UNIVERSITI PUTRA MALAYSIA

SYSTEMATIC REVIEW ON TRENDS OF PREVALENCE JOHNE'S DISEASE INVOLVING SMALL RUMINANT POPULATIONS IN THREE DIFFERENT REGIONS, NAMELY SOUTHEAST ASIA, ASIA, AND WORLDWIDE COUNTRIES FROM PAPERS PUBLISHED WITHIN 2010-2021

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DEDICATION

This project is dedicated to my parents (Rosmidi Selamat and Fauziah Mail), siblings, lecturers and DVM 2022.

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Thank you to Allah Almighty

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

TINJAUAN SISTEMATIK TERHADAP TREND PENYAKIT JOHNE YANG MELIBATKAN RUMINAN KECIL DAN RUSA DI TIGA WILAYAH BERBEZA IAITU ASIA TENGGARA, ASIA DAN NEGARA SELURUH DUNIA DARIPADA KERTAS YANG DITERBITKAN DALAM 2010-2021

oleh

Mohamad Afiq Ikhwan bin Rosmidi

2021

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ABSTRAK

Paratuberkulosis atau juga dikenali sebagai penyakit Johne, adalah penyakit buangan kronik yang disebabkan oleh Mycobacterium avium subs paratuberculosis dalam ruminan. Penyakit ini menyebabkan kesan ekonomi yang ketara di mana penyakit tersebut menyebabkan pengurangan ketara dalam pengeluaran susu biri-biri atau kambing tenusu yang terjejas, peningkatan kos untuk diagnosis, rawatan dan pemusnahan haiwan yang dijangkiti. Majoriti penyelidikan tertumpu kepada lembu dan pengetahuan tentang kadar semasa kelaziman yang melibatkan penyakit Johne di kalangan ruminan kecil dan rusa di tiga wilayah berbeza iaitu Asia Tenggara, Asia dan negara-negara di seluruh dunia tidak didokumenkan dengan baik sehingga kini. Oleh itu, kajian sistematik ini bertujuan untuk menyusun dan menganalisis kadar semasa kelaziman penyakit Johne dalam kalangan ruminan kecil dan rusa di tiga

rantau berbeza iaitu Asia Tenggara, Asia dan negara-negara di seluruh dunia daripada kertas kerja yang diterbitkan dalam tempoh 2010-2021. Pangkalan data SCOPUS digunakan untuk mencari kajian yang diterbitkan mengenai kelaziman penyakit Johne dan saringan awal untuk kelayakan asas dan penilaian kualiti yang komprehensif telah dilakukan sebelum pemilihan akhir kajian. Pencarian itu menghasilkan sejumlah 297 kajian. Selepas selesai pengekstrakan dan sintesis data, 21 kajian telah dipilih. Tiada kajian direkodkan atau diterbitkan untuk Asia Tenggara, manakala 10 kajian diterbitkan dari 5 negara di Asia. Di seluruh dunia, 10 negara hanya melaporkan 11 kajian. Asia dan negara-negara di seluruh dunia mengaitkan data untuk biri-biri, kambing dan rusa. Alat diagnostik yang paling biasa digunakan dalam ketiga-tiga wilayah ini ialah ELISA (ujian imunosorben berkaitan enzim). Semua tinjauan kelaziman wilayah ini tidak cukup komprehensif untuk menentukan kelaziman sebenar penyakit Johne di kalangan populasi ruminan kecil dan rusa yang terlibat dalam ketiga-tiga wilayah ini. Justeru, daripada kajian ini dicadangkan kajian kelaziman penyakit Johne pada masa hadapan dalam kalangan populasi ruminan kecil dan rusa perlu dilakukan dengan lebih sistematik dan holistik terutamanya bagi negara Asia Tenggara.

