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SYSTEMATIC REVIEW OF THE EPIDEMIOLOGY AND ANTIMICROBIAL RESISTANCE OF *CAMPYLOBACTER* SPP. IN BACKYARD CHICKEN FARMS

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DEDICATION

This project is dedicated to my past self,

congratulations for making it all the way through to the finishing line.

You made it.

ACKNOWLEDGEMENT

First and foremost, I would like to express my gratitude to my project supervisor, Dr Nur Indah binti Ahmad for all her guidance, motivation and advices throughout this whole project. Thank you for believing that I am capable of making my final year project a memorable one. Not to forget, my co-supervisor, Prof Jalila binti Abu, for her help and concern along the way.

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ABSTRAK

Abstrak daripada kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999- Projek Tahun Akhir

ULASAN SISTEMATIK EPIDEMIOLOGI DAN RINTANGAN ANTIMIKROB *CAMPYLOBACTER* SPP. DI LADANG AYAM TERNAKAN LAMAN RUMAH

Oleh

HUSAINI BIN AHMAD BORHAM

2021

Penyelia: Dr. Nur Indah binti Ahmad

Penyelia bersama: Professor Dr. Jalila binti Abu

Campylobacter spp. adalah satu bakteria bawaan makanan zoonosis penting yang menyebabkan gastroenteritis dalam manusia pada skala global, dengan cirit-birit sebagai gejala umumnya. *Campylobacter* spp. biasanya didapati sebagai komensal dalam saluran pencernaan banyak haiwan ternakan, termasuk ayam. Ayam ternakan laman rumah boleh menjadi punca Campylobacteriosis kepada manusia. Objektif utama ulasan ini adalah untuk menerangkan kelaziman dan rintangan antimikrob *Campylobacter* spp. dalam ayam ternakan laman rumah. Kami mengikuti garis panduan PRISMA untuk mencari kajian yang melaporkan kejadian *Campylobacter* spp. dalam ayam ternakan laman rumah dan corak rintangan antibiotik bagi isolat. Laman PubMed dan SCOPUS telah dicari untuk kajian berkenaan *Campylobacter* spp. Sepuluh artikel memenuhi kriteria kemasukan dan pengecualian berikutan penapisan dan penilaian artikel. Kajian ini mendapati tiada perbezaan yang jelas dalam prevalens *Campylobacter* spp. antara ayam ternakan laman rumah dan sistem pengeluaran ayam yang lain. Kelaziman *Campylobacter* spp. dalam ayam ternakan laman rumah yang dikumpulkan daripada ulasan ini adalah antara 18.2% hingga 68%. *Campylobacter jejuni* ialah spesies utama yang diasingkan daripada ladang ayam ternakan laman rumah seperti yang dilaporkan oleh kebanyakan kajian dalam ulasan ini, manakala *Campylobacter coli* lebih kerap dilaporkan untuk rintangan antimikrob (AMR) berbanding *C. jejuni*. Prevalens *C. jejuni* berkisar antara 13.1% hingga 88.6% manakala *C. coli* mempunyai julat prevalens antara 0% hingga 71%. Walau bagaimanapun, pelbagai fenotip rintangan dadah telah dilaporkan sama untuk kedua-dua *C. jejuni* dan *C. coli*, yang mana akan menyebabkan kebimbangan kesihatan awam yang lebih besar disebabkan oleh virulensi dan pilihan antimikrob yang terhad. Pada masa kini, didapati masih tidak mencukupi laporan kajian yang disemak secara professional mengenai kelaziman dan rintangan antimikrob *Campylobacter* spp. dalam ayam ternakan laman rumah dari seluruh dunia khususnya dari negara

membangun dan kurang maju. Oleh itu, menggalakkan lebih banyak penyelidikan berkualiti tinggi dalam bidang ini adalah penting untuk membolehkan kadar kelaziman yang lebih tepat dan dikemas kini dilaporkan di seluruh dunia, untuk mencerminkan beban sebenar dan penyebaran *Campylobacter* spp. dalam ayam ternakan laman rumah.

KATA KUNCI: *Campylobacter,* rintangan antimikrob, rintangan terhadap pelbagai dadah, ternakan laman rumah, skala kecil, ayam

ABSTRACT

An abstract of the project paper presented to the Faculty of Veterinary Medicine in partial fulfillment of the course VPD 4999-Final Year Project.

