UNIVERSITI PUTRA MALAYSIA

EPIDEMIOLOGY OF BOVID FASCIOLOSIS IN LARUT AND MATANG, PERAK, MALAYSIA

NAIM CHE KAMARUDDIN

FPV 2022 5

EPIDEMIOLOGY OF BOVID FASCIOLOSIS IN LARUT AND MATANG, PERAK, MALAYSIA

By

NAIM CHE KAMARUDDIN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

January 2022

© COPYRIGHT UPM

All material contained within the thesis, including without limitation text, logos, icons, photographs and all other artwork, is copyright material of Universiti Putra Malaysia unless otherwise stated. Use may be made of any material contained within the thesis for non-commercial purposes from the copyright holder. Commercial use of material may only be made with the express, prior, written permission of Universiti Putra Malaysia.

Copyright © Universiti Putra Malaysia

© COPYRIGHT UPM

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

EPIDEMIOLOGY OF BOVID FASCIOLOSIS IN LARUT AND MATANG, PERAK, MALAYSIA

By

NAIM CHE KAMARUDDIN

January 2022

Chair : Nur Mahiza Md Isa, PhD
Faculty : Veterinary Medicine

Fasciolosis is considered as an emerging neglected tropical disease that is threatening ruminant productivity and is zoonotic. In previous study, the Taiping abattoir showed the highest fasciolosis occurrence compared to the other investigated main abattoirs in Peninsular Malaysia, which could impede the government's initiatives to promote ruminant production in the region. Therefore, this study intended to describe the epidemiology of bovid fasciolosis in Larut and Matang (Taiping), Perak (LM) to initiate the effort to control fasciolosis which could drive to economic loss. A total of 371 faecal samples from bovid (dairy cattle, beef cattle, buffalo) from 23 selected farms were examined in this cross-sectional study from February until August 2020. Animals and farms detail were recorded, and a questionnaire has been completed by the farmers to collect data of risk factors during the farm visit. The coproscopical examination of faecal samples to record the *Fasciola* faecal egg count (fec) using Flukefinder® sedimentation was performed and the co-infection with Paramphistomes was observed. The correlation of *Fasciola* fec with Paramphistomes fec in co-infected bovids and also with *Fasciola* coproantigen concentration were correlated using Spearman correlation test. Heatmap density was used to interpolate the selected risk factors to visualise the fasciolosis exposure areas in LM. For the result, overall prevalence of bovid fasciolosis in LM was observed 36.9% (n=137/371). A total of 65.2% visited farms (n=15/23) having at least one case of bovid fasciolosis. Significant risk factors ($p<0.05$) for bovid fasciolosis in LM were buffalo (OR=9.5), bovid age more than three years (OR=5.5), body condition score lower than 5 (OR=1.2-14.9), larger grazing range (OR=1.3), more than one ruminant species in the farm (OR=2.0-2.1), extensive housing system (OR=4.0), increasing farm age (OR=1.2), and co-infection with Paramphistomes (OR=1.4). *Fasciola* and Paramphistomes fec in co-infected bovids was having a significant moderate positive correlation ($r=0.36$, $p<0.01$). Besides, *Fasciola* fec to *Fasciola* coproantigen concentration was also having significant moderate positive correlation ($r=0.55$, $p<0.01$). The exposure areas to fasciolosis in this study showed higher exposure in the northern LM compare to the central LM. Thereby, this study revealed moderate prevalence of bovid fasciolosis in LM and factors of host intrinsic, farm management,

© COPYRIGHT UPM

and co-infection with Paramphistomes are significantly associated with bovid fasciolosis in LM. The positive correlation of *Fasciola* and Paramphistomes in co-infected bovid could provide the predictive basis for bovid fasciolosis from the Paramphistomes occurrences. Besides, *Fasciola* coproantigen concentration could be useful in monitoring *Fasciola* eggs shedding to initiate targeted treatment of fasciolosis, however need further study for the application of coproantigen ELISA for this insight. The areas of high fasciolosis exposure in LM is beneficial to conduct control programmes to sustain the bovid production and welfare. The outcomes of this study are advantageous towards the understanding of the epidemiology of local bovid fasciolosis which is important in veterinary and public health.

Keywords: prevalence, fasciolosis exposure, risk factors, ruminant parasite, exposure map, livestock.