Kata kunci: *penyakit Johne; Paratuberkulosis; Kambing, Biri-biri; Rusa; Kelaziman; Asia Tenggara; Asia dan Seluruh Dunia.*

An abstract of the project paper presented to the Faculty of Veterinary Medicine, UPM in partial fulfilment of the course VPD 4999-Project

SYSTEMATIC REVIEW ON TRENDS OF PREVALENCE JOHNE'S DISEASE INVOLVING SMALL RUMINANT AND DEER POPULATIONS IN THREE DIFFERENT REGIONS, NAMELY SOUTHEAST ASIA, ASIA, AND WORLDWIDE COUNTRIES FROM PAPERS PUBLISHED WITHIN 2010-2021

by

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2021

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ABSTRACT

Paratuberculosis, also known as Johne's disease, is a chronic wasting disease caused by *Mycobacterium avium subs paratuberculosis* in ruminants. This disease causes a significant economic impact. The said disease led to a significantly reduced milk production of the affected dairy sheep or goats increased cost for diagnosis, treatment, and culling of infected animals. The majority of research focused on cattle, and the knowledge of the current trends of prevalence involving Johne's disease among small ruminants and deer in three different regions, namely Southeast Asia, Asia, and worldwide countries, is not well documented till date. Therefore, this systematic review aims to compile and analyse the current trends of prevalence of Johne's disease among small ruminants and deer in three different regions, namely

Southeast Asia, Asia, and worldwide countries, from papers published within 2010-2021. The SCOPUS database was used to search for published studies on the prevalence of Johne's disease. Prior to the final selection of studies, an initial screening for basic eligibility and a comprehensive assessment of quality. The search yielded a total of 297 studies. Following the completion of data extraction and synthesis, 21 studies were chosen. No study was recorded or published for Southeast Asia, whereas ten studies were published from 5 countries in Asia. Worldwide, ten countries only reported 11 studies. Asia and worldwide countries attributed data for sheep, goats, and deer. The most common diagnostic tool used in these three regions was ELISA (Enzyme-linked immunosorbent assay). These regions' prevalence surveys are not comprehensive enough to correctly establish the true prevalence of Johne's disease among small ruminant and deer populations involved in these three regions. Thus, this study suggests that future prevalence studies of Johne's disease among the small ruminant and deer populations should be done more systematically and holistically, especially for Southeast Asia countries.

Keywords: *Johne's disease; Paratuberculosis; Goat, Sheep; Deer; Prevalence; SEA; Asia and Worldwide.*

1.0 Introduction

Paratuberculosis or also known as Johne's disease is a chronic wasting disease caused by *Mycobacterium avium subs paratuberculosis* in ruminants (Barrero-Domínguez et al., 2019). MAP is a small gram-positive bacterium characterised as acid-fast bacteria which causes chronic granulomatous gastroenteritis and regional lymphadenitis (Stau., et al 2012). The first case of paratuberculosis in cattle was reported in Europe in 1895, and this disease was diagnosed among dairy cows (Windsor et al., 2013). The disease has also been diagnosed among small ruminants globally, where sheep and goats were diagnosed in many countries worldwide. Ovine paratuberculosis was reported in countries from the southern hemisphere such as Australia, New Zealand, and South Africa and for northern hemisphere countries such as in the United Kingdom, Norway, and Austria and para-Mediterranean countries such as Greece, Spain, Portugal, Morocco, and Jordan (Benazzi et al., 2010; Djnne, 2010; Hailat et al., 2010). Caprine paratuberculosis has been identified and reported in countries like Turkey, France, Norway, Switzerland, Croatia, Canada, the United States of America, and Chile (Rasmussen et al., 2021).

This disease's clinical signs and manifestation are chronic and may take up to two years before the clinical symptom arises and exhibits. The causative MAP bacteria can be shed in the faeces and maintained in the environment for many months, contributing to the challenges in the control and prevention of this disease (Stonos et al., 2017). The source of infection in Johne's disease is via oral route where the ingestion of contaminated colostrum and milk from the infected dam (Smith et al., 2013) or ingesting contaminated feed for older age animals (Selim et al., 2021). The

clinical signs reported in animals infected with Johne's disease are progressive weight loss with a good appetite, exercise intolerance, diarrhoea, and reduced milk production (Barrero-Domínguez et al., 2019). The condition has a significant impact on animal welfare as the animal appears to be emaciated over a period of time due to persistent diarrhoea. This disease causes a significant economic impact. The said disease led to significantly reduced milk production of the affected dairy sheep or goats and increased cost for diagnosis, treatment, and culling of infected animals (Sardaro et al., 2017).

Serological tests that are commonly used in screening and diagnosis of this disease are agar gel immunodiffusion (AGID), complement fixation test (CFT), and enzyme-linked immunosorbent assay (ELISA) (Coelho et al., 2007). Bacterial isolation and identification diagnosis technique for this disease said to be having low bacterial tissue culture sensitivities where it only ranged from 10% to 50% where the dormancy state of MAP makes the bacterial culture unreliable (Sonawane & Tripathi, 2019). Sonawane (2019) found that the molecular PCR technique detecting MAP is better where the sensitivity of IS900 PCR in sheep was around 80-85%, which agrees with previous research (90-100%) (Gwóźdź et al., 1997) and according to (Matos 2017) stated that the IS900 PCR is the most sensitive technique for detecting MAP in extra-intestinal samples because this technique is rapid and definite.