SYSTEMATIC REVIEW OF THE EPIDEMIOLOGY AND ANTIMICROBIAL RESISTANCE OF *CAMPYLOBACTER* SPP. IN BACKYARD CHICKEN FARMS

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2021

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Campylobacter spp. is an important zoonotic foodborne bacteria that causes human gastroenteritis globally, with diarrhoea as the most common symptom. It is generally found as a commensal in the digestive tracts of many agricultural animals, including chickens. Backyard chickens can be a source of Campylobacteriosis to humans. The main objective of this review was to describe the prevalence and antimicrobial resistance of *Campylobacter* spp. in backyard chickens. We followed PRISMA guidelines to search for studies reporting occurrence of *Campylobacter* spp. in backyard chickens and the antibiotic susceptibility patterns of the isolates. PubMed and SCOPUS were searched for studies published on the topic. Ten articles fulfilled the inclusion and exclusion criteria following filter and appraisal of the articles. This study found no clear difference in the prevalence of *Campylobacter* spp. between backyard chickens and other poultry production systems. Prevalence of *Campylobacter* spp. in backyard chickens gathered from this review ranged from 18.2% to 68%. *Campylobacter jejuni* is the predominant species isolated from backyard chicken farms as reported by most studies in this review, while *Campylobacter coli* was more frequently reported for antimicrobial resistance (AMR) compared to *C. jejuni*. Prevalence of *C. jejuni* ranges from 13.1% to 88.6% while *C. coli* has a prevalence range of between 0% to 71%. However, multiple drug resistance phenotypes were similarly reported for both *C. jejuni* and *C. coli*, of which will cause greater public health concern owing to virulence and limited antimicrobial options. There are still insufficient peer-reviewed studies reporting on the prevalence and AMR of *Campylobacter* spp. in backyard chickens from around the globe in particular from developing and underdeveloped countries. Therefore, encouraging more high-quality research in this area is important to allow for a more accurate and updated prevalence rate being reported worldwide, reflecting the actual burden and spread of *Campylobacter* spp. in backyard chickens.

KEYWORDS: *Campylobacter,* antimicrobial resistance, multidrug resistant, backyard, small scale, chickens

1.0 Introduction

Campylobacter is a genus of gram-negative bacteria that typically appears as spiral-shaped, "S"-shaped, or curved, rod-shaped. The genus *Campylobacter* now has 17 species and 6 subspecies, with *C. jejuni* (subspecies *jejuni*) and *C. coli* being the most commonly documented in human diseases. Other species, such as *C. lari* and *C. upsaliensis*, have also been isolated from diarrhoea patients, but they are less commonly reported. *Campylobacter* species can be found in almost all warm-blooded mammals. They're common in food animals like chickens, cattle, pigs, lambs, and ostriches, as well as pets like cats and dogs (WHO, 2020). Chicken has been named as the most common reservoir/source of *Campylobacter* infection in studies using MLST and mathematical modelling, with attribution rates ranging from 38 percent to 77 percent, whereas cattle has been named as the second most common source, with attribution rates ranging from 16 percent to 54 percent (Skarp et al., 2016).

One of the foodborne illnesses which has been linked to poultry meat consumption is Campylobacteriosis. While *Campylobacter* infection in poultry is generally nonpathogenic, Campylobacteriosis can be fatal in very young children, elderly, and immunosuppressed individuals. *Campylobacter* is considered to be one of the main global causes of diarrheal disease (WHO, 2020). In one study done in Germany, from 509 poultry flock samples, 41.1% were detected as *Campylobacter* positive (Atassanova & Ring, 1999). In another study, *Campylobacter* was found in 97% of caecal samples from layer farms (n = 5) and 93% of caecal samples from broiler farms with *Campylobacter*-positive flocks (n = 2/3). Moreover, *Campylobacter* was detected in 24% of environmental samples from layer farms and 29% of environmental samples from broiler farms with *Campylobacter*-positive flocks (Schets et al., 2017).

Backyard poultry is defined as small flocks with minimal biosecurity. In many underdeveloped countries, backyard flocks account for roughly 80% of the poultry stocks (Pym et al., 2006, Sonaiya, 2000). Backyard poultry are often made up of free, native, unselected breeds of varied ages, with several species intermingled in the same flock (Pym et al., 2006, Minga et al., 2004, Singh et al., 2011). Backyard Poultry interacts closely with humans in the same household, as well as wild birds and other livestock, and they are vulnerable to vermin and predators (Schets et al., 2017). However, it makes a major contribution to household income and food consumption in many developing countries' rural areas. Thus, this review will also describe the prevalence and factors associated to *Campylobacter* spp. from backyard chicken farms.

Antibiotic usage in animals destined for food has led to the rise of antibiotic resistance in *Campylobacter*. Antimicrobial resistance in *Campylobacter* spp. is assumed to have grown as a result of unrestricted use of antimicrobials, particularly in developing nations. Antimicrobials are still employed as growth promoters rather than therapeutic medicines in several countries (De Vries et al., 2018). From a study done on one hundred and sixty caecal and one hundred and thirty-two carcasses randomly sampled at the Kejetia poultry slaughter, 100% of the *Campylobacter* isolated was found to be multidrug resistant (Karikari et al., 2017). Infection by antibiotic resistant bacteria can be harder to treat, can last longer, and may result in more severe illness.

Thus, this review will also describe the antimicrobial resistance patterns in *Campylobacter* spp. reported in backyard chicken farms.

Therefore, the objectives of this review are:

1. To describe the prevalence and factors associated to *Campylobacter* spp. from backyard chicken farms.
2. To study the antimicrobial resistance patterns in *Campylobacter* spp. reported in backyard chicken farms.

Justification for this review are as follows:

1. Addressing the lack of studies being done on the epidemiology and antimicrobial resistance of *Campylobacter* spp. in backyard chicken farms.
2. No record of a systematic review on epidemiology and antimicrobial resistance of *Campylobacter* spp. in backyard chicken farms.

