry production in Southern Brazil. Front. Microbiol. 11(11), 604544.

Gundran, R.S., Cardenio, P.A., Villanueva, M.A., Sison, F.B., Benigno, C.C., Kreausukon, K., Pichpol, D., Punyapornwithaya, V., 2019. Prevalence and distribution of blaCTX-M, blaSHV, and blaTEM genes in extended-spectrum β-lactamase-producing *E. coli* isolates from broiler farms in the Philippines. BMC Vet. Res. 15(1), 227.

Hassen, B., Abbassi, M.S., Ruiz-Ripa, L., Mama, O.M., Hassen, A., Torres, C., Hammami, S., 2020. High prevalence of mcr-1 encoding colistin resistance and first identification of blaCTX-M-55 in ESBL/CMY-2-producing *Escherichia coli* isolated from chicken faeces and retail meat in Tunisia. Int. J. Food. Microbiol. 318, 108478.

Higgins, J.P.T., Thompson, S.G., Deeks, J.J., Itman, D.G., 2003. Measuring inconsistency in meta-analyses. BMJ. 327(7414), 557-560.

Hinenoya, A., Tran, S.T.T., Nguyen, N.T., Nguyen, H.C., Nguyen, D.D.L., Hoang, P.H., Awasthi, S.P., Hassan, J., Sumimura, Y., Yamamoto, Y., Yamasaki, S., 2018. Isolation and molecular characterization of extended-spectrum beta-lactamase producing *Escherichia coli* from industrial food animals in Mekong Delta, Vietnam. JPN J. Vet. Res. 66(1), 1-12.

Ilyas, S., Rasool, M.H., Arshed, M.J., Qamar, M.U., Aslam, B., Almatroudi, A., Khurshid, M., 2021. The *Escherichia coli* sequence type 131 harboring extended-spectrum beta-lactamases and carbapenemases genes from poultry birds. Infect. Drug. Resist. 14, 805-813.

Jouini, A., Klibi, A., Elarbi, I., Chaabene, M.B., Hamrouni, S., Souiai, O., Hanachi, M., Ghram, A., Maaroufi, A., 2021. First detection of human ST131-CTX-M-15-O25-B2 clone and high-risk clonal lineages of ESBL/pAmpC-producing *E. coli* isolates from diarrheic poultry in Tunisia. Antibiotics, 10(6), 670.

Karanika, S., Karantanos, T., Arvanitis, M., Grigoras, C., Mylonakis, E., 2016. Fecal Colonization with Extended-spectrum Beta-lactamase–Producing enterobacteriaceae and risk factors among healthy individuals: a systematic review and metaanalysis. Clin. Infect. Dis. 63(3), 310-318.

Kwoji, I.D., Musa, J.A., Daniel, N., Mohzo, D.L., Bitrus, A.A., Ojo, A.A., Ezema, K.U., 2019. Extended-spectrum beta-lactamase-producing *Escherichia coli* in chickens from small-scale (backyard) poultry farms in Maiduguri, Nigeria. Int. J. One. Health. 5, 26-30.

Laube, H., Friese, A., von Salviati, C., Guerra, B., Käsbohrer, A., Kreienbrock, L., Roesler, U., 2013. Longitudinal monitoring of extended-spectrum-beta-lactamase/AmpC-producing *Escherichia coli* at German broiler chicken fattening farms. Appl. Environ. Microbiol. 79(16), 4815-4820.

Li, S., Zhao, M.M., Liu, J.H., Zhou, Y.F., Miao, Z.M., 2016. Prevalence and antibiotic resistance profiles of extended-spectrum beta-lactamase-producing *Escherichia coli* isolated from healthy broilers in Shandong Province, China. J. Food. Prot. 79(7), 1169-1173.

Liebana, E., Carattoli, A., Coque, T.M., Hasman, H., Magiorakos, A.P., Mevius, D., Peixe, L., Poirel, L., Schuepbach-Regula, G., Torneke, K., Torren-Edo, J., Torres, C., Threlfall, J., 2013. Public health risks of enterobacterial isolates producing extended-spectrum β-lactamases or AmpC β-lactamases in food and food-producing animals: an EU perspective of epidemiology, analytical methods, risk factors, and control options. Clin. Infect. Dis. 56(7), 1030-1037.

Mikhayel, M., Leclercq, S.O., Sarkis, D.K., Doublet, B., 2021. Occurrence of the colistin resistance gene mcr-1 and additional antibiotic resistance genes in ESBL/AmpC producing *Escherichia coli* from poultry in Lebanon: a nationwide survey. Microbiol. Spectr. 9(2), e0002521.

Moawad, A.A., Hotzel, H., Neubauer, H., Ehricht, R., Monecke, S., Tomaso, H., Hafez, H. M., Roesler, U., El-Adawy, H., 2018. Antimicrobial resistance in Enterobacteriaceae from healthy broilers in Egypt: Emergence of colistin-resistant and extended-spectrum β-lactamase-producing *Escherichia coli.* Gut. Pathog. 10(1), 39.

Niero, G., Bortolaia, V., Vanni, M., Intorre, L., Guardabassi, L., Piccirillo, A., 2018. High diversity of genes and plasmids encoding resistance to third-generation cephalosporins and quinolones in clinical *Escherichia coli* from commercial poultry flocks in Italy. Vet. Microbiol. 216, 93-98.