A study was conducted by Coelho (2007) to determine the seroprevalence of ovine paratuberculosis among the sheep population where 3900 samples of sheep, which is from 70 herds in Portugal, were screened and analysed. The result showed that 3.7%

and 46.7% were seroprevalences for animal and herd levels, respectively. Barrero-Domínguez (2019) conducted a detailed seroprevalence study of MAP infection in dairy goat flocks in southern Spain where a total of 48 flocks involving 3312 dairy goats were sampled, and the result revealed that a total of 511 goats were seropositive, with an overall true seroprevalence of 22.54% and for herd seroprevalence was 87.5%. Meng (2015) studied the current seroprevalence of MAP among domestic sika deer in China, where 1400 sika deer serum samples from 16 sika deer herds were collected and analysed. The result revealed that 17.64% of sika deer were tested positive for MAP antibodies. This study also stated that the leading risk factor associated with MAP infection was the farms' management level.

The current trends of prevalence involving Johne's disease among small ruminants and deer in three different regions, namely Southeast Asia, Asia, and worldwide countries, are not documented till date. Therefore, this systematic review aims to compile and analyse the current trends of prevalence of Johne's disease among small ruminants and deer in three different regions, namely Southeast Asia, Asia, and worldwide countries, from papers published within 2011-2020.

2.0 Justification of study and Objectives.

MAP infection is a well-known, and common disease that affects the large ruminant, particularly the cattle livestock, but this disease is rarely screened and diagnosed among small ruminant herds, including sheep and goats. From the knowledge we have, it is known that MAP possesses the same strain either from the cattle or sheep and goat, where this causative organism has the potential to cross infect and can be transmitted among the ruminant livestock herds, including the large and small ruminants. Therefore, it's crucial to determine and know the pattern of prevalence of MAP infection among small ruminant herds in order to have an overall picture of the current infection data that will aid in the effective and holistic planning of control and prevention of this disease. Most countries, including Malaysia, adopt a test and cull method to ensure the ruminant herd is free from MAP infection. The method of test and cull should be holistically done in order to make sure the ruminant herd is free from the said disease as we know that the chances of transmission of the said disease can be either from cattle to goat or/and sheep or vice versa. Therefore, it's crucial to determine and know the pattern of prevalence of MAP infection among small ruminant herds in order to have an overall picture of the current infection data that will aid in the planning of control and prevention of this disease. Till date, no study has been analysed collectively or any data recorded on the trends of prevalence of MAP infection among small ruminants involving Southeast Asia, Asia, and worldwide. This systematic review is crucial to establish the current MAP disease prevalence trends, particularly in countries or regions/localities from which small ruminants are imported or brought in. From pooled data related to MAP disease

using a systematic approach will help in better understanding of this disease where can look into the options of an early precautions steps such as either by adapting control programmes from neighbouring countries such as in Australia and New Zealand which uses vaccine (Gudair vaccine) to control the clinical progress of MAP disease or implementing eradication programmes test-cull as practised currently in Malaysia. To holistically make sure the ruminant livestock herd can achieve MAP-free herd, a proper study needs to be done to determine the possibilities of cross-transmission of MAP disease within-herd where inter-species infection from large ruminant to small ruminant and vice-versa. If we only opted to test and cull the large ruminant, this test and cull exercise will be wasted as the infection can still be persisted among the small ruminant herd and can cause cross-infection and, in the end, the MAP disease will still persist. Therefore, having good data set in current trends of MAP disease prevalence rate will be helpful to the policymaker for consistent planning and frequent MAP surveillance programme among selected small ruminant herds and to have good control and prevention strategies for the said disease.

Thus, the objective of this study is to

1. To compile and analyse current trends in the prevalence of Johne's disease among small ruminants and deer in Southeast Asian countries between 2010 and 2021, using papers published between 2010 and 2021.

2. To compile and analyse the current trends of the prevalence of Johne's disease among small ruminants and deer in Asian countries from papers published between 2010 and 2021.