2.0 Materials and Method

2.1 Review protocol – PRISMA

This review was adapted from guidelines set by PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) described by Moher et al., 2010.

2.2 Research questions

In formulating the research question, the mnemonic of PICo, which signified 'P' (Population or Problem), 'I' (interest) and 'Co'(Context) described by Lockwood et al., 2015 was referred to. Based on this, three main aspects of this review were recognized; namely backyard chicken (population), prevalence and antimicrobial resistance of *Campylobacter* spp. (interest) and globally (context). Research questions were then formulated based on these aspects:

RQ1: What is the prevalence and associated factors *Campylobacter* spp.-positive backyard chicken farms?

RQ2: What is the antimicrobial resistance profile of *Campylobacter* spp. in backyard chickens?

2.3 Systematic searching strategies

As proposed by Shaffril et al., 2018, three systematic processes of identification, screening, and eligibility were used to retrieve relevant articles. Using these procedures, we were able to locate and synthesize all of the studies in order to conduct a well-organized and transparent systematic literature review.

2.3.1 Identification

Four important keywords were determined based on the research questions: backyard chickens, prevalence, antibiotic resistance, and *Campylobacter*. By using thesaurus and consulting experts, we were able to find synonyms, related terms, and variations for these keywords. In two databases, SCOPUS and PubMed, the combinations of these terms were analysed using advanced search functions with Boolean operators (see Table 1). A total of 1320 possible articles were identified from the selected databases as a result of the search attempt.

Table 1: Search string used in the selected databases

Database	**String**
Scopus	(prevalence OR occurrence) OR *Campylobacter* AND ("antimicrobial resistance" OR "antibiotic resistance" OR "multidrug resistant") AND (backyard OR "free range" OR "small scale") AND (chicken OR poultry)
Pubmed	(prevalence OR occurrence) OR *Campylobacter* AND ("antimicrobial resistance" OR "antibiotic resistance" OR "multidrug resistant") AND (backyard OR "free range" OR "small scale") AND (chicken OR poultry)

2.3.2 Screening

Searched articles were screened by assistance of databases to be included or excluded in the review based on specific criteria (see Table 2). This review was limited to research and review articles. Only papers written in English, available in full text and open access were considered.

Table 2: Inclusion and exclusion criteria

Criterion	Inclusion	Exclusion
Document type	Research and review articles	Other than research and review articles
Language	English	Non English
Full text availability	Available in full text	Not available in full text
Accessibility	Open access	Not open access

In Scopus, to exclude more unrelated articles, keywords such as antibiotic resistance, chicken, prevalence, chickens, multidrug resistance, antimicrobial resistance and *Campylobacter* were added to further filter the results. A total of 893 articles were gathered from both databases.

2.3.3 Eligibility

From a total of 893 articles, 39 articles were found to be duplicates and were excluded. The remaining papers were then checked manually by reading the title and abstract whether it matched with already established inclusion criteria. 840 articles were excluded after screening the titles and abstract. One article was removed after full text screening and another three were excluded during data extraction. The final number of articles for the quality appraisal stage was ten.

2.4 Assessment of quality and risk of bias

Assessment of quality and risk of bias was done using McMaster Critical Review Form-Quantitative studies adapted from Law et al., 1998. Studies were appraised based on study purpose, literature review, study design, sample size, outcomes, intervention, result and conclusion. Scoring was based on the criteria assessed with 'yes' assigned to a score of 1 while 'no' was given 0 score. Components that were 'not addressed' or 'not applicable' were removed from the final scoring. All studies were found to be qualified and as of quality as the final score exceeded 50%.

2.5 Data extraction and analysis

Data was analyzed by reading the abstracts and screening through the articles gathered. Information relevant to the review were extracted and compared. Component of data extraction included all of the following:

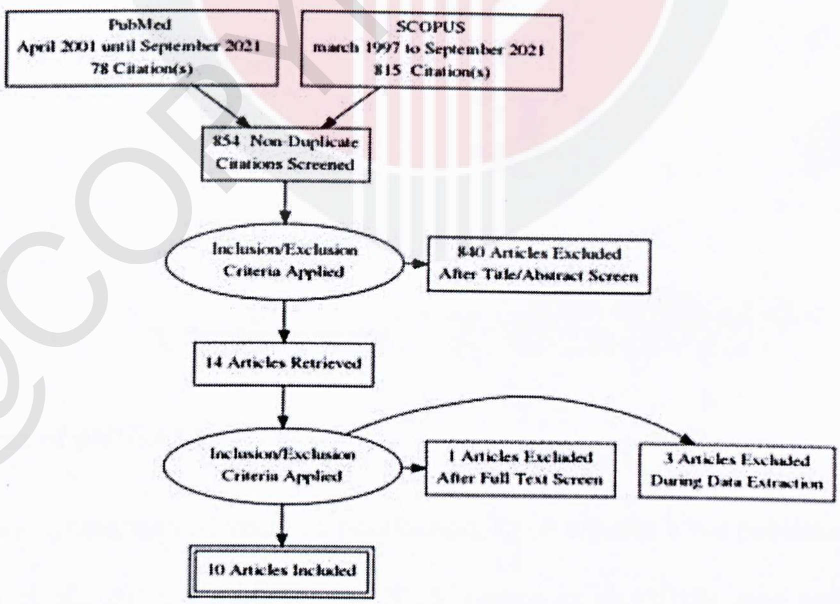
1. Study
2. Location
3. Timeframe
4. Type of animals
5. Study design
6. Type of samples
7. Isolation and identification methods
8. Antibiotic susceptibility tests
9. Number of samples
10. Number of isolates
11. Number of strains
12. Number of isolates by species