© COPYRIGHT UPM

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

EPIDEMIOLOGI FASCIOLOSIS BOVID DI LARUT DAN MATANG, PERAK, MALAYSIA

Oleh

NAIM CHE KAMARUDDIN

Januari 2022

Pengerusi : Nur Mahiza Md Isa, PhD
Fakulti : Perubatan Veterinar

Fasciolosis dianggap sebagai penyakit tropika yang terabai yang mengancam produktiviti ruminan dan bersifat zoonotik. Dalam kajian lepas, rumah sembelih Taiping menunjukkan kejadian fasciolosis yang tertinggi berbanding dengan rumah sembelih utama lain yang diselidik di Semenanjung Malaysia, yang boleh menghalang inisiatif kerajaan untuk meningkatkan pengeluaran ruminan di rantau ini. Oleh itu, kajian ini bertujuan untuk menghuraikan epidemiologi fasciolosis bovid di Larut dan Matang (Taiping), Perak (LM) bagi memulakan usaha mengawal fasciolosis yang boleh menyebabkan kerugian ekonomi. Sebanyak 371 sampel najis daripada bovid (lembu tenusu, lembu pedaging, kerbau) dari 23 ladang terpilih telah diperiksa dalam kajian keratan rentas ini dari Februari hingga Ogos 2020. Perincian haiwan dan ladang telah direkodkan, dan soal selidik telah dilengkapkan oleh penternak untuk mengumpul data faktor risiko semasa lawatan ladang. Pemeriksaan koproskopik sampel najis untuk merekodkan kiraan telur najis (fec) *Fasciola* menggunakan pemendapan Flukefinder® telah dilakukan dan jangkitan bersama Paramphistome telah diperhatikan. Korelasi *Fasciola* fec dengan Paramphistomes fec dalam bovid yang dijangkiti bersama dan juga dengan kepekatan koproantigen *Fasciola* telah dikorelasikan menggunakan ujian korelasi Spearman. Ketumpatan peta haba digunakan untuk menginterpolasi faktor risiko yang dipilih untuk menggambarkan kawasan terdedah fasciolosis di LM. Keputusannya, prevalens keseluruhan fasciolosis bovid di LM diperhatikan 36.9% (n=137/371). Sejumlah 65.2% ladang dilawat (n=15/23) mempunyai sekurang-kurangnya satu kes fasciolosis bovid. Faktor risiko yang signifikan ($p<0.05$) untuk fasciolosis bovid di LM ialah kerbau (OR=9.5), umur bovid lebih daripada tiga tahun (OR=5.5), skor keadaan badan lebih rendah daripada 5 (OR=1.2-14.9), julat kawasan ragut yang lebih besar (OR=1.3), lebih daripada satu spesis ruminan dalam ladang (OR=2.0-2.1), sistem perumahan yang luas (OR=4.0), umur ladang yang semakin meningkat (OR=1.2), dan jangkitan bersama Paramphistome (OR=1.4). *Fasciola* dan Paramphistome fec dalam Bovid yang dijangkiti bersama mempunyai korelasi positif sederhana yang signifikan ($r=0.36$, $p<0.01$). Selain itu, kepekatan *Fasciola* fec dan koproantigen *Fasciola* juga mempunyai korelasi positif sederhana yang signifikan ($r=0.55$, $p<0.01$). Kawasan

© COPYRIGHT UPM

terdedah kepada fasciolosis dalam kajian ini menunjukkan pendedahan yang lebih tinggi di utara LM berbanding di pusat LM. Dengan itu, kajian ini mendedahkan prevalens sederhana fasciolosis bovid di LM dan faktor intrinsik perumah, pengurusan ladang, dan jangkitan bersama dengan Paramphistomes merupakan signifikan dikaitkan dengan fasciolosis bovid di LM. Korelasi positif *Fasciola* dan Paramphistomes dalam bovid yang dijangkiti bersama boleh memberikan asas ramalan untuk fasciolosis bovid daripada kejadian Paramphistome. Selain itu, kepekatan koproantigen *Fasciola* berguna dalam memantau pengeluaran telur *Fasciola* untuk memulakan rawatan fasciolosis yang disasarkan, namun memerlukan kajian lanjut bagi penggunaan ELISA koproantigen untuk pendapatan ini. Kawasan terdedah fasciolosis yang tinggi di LM berguna untuk menjalankan program kawalan untuk mengekalkan pengeluaran dan kebajikan bovid. Hasil kajian ini berfaedah ke arah pemahaman epidemiologi fasciolosis bovid tempatan yang penting dalam kesihatan veterinar dan awam.

Kata kunci: prevalens, pendedahan fasciolosis, faktor risiko, parasit ruminan, peta dedahan, ternakan.