3. To compile and analyse current trends in Johne's disease prevalence among small ruminants and deer in countries worldwide from papers published between 2010 and 2021.

3.0 Methodology

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-analysis) checklist was used to perform this research (Moher et al., 2009)

3.1 Search strategy

A thorough and exhaustive search strategy was used to find all relevant studies. SCOPUS is the only database used in this study for literature searches to find relevant papers. The required searching terms were identified using the Condition, Context, and Population (CoCoPop) format. Medical Subject Heading (MeSH) terms and various relevant keywords were used in the search strategy.

"What are the trends of the prevalence of Johne's Disease in small ruminant populations in three different regions, namely Southeast Asia, Asia, and worldwide countries from 2010 to 2021?" were the research questions. The searching terms used was (Johne's disease OR Johne's infection OR Small ruminant paratuberculosis AND (epidemiology OR prevalence OR infection rate) AND (goat OR sheep OR deer OR small ruminant infected) AND (goat OR sheep OR deer OR small ruminant infected) AND (goat OR sheep OR deer OR small ruminant infected) AND (goat OR sheep OR deer OR small ruminant AND (list of Southeast Asia and Asia countries).

3.2 Study eligibility and application of inclusion and exclusion criteria

Abstracts were evaluated for relevance and eligibility based on the inclusion criteria after the preliminary screening of all titles received through our searches. The report was prepared using the sole database (SCOPUS). Following that, papers conducted in Southeast Asia, Asia, and Worldwide that report the prevalence of Johne's disease infection in a small ruminant (goat, sheep, and deer) population will

be evaluated for systematic review. Finally, this systematic review includes articles that met all of the following criteria. Studies that reported data acquired before 2010 and published in a language other than English were excluded from providing contemporaneous and representative estimates.

3.3 Study selection and data extraction process

A standardised data collection format was created to extract the necessary data from the articles. The first author's last name, the study population, the study period, the species (infected goat/sheep or deer), sample size, study design, diagnostic test, and main findings of prevalence were all included in the data. Due to differences in reference styles among sources, some duplicates had to be manually addressed. The student and supervisor then sat down to screen the titles and abstracts against predetermined inclusion criteria. The student and supervisor gathered all of the full texts and assessed them for final inclusion. Any data discrepancies were resolved by consulting the original study.

3.4 Study quality assessment

Two independent investigators (student and supervisor) assessed the quality of the included papers (risk of bias) using a quality assessment checklist (standard strengthening the Reporting of Observational Studies in Epidemiology checklist (STROBE)) (von Elm et al., 2008). The title, abstract, introduction, methods, results, and discussion are among the 22 items on this checklist, which comprise various sections of the articles. The index focuses on the studies' objectives, various methods components (e.g., study design, sample size, study population, bias, statistical methods), results, limitations, and funding.

3.5 Data synthesis and statistical analysis

Extracted data will be entered and saved into a Microsoft Excel spreadsheet and exported into a statistical database for analysis. Figures and tables were utilised to present the summarised and descriptive results.

4.0 Results

Table 01: Asian Countries for sheep animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	India	2012	133	NR	Microscopy	25.5% (34/133)	(S. V. Singh et al., 2013)
2	India	2012	602	NR	Microscopy	33.4% (201/602)	(S. V. Singh et al., 2013)
3	Turkey	Jan 2013-Aug 2013	450(>24 months of age)	Simple random sampling	ELISA	6.2% (28/450)	(Buyuk et al., 2014)
4	Turkey	2017	150(>2 years old age female	Simple random sampling	ELISA	48% (72/150)	(Celik & Turutoglu, 2017)
5	India	2019	53	NR	ELISA	58.5% (31/53)	(Hemati, et al., 2020)
6	Saudi arabia	Feb-Sept 2018	492	Simple random sampling	ELISA	11.1% (55/492)	(Shabana & Aljohani, 2020)
7	Iran	2021	568(>6 months of age)	Simple random sampling	ELISA	6.87% (39/568)	(Pourmahdi Borujeni et al., 2021)

In this study, the prevalence studies involving sheep at the animal level for Asian countries (n=7) are shown in Table 1. The studies revealed that India showed prevalence of 43%, Turkey with a prevalence of 29%, and Saudi Arabia and Iran with a prevalence of 14%, respectively. These studies only reported samples tested from adult animals only. All these studies adopted variable diagnostic tools to measure the prevalence rate of detection.