3.0 Result

3.1 General findings and background of the studies included in this review

The process of the literature review was presented in a flow diagram (Figure 1). In total, 893 articles were initially identified from both databases. After removal of duplicates and further screening steps, the eligibility assessment considered 14 studies. From the 14 studies included, 4 studies were further excluded after full text screen and data extraction process. Further exclusion reasons were no Antimicrobial Susceptibility Test component (1), no separation of origin of results according to poultry farms systems (2), and no data component (1). In total ten studies met the inclusion criteria, provided relevant information and were included in the review.

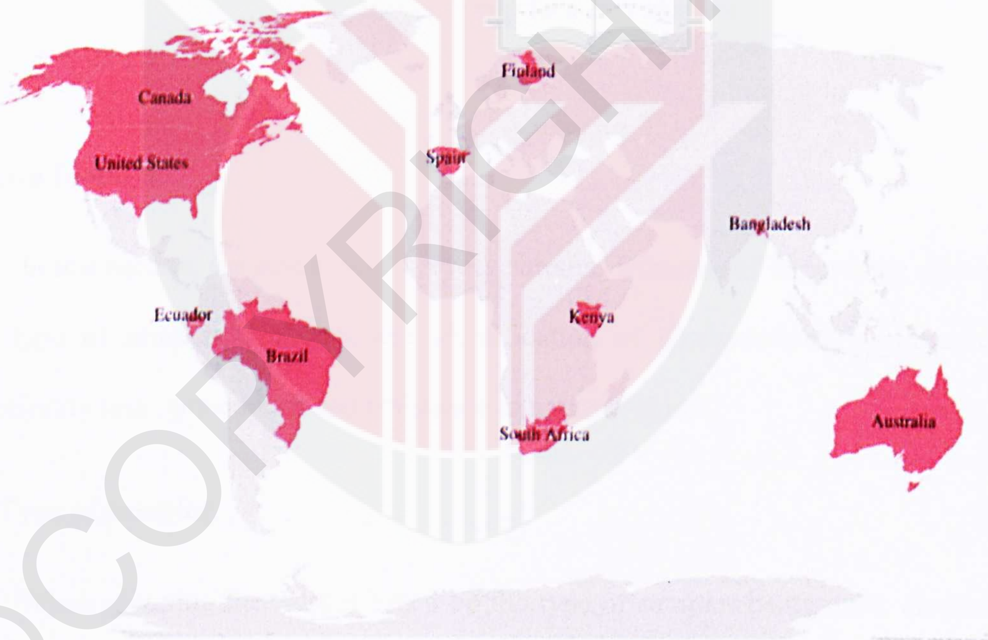
Figure 1: PRISMA or Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart diagram



3.1.1 Location

60% of the studies were done in developed countries (Dias et al., 2021, Novoa Rama et al., 2018, Obeng et al., 2012, Oporto et al., 2009, Pohjola et al., 2016, Varga et al., 2019) consisting of Brazil, United States, Australia, Spain, Finland and Canada while another 40% were done in underdeveloped and developing countries (Ochoa et al., 2016, Alam et al., 2020, Bester & Essack, 2012, Nguyen et al., 2016) in Kenya, South Africa, Ecuador and Bangladesh.

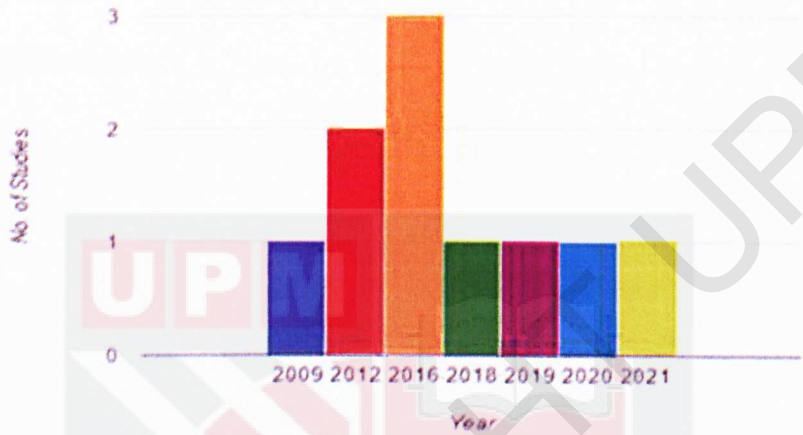
Figure 2: Countries where the studies were published



3.1.2 Year of publication

By comparison of years of publication, three articles were published in 2016 (Nguyen et al., 2016, Pohjola et al., 2016, Ochoa et al., 2016), two articles were published in 2012 (Bester & Essack, 2012, Obeng et al., 2012), and one article was published each in the year 2009 (Oporto et al., 2009), 2018 (Novoa Rama et al., 2018), 2019 (Varga et al., 2019), 2020 (Alam et al., 2020), and 2021 (Dias et al., 2021).