© COPYRIGHT UPM

ACKNOWLEDGEMENTS

I would like to thank my parents for supporting my study financially and emotionally which I know getting accreditation and certification from institutions and universities is no cheap. Also, thanks to Majlis Amanah Rakyat (MARA), Malaysia for selecting me in the Graduate Excellence Programmes which supporting me to enjoy expensive foods (sometimes) which students normally cannot afford. I really appreciate the programme which helps many postgraduate students to have peace of mind financially during the study. Not to forget my housemate, kitchen assistant, sometimes driver, Jackson Richard, the same person that I thank in my bachelor's degree thesis. My son and daughters; Royon, Lico, and Junee, especially Royon that always accompany me during this study, but of course I have to give you wet foods and treats after that. Last but not least, I would like to thank all members in academic studies especially my supervisor Dr Nur Mahiza Md Isa, and my co-supervisors Dr Nur Fazila Saulol Hamid, Dr Zulfa Hanan Ashaari, and Dr Ferdius @ Ferdaus Mohamat Yusuff for guiding me and advise in this project; this also including staffs and fellow friends from Veterinary Parasitology Laboratory team.

For Dr Taylor Swift, I also thank you for dropping four albums in these two years which really giving vibes during my sampling, lab works, and thesis writing. Imagine the feels and mood from the lyrics "What a shame she's stuck in her head" when I was experiencing writer's block. Thank you for your songs, I am still waiting for your Speak Now (Taylor's Version) though.

By that, thank you everyone.

© COPYRIGHT UPM

This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

Nur Mahiza binti Md Isa, PhD
Senior Lecturer
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Chairman)

Nur Fazila binti Saulol Hamid, PhD
Senior Lecturer
Faculty of Veterinary Medicine
Universiti Putra Malaysia
(Member)

Zulfa Hanan binti Ashaari, PhD
Senior Lecturer
Faculty of Forestry and Environment
Universiti Putra Malaysia
(Member)

Ferdius @ Ferdaus binti Mohamat Yusuff, PhD
Senior Lecturer
Faculty of Forestry and Environment
Universiti Putra Malaysia
(Member)

_____
ZALILAH MOHD SHARIFF, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 11 August 2022

© COPYRIGHT UPM

Declaration by graduate student

I hereby confirm that:

- this thesis is my original work;
- quotations, illustrations and citations have been duly referenced;
- this thesis has not been submitted previously or concurrently for any other degree at any other institutions;
- intellectual property from the thesis and copyright of thesis are fully-owned by Universiti Putra Malaysia, as according to the Universiti Putra Malaysia (Research) Rules 2012;
- written permission must be obtained from supervisor and the office of Deputy Vice-Chancellor (Research and Innovation) before thesis is published (in the form of written, printed or in electronic form) including books, journals, modules, proceedings, popular writings, seminar papers, manuscripts, posters, reports, lecture notes, learning modules or any other materials as stated in the Universiti Putra Malaysia (Research) Rules 2012;
- there is no plagiarism or data falsification/fabrication in the thesis, and scholarly integrity is upheld as according to the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) and the Universiti Putra Malaysia (Research) Rules 2012. The thesis has undergone plagiarism detection software.

Signature: _____ Date: _____

Name and Matric No.: Naim Che Kamaruddin, GS56052

© COPYRIGHT UPM

Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities, as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) were adhered to.

Signature : _____
Name of Chairman of
Supervisory Committee : Nur Mahiza Md Isa

Signature : _____
Name of Member of
Supervisory Committee : Nur Fazila Saulol Hamid

Signature : _____
Name of Member of
Supervisory Committee : Zulfa Hanan Ashaari

Signature : _____
Name of Member of
Supervisory Committee : Ferdius @ Ferdaus Mohamat Yusuff

© COPYRIGHT UPM

TABLE OF CONTENTS

© COPYRIGHT UPM

© COPYRIGHT UPM

© COPYRIGHT UPM

LIST OF TABLES

© COPYRIGHT UPM

LIST OF FIGURES

© COPYRIGHT UPM

LIST OF ABBREVIATIONS

AIC	Akaike's information criterion
ANOVA	Analysis of variance
BCS	Body condition score
CO1	Cytochrome oxidase subunit 1
COWS	Control of Worms Sustainably
EPG / epg	egg per gram
ESA	Excrete/secrete antigen
F. gigantica	*Fasciola gigantica*
F. hepatica	*Fasciola hepatica*
FCathL	*Fasciola* cathepsin-L
FEC / fec	faecal egg count
FECRT	faecal egg count reduction test
FFEC	*Fasciola* faecal egg count
GLDH	Glutamate dehydrogenase
IH	Intermediate host
ITS2	Internal transcribed spacer 2
ITT sheep	Indonesian thin tail sheep
L. auricularia	*Lymnaea Auricularia*
L. rubiginosa	*Lymnaea rubiginosa*
L. swinhoei	*Lymnaea swinhoei*
L. viridis	*Lymnaea viridis*
mAb	Monoclonal antibody
MCH	Mean corpuscular haemoglobin