Table 02: Asian Countries for sheep herd level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Turkey	Jan 2013-Aug 2013	26 sheep herd (non-vaccinated against MAP)	Simple random sampling	ELISA	57.7% (15/26)	(Buyuk et al., 2014)
2	Turkey	2017	15 (>2 years old age female)	Simple random sampling	ELISA	100% (15/15)	(Celik & Turutoglu, 2017)

This study shows the herd prevalence infection rate involving the sheep population in Asian countries in Table 2. Only two studies were reported from the same country, Turkey, where the prevalence of 57.7% and 100% were reported respectively in 2014 and 2017. These studies used simple random sampling methods and adopted ELISA as the diagnostic tool.

Table 03: Asian Countries for goat animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	India	2012	39	NR	Microscopy	25.6% (10/39)	(S. V. Singh et al., 2013)
2	India	2009-2010	281	NR	Microscopy	41.3% (116/281)	(S. V. Singh et al., 2013)
3	Turkey	2017	150 (> 2 years old female)	Simple random sampling	ELISA	24% (36/150)	(Celik & Turutoglu, 2017)
4	India	2018	22	NR	ELISA	68.19% (15/22)	(Biswal et al., 2018)
5	India	Jan 2015-Nov 2017	465(lactating goat)	NR	Microscopy	46.6% (217/465)	(M. Singh et., 2019)

6	India	2019	251	NR	ELISA	55.4% (139/251)	(Hemati, et al., 2020)
7	Saudi Arabia	Feb-Sept 2018	224	Simple random sampling	ELISA	13.8% (31/224)	(Shabana & Aljohani, 2020)
8	Iran	2021	368	Simple random sampling	ELISA	7.07% (26/368)	(Pourmahdi Borujeni et al., 2021)

In this study, the prevalence studies involving goats at the animal level show the prevalence studies in goats for Asian countries, as shown in Table 3. The results revealed India with a prevalence of 62.5%, Turkey with a prevalence of 12.5%, and Saudi Arabia and Iran with a prevalence of 12.5%, respectively. These studies reported that the sampled animals are only from the adult age group. A simple random sampling method was used, and variable diagnostic tools were adopted in all these studies.

Table 04: Asian Countries for goat herd level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Turkey	Oct 2014-Feb 2015	15 (> 2 years old female)	Simple random sampling	ELISA	93.3% (14/15)	(Celik & Turutoglu, 2017)

This study shows the result of herd-level prevalence infection rate involving the goat population in Asian countries, as shown in Table 4. Only 1 study was reported from Turkey, where the study was conducted from 2014 till 2015. This study used a simple random sampling method, and ELISA diagnostic tool was adopted.

Table 05: Asian Countries for deer animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	China/Jilin Province	May 2013-Aug 2014	1400	Simple random sampling	ELISA	17.64% (247/1400)	(Meng et al., 2015)

The result of animal-level prevalence infection rates involving the deer population in Asian countries is shown in Table 5. There was only one study recorded from China in 2015 where simple random sampling and ELISA diagnostic were adopted in this study with seroprevalence Johne's disease of 17.64%.

Table 06: Asian Countries for deer herd level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	China/Jilin Province	May 2013-Aug 2014	16	Simple random sampling	ELISA	100% (16/16)	(Meng et al., 2015)

The result of herd-level prevalence infection rate involving the deer population in Asian countries is shown in Table 6. ELISA diagnostics were adopted in this study with a herd-level prevalence of 100% Johne's disease.

Table 07: Worldwide Countries for sheep animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Italy	Jul-08	2086 (> 2 years old age)	Stratified sampling	ELISA	6.29% (129/2086)	(Rita et al., 2011)
2	Germany	Nov 09-Dec 10	1473(10 animals from each flock with poorest BCS)	Simple random sampling	ELISA	14% (212/1473)	(Stau et al., 2012)

3	New Zealand	Jul-12	24 healthy mixed-age East Friesian, Romney, and Highland cross ewes	Simple random sampling	Tissue Culture	50% (12/24)	(Smith et al., 2013)
4	Tunisia	Oct-18	338 female sheep	NR	ELISA	3.25% (11/338)	(Khamassi Khbou et al., 2020)
5	Mexico (Sonora)	Feb 12-Dec 14	1178	NR	AGID	6.54% (77/1178)	(Morales-Pablos et al., 2020)
6	Egypt (Kafr Elsheikh, Gharbia, Menofia, and Qalyubia)	Jan - Dec2019	370	NR	ELISA	7.8% (29/370)	(Selim et al., 2021b)
7	Colombia (Antioquia)	Aug-Sept 2017	456(>1 years old age)	NR	ELISA	8% (37/456)	Hernandez et al., 2021

The result of animal-level prevalence infection rates involving sheep populations worldwide is shown in Table 7. Countries that recorded this disease are Italy, Germany, New Zealand, Tunisia, Mexico, Egypt, and Columbia. All these studies sampled only adult animals, and a simple random sampling selection technique was used. Variable diagnostic tests were adopted in these studies.