Figure 3: Bar chart of the number of articles reviewed between 2009 to 2021



3.2 Main findings

In this section, the result would revolve around 5 themes of importance which were; type of samples, isolation and identification of *Campylobacter*, antibiotic susceptibility tests, prevalence and resistance to antimicrobials.

3.2.1 Type of samples

When grouping the studies based on the type of samples being used, cloacal swab was the most common type of sample to assess for *Campylobacter* prevalence as evident by four studies (Pohjola et al., 2016, Alam et al., 2020, Nguyen et al., 2016, Ochoa et al., 2016) using the same type of sample. Caecal samples were used in three studies (Dias et al., 2021, Bester & Essack, 2012, Varga et al., 2019). Another three studies (Obeng et al., 2012, Nguyen et al., 2016, Novoa Rama et al., 2018) used fecal sample as their sample of choice. Other types of sample utilized in this review include shell pool emulsion (Novoa Rama et al., 2018), feed (Alam et al., 2020), drinking water (Alam et al., 2020), attendants' hand rinsed water (Alam et al., 2020), carcass (Alam et al., 2020), environmental swab (Novoa Rama et al.,2018) and lastly boot swab sample (Pohjola et al., 2016). One study (Oporto et al., 2009) did not mention the type of sample used.

Figure 4: Bar chart shows the type of samples employed in the reviewed articles

3.2.2 Isolation and identification of *Campylobacter*

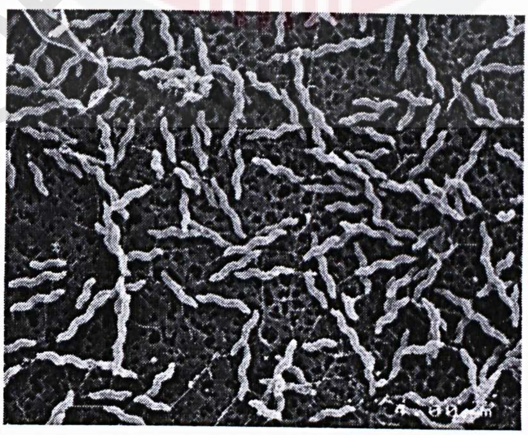
Campylobacter in this review were mostly isolated by culturing on *Campylobacter* growth plates. Identification of *Campylobacter* was first done through microscopy techniques such as gram staining and looking through its typical morphology and motility. Standard sets of biochemical tests were also used to identify *Campylobacter*. For molecular detection, mainly PCR was used. Isolation and identification methods used in this review were summarized in Table 3.

Table 3: Summary of isolation and identification methods

Author	*Campylobacter* spp. isolation and identification methods
Dias et al., 2021	Culture: Columbia agar plates supplemented with 0.4% activated charcoal and Campylofar® Microscopy: Gram stain Biochemical test: Catalase and oxidase test Other: Ability to grow aerobically at 25°C , 30°C and 37°C and microaerophilically at 25°C, 30°C and 42°C, to produce urease, growth on MacConkey agar at 30°C and the ability to grow in media containing 2% and 3.5% NaCl Molecular: PCR
Novoa Rama et al., 2018	Culture: Tryptic soy agar plates with 5% laked horse blood and restreaked onto blood-enriched TSA Microscopy: Morphology and darting motility Biochemical test: API Campy biochemical test kit Molecular: Real Time PCR
Ochoa et al., 2016	Culture: Butzler medium plates Microscopy: Gram stain Biochemical test: Oxidase, catalase, hippurate and indoxylacetate hydrolisis test Other: Sensitivity to nalidixic acid and cephalotin Molecular: Multiplex PCR
Alam et al., 2020	Culture: Blood base agar no. 2 (BBA) plate supplemented with 5% sheep blood, afterwards blood agar base no. 2 with Skirrow supplement/growth supplement Microscopy: Gram stain Biochemical test: Catalase test, oxidase test, hippurate hydrolysis test, and motility test Molecular: PCR
Bester & Essack, 2012	Culture: Butzler plate and *Campylobacter* growth supplement SR0232E (Oxoid) containing 5% lysed horse or sheep blood Microscopy: Gram stain Biochemical test: Indoxyl acetate hydrolysis, hippurate hydrolysis Other: Growth at 42°C and 24°C, and sensitivity to nalidixic acid Molecular: -
Nguyen et al., 2016	Culture: Mueller–Hinton agar and CCDA Microscopy: - Biochemical test: - Molecular: Multiplex PCR

Author	*Campylobacter* spp. isolation and identification methods
Obeng et al., 2012	Culture: *Campylobacter* agar base (Karmali – Oxoid CM0935) plates supplemented with Karmali selective supplement SR0167E (Oxoid, Thebarton, Adelaide, Australia), afterwards 5% horse blood agar plates Microscopy: Gram stain Biochemical test: Catalase and oxidase Molecular: PCR
Oporto et al., 2009	Not mentioned
Pohjola et al., 2016	Culture: mCCDA (modified charcoal Cefoperazone deoxycholate) Microscopy: Gram stain Biochemical test: - Molecular: PCR
Varga et al., 2019	Culture: *Campylobacter* Blood Free Media Microscopy: Matrix-assisted laser desorption ionization time-of-flight mass spectrometry Biochemical test: - Molecular: -