© COPYRIGHT UPM

MLR	Multiple linear regression
n	Sub-total number of populations
N	Total number of populations
n_{adj}	Adjusted sub-total number of populations
Nad1	NADH dehydrogenase subunit 1
NEJ	Newly excysted juvenile
NTD	Neglected tropical disease
OD	Optical density
OR	Odd ratio
PCV	Packed cell volume
r	Coefficient of correlation
RBC	Erythrocyte counts
SCOPS	Sustainable Control of Parasites
SD	Standard deviation
SDH	Sorbitol dehydrogenase
Th	T helper
VIF	Variance inflation factor
VRI	Veterinary Research Institute
VRL	Veterinary Regional Laboratories
WHO	World Health Organization
WPI	Weeks post-infection

© COPYRIGHT UPM

CHAPTER 1

INTRODUCTION

1.1 Background

Fasciolosis is a significant food borne parasitic disease to domestic ruminants and capable to infect human through the consumption of plants or water which containing infective *Fasciola* metacercariae (Saleha, 1991). This disease is an emerging neglected tropical disease (NTD) towards human public health with the estimation of 180 million human are at risk of fasciolosis worldwide (Cwiklinski et al., 2016). Fasciolosis is considered as an endemic disease to ruminant livestock in Malaysia due to the climate that is optimal for the snails proliferation. The freshwater snail is known to play an important role as intermediate host and suitable for the development of *Fasciola* cercariae.

Two species of Fasciolid parasite, namely *Fasciola hepatica* and *F. gigantica* can parasitise the herbivorous mammals through ingestion of the infective *Fasciola* metacercariae. However, the researchers in several countries like Vietnam, Thailand and China revealed that there is a newly discovered *Fasciola*, which is "*Fasciola*-hybrid" due to the unusual events from the areas of *F. hepatica* and *F. gigantica* co-exist (Nguyen et al., 2018). Although, in Malaysia, *F. gigantica* is the only *Fasciola* found in this country (Diyana et al., 2020).

Fasciolosis is a significant problem to ruminant livestock because *Fasciola* is causing morbidity and mortality to the infected animals, hence leads to the economic loss. Estimation of round 3.2 billion USD loss is recorded worldwide annually, due to fasciolosis in livestock (Mehmood et al., 2017). This is associated with the decrease in the animal production (i.e. milk and meat), liver condemnation, and fatality apart from morbidity and mortality (Saleha, 1991). Morbidity in infected ruminant is associated with the reduction of weights, fertility rate, and weaker immune system (Mehmood et al., 2017). Whilst, mortality in infected sheep was associated with chronic liver damage accumulated over several years if without successful treatment (Munita et al., 2019).

Infected ruminant usually results to liver condemnation during the inspection from abattoirs. However, the economic loss due to the liver condemnation is considerable (Shinggu et al., 2019) and demonstrated by the body weight reduction and the narrowing of growth rate (Shinggu et al., 2019). Due to this reason, the *Fasciola*-infected animal will not result in maximum profitability (Shinggu et al., 2019). Fasciolosis is more prevalent in developing country, including Malaysia compared to the developed countries, mainly because of the husbandry management practices, farmers' knowledge on the livestock diseases and the availability of appropriate control programme (Mehmood et al., 2017; Shahudin et al., 2018).

© COPYRIGHT UPM

1.2 Problem statements and relevance of the study

Malaysia is a country that is committed in promoting the food security in the country. Thus, around RM99.5 billion of gross domestic product is allocated for the agricultural sector; and the livestock production contributes of 14.9% of the agricultural sector. Subsequently, this makes the third largest agricultural industry after the oil palm plantation and other cultivations (Malaysian Department of Statistics, 2019). In line with the conceptualisation of national Shared Prosperity Vision 2021 to 2030, the sixth strategic thrust in the first strategy is; to recognise the potential economic areas for regional development based on each states in Malaysia. One of the key activities for the economic growth is by strengthening the livestock sector, mainly in Perlis, Kedah, Perak, Selangor, Negeri Sembilan, Sarawak, and Sabah (Malaysian Ministry of Economic Affairs, 2019). However, there are challenges as ruminant livestock are potentially exposed to parasites, thus limiting the livestock quality, security, and safety products in Malaysian agricultural industry (Azima Laili et al., 2020).