Table 08: Worldwide Countries for sheep herd level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Italy	Jul-08	38 (> 2 years old age)	Stratified sampling	ELISA	73.7% (28/38)	(Rita et al., 2011)
2	Germany	Nov 09-Dec 10	150	Simple random sampling	ELISA	65% (97/150)	(Stau et al., 2012)

3	Tunisia	Oct-18	15	NR	ELISA	40% (6/11)	(Khamassi Khbou et al., 2020)
4	Mexico (Sonora)	Feb 12-Dec 14	43	NR	AGID	53.5% (23/43)	(Morales-Pablos et al., 2020)
5	Colombia (Antioquia)	Aug-Sept 2017	24(>1 years old of age)	NR	ELISA	71% (17/24)	(Hernández-Agudelo et al., 2021)

The result of herd-level prevalence infection rate involving sheep population in worldwide countries is shown in Table 8. Countries that recorded this said disease are Italy, Germany, New Zealand, Tunisia, Mexico, Egypt, and Columbia and the result of herd-level prevalence revealed prevalence of 73.7% in Italy, 65% in Germany, 40% in Tunisia, 53.5% in Mexico and 71% in Colombia (Hernandez et al., 2021). All these studies sampled only adult animals, and a simple random sampling selection technique was used. Variable diagnostic tests were adopted in these studies.

Table 09: Worldwide Countries for goat animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Germany	Nov 09-Dec 10	136(10 animal from each flock with poorest BCS)	Simple random sampling	ELISA	21% (28/136)	(Stau et al., 2012)
2	Brazil (Monteiro, Paraiba)	March 09-July 12	727 female goats	NR	ELISA	0.82% (6/727)	(Freitas et al., 2015)
3	Spain (Andalusia)	2019	3312 female goats	NR	ELISA	22.54% (511/3312)	(Barrero-Domínguez et al., 2019)

The result of animal-level prevalence infection rates involving the goat population in worldwide countries is shown in Table 9. Countries recorded these said diseases are Germany, Brazil, and Spain, and the result of prevalence revealed a prevalence of 21%, 0.82%, and 22.54%, respectively. All these studies used various sampling selection techniques, and ELISA diagnostic tests were adopted in these studies.

The highest prevalence is from Spain with 22.54% prevalence (Barrero-Domínguez et al., 2019) and the lowest prevalence was obtained from Brazil with only 0.82%% prevalence (Freitas et al., 2015). Both studies used the commercial ELISA kit.

Table 10: Worldwide Countries for goat herd level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	Germany	Nov 09-Dec 10	17	Simple random sampling	ELISA	71% (12/17)	(Stau et al., 2012)
2	Brazil (Monteiro, Paraiba)	March 09-July 12	86	NR	ELISA	7% (6/86)	(Freitas et al., 2015)
3	Spain (Andalusia)	2019	48	NR	ELISA	87.5% (42/48)	(Barrero-Domínguez et al., 2019)

The result of herd-level prevalence infection rate involving the goat population in worldwide countries is shown in Table 10. Countries that recorded this said disease are Germany, Brazil, and Spain, and the result of herd prevalence revealed a prevalence of 71%, 7%, and 87.5%, respectively. All these studies used various sampling selection techniques, and ELISA diagnostic tests were adopted in these studies.

Table 11: Worldwide Countries for deer animal level infection rate.

Study	Country/region	Study period	Sample size	Selection	Diagnostic test	Results	Reference
1	New Zealand	Oct 2008-Jan 2009	251	NR	Tissue culture	39% (98/251)	(Hunnam et al., 2013)
2	Portugal	2009-2011	877	NR	Microscopy	4.2% (37/877)	(Matos et al., 2017)

The result of animal level prevalence infection rate involving deer population in worldwide countries is as shown in Table 11. Countries that recorded this said disease are New Zealand and Portugal, and the result of prevalence revealed a prevalence of 39% and 4.2%, respectively. Tissue culture and microscopy diagnostic tests were adopted in these studies.