Figure 5: Typical morphology of *Campylobacter* adapted from Donnison, A. M., & Ross, C. M. (2004). MICROBIOLOGICAL SAFETY OF MEAT | Thermotolerant *Campylobacter*. Encyclopedia of Meat Sciences, 798–804. https://doi.org/10.1016/B0-12-464970-X/00055-6



3.2.3 Antibiotic susceptibility tests

Antibiotic susceptibility tests were methods used to test the susceptibility of microorganisms to antibiotics. In this review, four main methods were observed namely disc diffusion test, agar dilution, broth microdilution and molecular technique. Four studies (Novoa Rama et al., 2018, Nguyen et al., 2016, Oporto et al., 2009, Varga et al., 2019) used broth microdilution method while three other studies (Dias et al., 2021, Ochoa et al., 2016, Alam et al.,2020) utilized disc diffusion test. Another three studies (Bester & Essack, 2012, Pohjola et al., 2016, Obeng et al., 2012) used agar dilution method. Two studies (Nguyen et al., 2016, Obeng et al., 2012) managed to use molecular detection to detect antibiotic resistance genes.

Table 4: Summary of antibiotic susceptibility tests

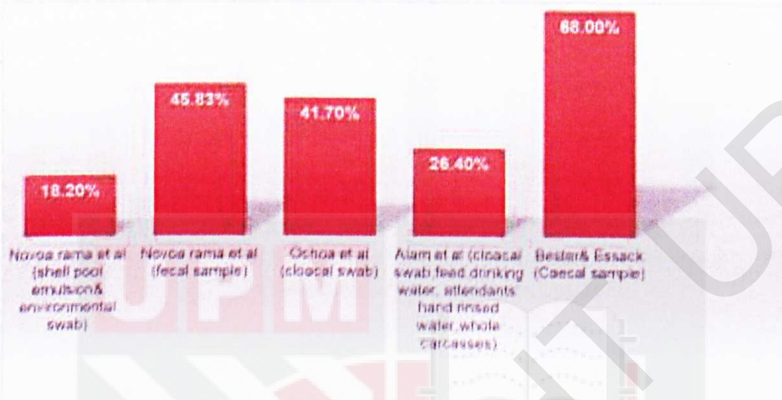
AST	Number of studies
Disc Diffusion test	3
Broth Microdilution Assay	4
Agar dilution	3
Molecular Detection	2

3.2.4 Prevalence

3.2.4.1 Prevalence of *Campylobacter* spp.

Only four studies in this review (Novoa Rama et al., 2018, Ochoa et al., 2016, Alam et al., 2020, Bester& Essack, 2012) provided prevalence on *Campylobacter* spp. Highest prevalence of *Campylobacter* spp. was reported at 68% in caecal sample of rural production and the lowest prevalence recorded was 18.2% in shell pool emulsion and environmental swab samples from free range housing layers.

Figure 6: Prevalence of *Campylobacter* spp. across studies

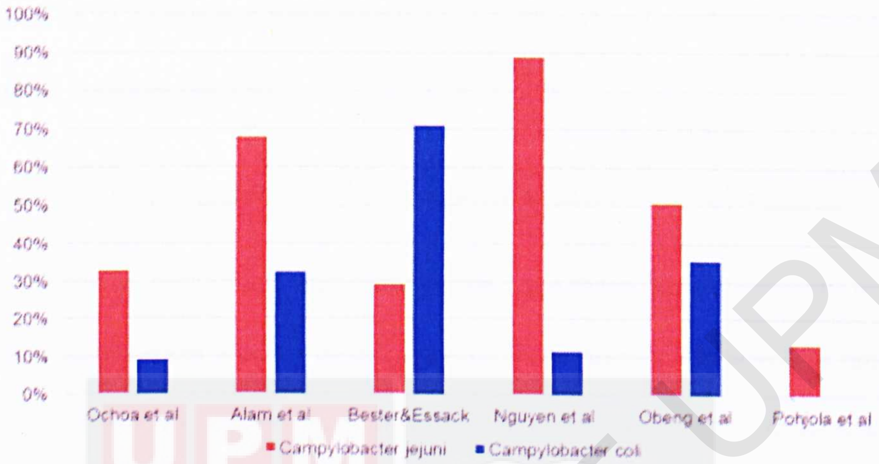


3.2.4.2 Prevalence of *Campylobacter* by species

In regards to prevalence of *Campylobacter* by species, six studies mentioned on the prevalence of *C. coli* and *C. jejuni* as these two species were the ones identified primarily. *C. jejuni* was more prevalent in 83.33% of the studies. For instance, Ochoa et al.,2016 reported to have found *C. jejuni* prevalence to be at 32.5% (39 out of 120 samples) while *C. coli* was at 9.2% prevalence (11 out of 120 samples). Moreover, study from Alam et al.,2020 reported to find *C. jejuni* prevalence from both small scale conventional and good practice broiler farms to be at 67.7% (63 out of 93 isolates) and *C. coli* at 32.3% (30 out of 93 isolates). Therefore, *C. jejuni* was the predominant isolated species compared to *C. coli* in backyard chicken farm setting.