World Organization for Animal Health, 2020. OIE Standards, Guidelines and Resolution on Antimicrobial Resistance and the use of antimicrobial agents. Available online: https://www.oie.int/en/document/book-amr-ang-fnl-lr/

Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., Shamseer, L., Tetzlaff, J.M., Akl, E.A., Brennan, S.E., Chou, R., Glanville, J., Grimshaw, J.M., Hróbjartsson, A., Lalu, M.M., Li, T., Loder, E.W., Mayo-Wilson, E., McDonald, S., McGuinness, L.A., Stewart, L.A., Thomas, J., Tricco, A.C., Welch, V. A., Whiting, P., Moher, D., 2021. The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. BMJ. 2021, 372.

Page, S.W., Gautier, P., 2012. Use of antimicrobial agents in livestock. Rev. Sci. Tech. 31(1), 145-188.

Paivarinta, M., Pohjola, L., Fredriksson-Ahomaa, M., Heikinheimo, A., 2016. Low occurrence of extended-spectrum beta-lactamase-producing *Escherichia coli* in Finnish food-producing animals. Zoonoses. Public. Health. 63(8), 624-631.

Rodroo, J., Intanon, M., Kreausukon, K., Kongkaew, A., Bender, J., Awaiwanont, N., 2021. Occurrence of extended-spectrum beta-lactamase producing *E. coli* in broiler farm workers and the farm environment in Chiang Mai-Lamphun, Thailand. Vet. Integr. Sci. 19(1), 23-35.

Rojs, O.Z., Zdovc, I., Dovč, A., Žgajnar, J., Slavec, B., Krapež, U., Ambrožič, J.A., 2019. Presence and distribution of extended-spectrum and AmpC beta-lactamases-producing *Escherichia coli* on poultry farms in Slovenia. J. Appl. Poult. Res. 28(1), 200-209.

Roth, N., Käsbohrer, A., Mayrhofer, S., Zitz, U., Hofacre, C., Domig, K.J., 2019. The application of antibiotics in broiler production and the resulting antibiotic resistance in *Escherichia coli*: a global overview. Poult. Sci. 98(4), 1791-1804.

Rousham, E.K., Asaduzzaman, M., Amin Uddin Mozmader, T.I.M., Amin, M.B., Rahman, M., Hossain, M.I., Islam, M.R., Mahmud, Z.H., Unicomb, L., Islam, M.A., 2021. Human colonization with extended-spectrum beta-lactamase-producing *E. coli* in relation to animal and environmental exposures in Bangladesh: an observational One Health study. Environ. Health. Perspect. 129(3), 37001.

Sayin, N., Turkyilmaz, S., 2020. Investigation of antimicrobial resistance status of aerobic bacteria causing arthritis in broilers. Refu. Vet. 75(3), 153-160.

Shafiq, M., Huang, J., Shah, J.M., Ali, I., Rahman, S.U., Wang, L., 2021. Characterization and resistant determinants linked to mobile elements of ESBL-producing and mcr-1-positive *Escherichia coli* recovered from the chicken origin. Microb. Pathog. 150, 104722.

Shoaib, M., Kamboh, A.A., Sajid, A., Mughal, G.A., Leghari, R.A., Malhi, K.K., Bughio, S., Ali, A., Alam, S., Khan, S., Ali, S., 2016. Prevalence of extended spectrum beta-lactamase producing Enterobacteriaceae in commercial broilers and backyard chickens. Adv. Anim. Vet. Sci. 4(4), 209-214.

Solà-Ginés, M., González-López, J.J., Cameron-Veas, K., Piedra-Carrasco, N., Cerdà-Cuéllar, M., Migura-Garcia, L., 2015. Houseflies (Musca domestica) as vectors for extended-spectrum β-lactamase-producing *Escherichia coli* on Spanish broiler farms. Appl. Environ. Microbiol. 81(11), 3604-3611.

Subramanya, S.H., Bairy, I., Nayak, N., Amberpet, R., Padukone, S., Metok, Y., Bhatta, D. R., Sathian, B., 2020. Detection and characterization of ESBL-producing Enterobacteriaceae from the gut of healthy chickens, *Gallus gallus domesticus* in rural Nepal: Dominance of CTX-M-15-non-ST131 *Escherichia coli* clones. PLoS One. 15(5), e0227725.

Ur Rahman, S., Ahmad, S., Khan, I., 2019. Incidence of ESBL-producing *Escherichia coli* in poultry farm environment and retail poultry meat. Pak. Vet. J. 39(1), 116-120.

Van Hoek, A.H.A.M., Dierikx, C., Bosch, T., Schouls, L., Van Duijkeren, E., Visser, M., 2020. Transmission of ESBL-producing *Escherichia coli* between broilers and humans on broiler farms. J. Antimicrob. Chemother. 75(3), 543-549.

Wibisono, F.J., Sumiarto, B., Untari, T., Effendi, M.H., Permatasari, D.A., Witaningrum, A. M., 2021. Cases of multidrug resistance (MDR) and extended spectrum beta-lactamase (ESBL) producing *Escherichia coli* from broiler chicken in Blitar, Indonesia. Biochem. Cell. Arch. 21, 1923-1929.

How to cite this article;

Phirum Or, Sukolrat Boonyayatra, Veerasak Punyapornwithaya, Nattakarn Awaiwanont. Prevalence of extended-spectrum beta-lactamase-producing *Escherichia Coli* in broiler farms: A systematic review and meta-analysis. Veterinary Integrative Sciences. 2025; 23(2): e2025033-1-18.