In conclusion of the result of this study, in Asia countries excluding the Southeast Asia countries where out of 43 countries, only five countries, India, Turkey, Saudi Arabia, Iran, and China, reported Johne's disease among the small ruminant population. For worldwide countries, excluding the Asia countries where out of 141 countries, only ten countries are Italy, Germany, New Zealand, Tunisia, Mexico, Egypt, Colombia, Brazil, Spain, and Portugal reported Johne's disease among small ruminant populations. No studies were recorded among Southeast Asia countries on the occurrence of Johne's disease among small ruminant populations.

5.0 Discussion

This systematic review study aimed to assemble and assess the current prevalence trends in Johne's disease among small ruminants and deer populations in three different regions, namely Southeast Asia, Asia, and worldwide countries reported from scientific papers published in the SCOPUS database from the year 2010 till 2021. The result of this study revealed that the number of paratuberculosis reported among small ruminant populations in India exceeded the expectations showed that there is a need in dwelling in the research of paratuberculosis among small ruminants as currently only a few articles and studies that dealt with estimating the prevalence of paratuberculosis among small ruminant populations.

In this study, only sheep, goats, and deer are the only farmed animals included, as the main objective of this study is to focus only on small ruminants. Therefore, the inter-relationship infection of Johne's disease among large ruminants and small ruminants was not detailed and studied. Therefore, future research is needed to study this part to conclude the cross-infection and have better herd health programs and prevention strategies for this disease.

Some of the reported studies showed that the random sampling was not attained, resulting in possibly biased and non-interpretable data, which was a key critical concern in several of the studies assessed in this study. We must consider that the age factor of the animals also played an essential role in the shedding of this disease, and this study age selection of animals focused only on certain groups. If the test cannot detect the infected animals, a sample of old animals can result in a "healthy worker survivor" bias. In contrast, sampling of young animals can result in

low test accuracy (Nielsen & Toft, 2009). ELISAs will not identify MAP infections in animals less than two years old because they have not produced antibodies to MAP. By including age-specific test accuracy estimates, the bias created by a diagnostic test can be decreased. Another condition is that the diagnostic tests utilised can distinguish between infected and noninfected animals. Current diagnostic techniques cannot provide near-complete discrimination, highlighting the importance of a thorough test evaluation. The MAP goal condition in the test evaluation should be identical to the prevalence study's target condition.

This study revealed that there was no paper recorded or published in Southeast Asia countries. This may be due to a few reasons where Southeast Asia is not a main small ruminant production region that does activities of import and export ruminant livestock compared to countries such as New Zealand and Australia, which have reported Johne's disease among the small ruminant population.

Another reason may be due to the nature of the pathogenesis of this disease, where MAP is a slow-growing bacterium where infected animals may take up to 2 years of incubation period before starting to show clinical signs. Moreover, to grow this fastidious bacterium needs special media for culture. These challenges may cause many countries to reduce interest in screening this said disease among a small ruminant population.

Although a limited number of studies were reported in this study, a steady pattern of incrementing the number of reported studies showed that this disease among the small ruminant population is of interest.

For future direction from this systematic review study, it is essential to have the holistic screening of the prevalence of Johne's disease among small and large ruminant populations in all countries with ruminant livestock as main commodities to have a true picture of this disease status. This is important to have adequate prevention strategies and avoid unnecessary culling of large ruminants only where the small ruminant population was not screened for this disease. Therefore, the control and prevention strategies can be questionable.

MAP is known to infect all species, including cattle, camels, and small ruminants. Cross-contamination may occur between small ruminants and cattle. Therefore, to avoid possible recurrent infection, testing and culling programs should be done in all ruminant animal animals, including large and small ruminant animals on the farm.

Future control strategies adopted from this study include vaccination for this disease in small and large ruminants where Australia and New Zealand have adopted this strategy.

6.0 Conclusion

In conclusion, this systematic review reveals that the prevalence studies reported by the three regions are not holistically done to accurately determine the true prevalence of MAP infection in these regions. This is especially true for Southeast Asian countries as the data is not reported and still lacking. Thus, it is recommended that future prevalence studies of MAP infection among the small ruminant populations should be done more systematically and holistically.

7.0 Reference

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