Perak is one of the states identified for strengthening the livestock sector in the national Shared Prosperity Vision 2021 to 2030 (*Wawasan Kemakmuran Bersama 2021 sehingga 2030*). However, a survey was done in the Larut and Matang (Taiping), Perak abattoir; revealed that Larut and Matang (Taiping) showed the highest bovid fasciolosis occurrence compare to other main abattoirs in Peninsular Malaysia (Diyana et al., 2020). In addition, Larut and Matang (Taiping) town is receives the highest rainfall in Peninsular Malaysia with mean of over 4,000mm annually (The Strait Times, 1959; Malaysian Department of Meteorology, 2020), which is a suitable site for *Fasciola* to thrive (Mochankana and Robertson, 2018; John et al., 2019). Following this finding, it is crucial to investigate further on the fasciolosis prevalence in Larut and Matang (Taiping). In addition, the risk factors of the disease are also needed to be determined for the local bovid fasciolosis epidemiology.

Recently, co-infection of *Fasciola* and Paramphistomes occurrence has been increasingly reported by several investigations which might provide significant understanding on fasciolosis epidemiology (Sargison et al., 2016; Huson et al., 2017; Naranjo-Lucena et al., 2018; Munita et al., 2019). Therefore, it is important to see the correlation between these two parasite species in Larut and Matang (Taiping) as the interaction of co-parasitism might influence the disease dynamics among the co-infected host (Huson et al., 2017).

A recent coproantigen ELISA was developed by Mezo et al. (2004) and has been consider as a sensitive diagnostic in detecting early active *Fasciola* infection (four to seven weeks before patency) (Valero et al., 2009). The diagnostic is more practical in a large scale of fasciolosis surveillance compare to the conventional faecal sedimentation (Mezo et al., 2004; Brockwell et al., 2013; Kajugu et al., 2015). However, the association of *Fasciola* faecal egg count (FFEC) with the *Fasciola* coproantigen concentration through coproantigen ELISA is needed, to observe the application of this diagnostic in detecting the fasciolosis predominantly by determining the animals which excreting high FFEC. Therefore, it is important to evaluate the correlation of *Fasciola* coproantigen concentration to *Fasciola* faecal egg count (FFEC).

© COPYRIGHT UPM

Moreover, determination of exposure areas is beneficial to observe the spatial distribution of *Fasciola* which were increasingly applied in UK for fasciolosis forecasting (Rapsch et al., 2008; Novobilsky et al., 2014). Hence, the identification of exposure areas of bovid fasciolosis is important to ease in planning control measures to sustain the livestock production in Larut and Matang (Taiping). Besides, could be used as a tool to alert the zoonotic potential to the public.

1.3 Scope of the study

This study focuses on describing the epidemiology of bovid fasciolosis in Larut and Matang (Taiping), Perak, Malaysia. In developing parasite control programme to limit the negative impact to ruminant production, the prevalence and significant risk factors in the region must be described first. This study is a cross-sectional study of bovid fasciolosis which has been conducted in randomly selected farms as to identify the risk factors that may drive the infection which subsequently extent the exposure or transmission to susceptible hosts. The main factors investigated in present study were the host intrinsic and farm management system employed in the selected farms, whilst the occurrence of Paramphistomes through the detection of eggs was also noted as the co-infection of *Fasciola* and Paramphistomes was common from the faecal samples of the study. The host intrinsic factors include the ruminant species, sex, age group, and body condition score; while the farm management factors include the water source, mixed species farming, housing system, grazing range, and number of bovid per farm; and also, the positivity of co-infection with Paramphistomes which were analysed through the logistic regression model to identify the significant risk factors of bovid fasciolosis in this study. Owing to the common occurrence of *Fasciola* co-infected with Paramphistomes, correlation analysis was done for further evaluation of Paramphistomes co-infection as the risk factor for bovid fasciolosis. In particular, this study evaluated the use of coproantigen ELISA to monitor the *Fasciola* faecal egg count disperse to the environment through correlation analysis which providing basis on the potential use of coproantigen ELISA in controlling fasciolosis. Exposure mapping of bovid fasciolosis was visualised in this study to locate the exposure areas in Larut and Matang (Taiping). Findings in this study may be utilised to formulate the hypotheses in future studies to improve the understanding of the epidemiology of local bovid fasciolosis.