C. jejuni prevalence ranged from 13.1% to 88.6% while *C. coli* was found within range of 0% to 71%.

Figure 7: Prevalence of *C. jejuni* and *C. coli*



3.2.4.3 Prevalence of *Campylobacter* spp. by farm systems

When comparing different poultry farm systems to *Campylobacter* spp. prevalence, several studies were reviewed (Bester & Essack, 2012; Novoa Rama et al., 2018). One study (Novoa Rama et al., 2018) reported to find *Campylobacter* spp. prevalence to be highest at about 45.83% in free range housing layers if fecal samples were taken. When the type of samples used in the same study were shell pool and environmental swabs, prevalence of *Campylobacter* spp. dropped to 18.2% in free range housing layers. Conventional cage layers had a prevalence of 19.7%. Bester & Essack., 2012 reported prevalence of *Campylobacter* spp. in commercial free-range broiler to be 47% only, with other poultry system such as industrial layer hens with 94% *Campylobacter* spp. prevalence. Therefore, in sight, there was no clear difference between prevalence of *Campylobacter* spp. and different poultry production systems.

3.2.5 Resistance against antimicrobials

A total of 23 different antimicrobials were analyzed and similar antimicrobials were compared between studies.

3.2.5.1 Resistance of *Campylobacter jejuni* against common antimicrobials

Ciprofloxacin, gentamicin and tetracycline were three most commonly tested antimicrobials across most studies in this review. Resistance to tetracycline ranged from 36.5% to 94.9% while ciprofloxacin resistance ranged from 3.9% to 84.6%. *C. jejuni* was still susceptible to gentamicin in three studies. Only two studies reported resistance to gentamicin ranging from 6.3% to 25.8%.

Table 5: Resistance profile of *Campylobacter jejuni*

Studies	Tetracycline	Ciprofloxacin	Gentamicin
Ochoa et al	94.9%	84.6%	0%
Alam et al	36.5%	11.10%	6.3%
Nguyen et al	71%	71%	25.8%
Oporto et al	42.1%	57.9%	0%
Varga et al	76.62%	3.9%	0%

3.2.5.2 Resistance of *Campylobacter coli* against common antimicrobials

C. coli resistance against commonly tested antimicrobials in this study follows the same pattern as *C. jejuni*. Tetracycline resistance ranged from 25% to 91% while ciprofloxacin resistance remained the widest with a range of 9.38% to 100%. *C. coli* was susceptible in one study to gentamicin and resistant to the rest. Range of resistance was found to be between 1.56% to 25%.

Both *C. jejuni* and *C. coli* were reported to be multidrug resistant. MDR is defined as acquiring non-susceptibility to at least one agent in three or more antimicrobial categories.

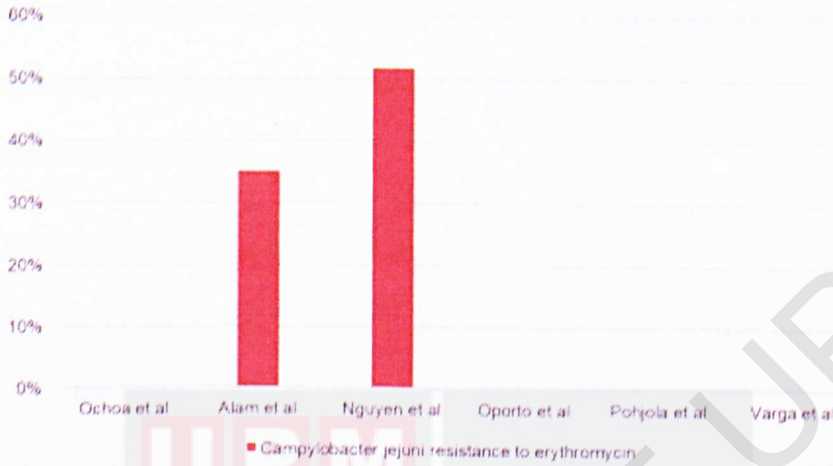
Table 6: Resistance profile of *Campylobacter coli*

Studies	Tetracycline	Ciprofloxacin	Gentamicin
Ochoa et al	91%	100%	0%
Alam et al	36.7%	10%	6.7%
Nguyen et al	25%	75%	25%
Varga et al	35.94%	9.38%	1.56%

3.2.5.3 Resistance to erythromycin

33.3% out of Six studies reported erythromycin resistance in *C. jejuni* isolates. Azithromycin or erythromycin are the first line of choice for antibiotic treatment of *Campylobacteriosis* and are therefore of public health importance if resistance is found to it. Based on this review, *C. jejuni* was still susceptible to erythromycin in four studies. Resistance to erythromycin ranges from 35% to 52%.

Figure 8: *Campylobacter jejuni* resistance to erythromycin



4.0 Discussion

From the spread of location of articles in this review, it was seen that a lesser number of studies were reported by underdeveloped and developing countries. This could very well be due to the lack of peer-reviewed journals being submitted by these countries compared to their developed counterparts.

An increasing trend in the number of studies done in the recent decade compared to the years before indicate *Campylobacter* spp. had gained more and more important as the years go by in the eyes of the scientific community.

The cloacal sample was the most used choice in this review compared to other samples. According to Urdaneta et al.,2015, *Campylobacter* is most commonly found in the caeca of chickens, where it can reach quantities of up to 109 CFU g–1 in caecal contents. As a result, it would be expected that caecal samples identify *Campylobacter* more easily than cloacal swab samples. However, when using cloacal swab samples, the detection was improved, likely due to less regrowth of surrounding microbiota, which, while not as common when using mCCDA plates, could sometimes hide *Campylobacter* colonies, obstructing its detection. In addition, the use of cloacal swabs allowed obtaining samples without the need to euthanize any bird, which also improved the birds welfare.

From this review, it could be deduced that the highest *Campylobacter* spp. prevalence was probably due to chickens in rural agricultural systems were frequently only confined to holding area in the evenings and interact with other animals such as cattle, sheep, and rats in the regions where they scavenge for food (Bester& Essack, 2012). These animals could carry and spread *Campylobacter* spp. to the chickens through contaminated feces. The other two studies (Ochoa et al., 2016, Novoa Rama et al., 2018) which reported prevalence of *Campylobacter* spp. at more than 40% revealed that prevalence of *Campylobacter* spp. was affected by living condition of the chickens, interaction with other known *Campylobacter* reservoirs like pigs, dogs, cats, sparrows and lack of biosecurity practices such as disinfecting the premises. Novoa Rama et al., 2018 further explained that birds raised outdoors were exposed to potential pathogen vectors and were susceptible to stress due to weather variations. Additionally, free-range birds could become infected with pathogens that persist in the soil environment of the farm due to the difficulty of disinfection practices in such systems.

When comparing prevalence of *C. jejuni* and *C. coli*, higher prevalence of *C. jejuni* compared to *C. coli* was in fact in agreement with other literatures. For instance, Anderson et al., 2011 reported to have found out of 35 backyard chicken flocks from their study, *C. jejuni* alone was detected in 20 (57%) of the flocks, while *C. coli* was detected in two (6%) of the flocks and both *C. jejuni* and *C. coli* were detected in eight (23%) of the flocks. Another study on the prevalence of *Campylobacter* on chicken meat on Vietnam also reported *C. jejuni* was the most frequently isolated at 45.2% followed by *C. coli* at 25.8% (Luu et al., 2006).

Based on this review, the factors associated with antimicrobial resistance were mostly from overuse and misuse of antibiotics in poultry production. Studies across this review had mention using antibiotics without veterinary prescriptions and without proper instructions. Varga et al., 2019 reported antibiotic use in food animals, including abuse and misuse, was thought to be a factor in the selection and establishment of antimicrobial resistant enteric bacteria. Until recently, small flock owners in Canada could buy antimicrobials without a prescription from a veterinarian. Moreover, antibiotics were still used as growth promoter and in feed. This statement was supported by multiple studies, for instance, Bester& Essack, 2012 explained antibiotics for agricultural use were more widely available in South Africa than they were in the United Kingdom, where growth-promoting antibiotics were only available on prescription. Moreover, Nguyen et al., 2016 further emphasized in their study that antibiotics were employed as part of the feed ingredients by all of the manufacturers and were utilized without guidelines for disease prevention and treatment during the upbringing of the chickens. Dias et al., 2021 explained antimicrobials as growth promoters were currently in decline in Brazil, owing to government legislation prohibiting the usage of certain chemicals for this purpose. It was, nevertheless, a frequent practice for many years, and this may contribute to the selection of resistant strains that could still be found in poultry environments. As indiscriminate use of antibiotics as feed additives and growth promoters in poultry feed was usually responsible for AMR development, this could have a direct link to the development of multidrug resistance *Campylobacter* in chicken (Alam et al., 2020).

5.0 Conclusion

In conclusion, the prevalence of *Campylobacter* spp. in backyard chickens gathered from this review ranged from 18.2% to 68%. Moreover, *Campylobacter* spp. isolated from backyard chickens demonstrated antimicrobial resistance to commonly used drugs in poultry farms. From an epidemiological aspect, factors that influenced the prevalence of *Campylobacter* spp. include good farm biosecurity, good husbandry, good farm hygiene and interaction with *Campylobacter* reservoirs.

6.0 Limitation

This study had limitations in terms of insufficiency of peer-reviewed studies reporting on the prevalence and AMR of *Campylobacter* spp. in backyard chickens from around the globe particularly from developing and underdeveloped countries as poultry farms from these countries are more likely to harbour *Campylobacter* and thus underreported.

Secondly, lack of access to certain articles due to limitation on databases with peer-reviewed contents also limit the number of studies that were able to be gathered. These were the studies that fulfilled the inclusion criteria but were not accessible to be included in the review.

7.0 Recommendation

The recommendation for this study is to encourage more high-quality research in this area to allow for a more accurate and updated prevalence rate being reported worldwide, reflecting the actual burden and spread of Campylobacter spp. in backyard chickens. High-quality research will ensure data will be comparable to one another which then will allow a more reliable estimation of pooled prevalence of Campylobacter spp.

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