© COPYRIGHT UPM

1.4 Main aim and objectives

The main aim of this study was to describe the epidemiology of bovid fasciolosis in Larut and Matang (Taiping) Perak, Malaysia. Thus, to achieve the goals, this study focuses on five (5) specific objectives as below:

1. To determine the bovid fasciolosis prevalence of selected farms in Larut and Matang (Taiping), Perak by faecal examinations.
2. To identify the risk factors associated with bovid fasciolosis in Larut and Matang (Taiping) by questionnaire survey.
3. To correlate the *Fasciola* and Paramphistomes faecal egg count in co-infected bovid.
4. To correlate the *Fasciola* faecal egg count and *Fasciola* coproantigen concentration through optical density of coproantigen ELISA.
5. To map the exposure areas of bovid fasciolosis in Larut and Matang (Taiping) through heatmap density based on *Fasciola* exposures (prevalence, *Fasciola* faecal egg count) and farm management (herd amount and grazing area) factors.

1.5 Study hypotheses

1. High fasciolosis prevalence is present from bovid population in Larut and Matang (Taiping) from the descriptive analysis of this study.
2. The factors of host intrinsic, farm management, and co-infection with Paramphistomes are significant risk factors associated with bovid fasciolosis in Larut and Matang (Taiping) through the logistic regression model of data obtained in this study.
3. There is significant positive correlation of the *Fasciola* faecal egg count with Paramphistomes faecal egg count in the co-infected bovid through the correlation test
4. There is significant positive correlation of *Fasciola* coproantigen concentration of ELISA optical density (OD) with *Fasciola* faecal egg count through the correlation test.
5. The exposure areas of Larut and Matang (Taiping)) to fasciolosis are reflected to the sampling areas from this study which have a high index of combined selected risk factors from the bovid fasciolosis.

© COPYRIGHT UPM

REFERENCES

Abrous, M., Rondelaud, D., & Dreyfuss, G. (2001). The Stress of *Lymnaea truncatula* just before miracidial exposure with *Fasciola hepatica* increased the prevalence of infection. *Experimental Parasitology, 99*(1), 49-51.

Abrous, M., Rondelaud, D., Dreyfuss, G., & Cabaret, J. (1999). Infection of *Lymnaea truncatula* and *Lymnaea glabra* by *Fasciola hepatica* and *Paramphistomum daubneyi* in farms of central France. *Veterinary Research, 30*, 113-118.

Adedokun, O.A., Ayinmode, A.B., & Fagbemi, B.O. (2008). Seasonal prevalence of *Fasciola gigantica* infection among the sexes in Nigerian cattle. *Veterinary Research, 2*(1), 12-4.

Adekiya, T.A., Aruleba, R.T., Oyinloye, B.E., Okosum, K.O., & Kappo, A.P. (2020). The effect of climate change and the snail-schistosome cycle in transmission and bio-control of schistosomiasis in sub-Saharan Africa. *International Journal of Environmental Research and Public Health, 17*(181), 1-22.

Ai, L., Chen, J.X., Cai, Y.C., Lu, Y., Chu, Y.H., Chen, S.H., Li, H., Song, P., Chen, M.X., & Zhou, X.N. (2019). Prevalence and risk factors of fascioliasis in China. *Acta Tropica, 196*, 180-188.

Alba, A., Vazquez, A.A., & Hurtrez-Bousses, S. (2021). Towards the comprehension of fasciolosis (re-) emergence: an integrative overview. *Parasitology, 148*(4), 385-407.

Alda, P., Lounnas, M., Vázquez, A.A., Ayaqui, R., Calvopiña, M., Celi-Erazo, M., Dillon, R.T., Jr-Jarne, P., Loker, E.S., Muñiz-Pareja, F.C., Muzzio-Aroca, J., Nárvaez, A.O., Noya, O., Robles, L.M., Rodríguez-Hidalgo, R., Uribe, N., David, P., Pointier, J.P., & Hurtrez-Boussès, S. (2018). A new multiplex PCR assay to distinguish among three cryptic Galba species, intermediate hosts of *Fasciola hepatica*. *Veterinary parasitology*, *251*, 101–105.

Alvarez Rojas, C.A., Jex, A.R., Gasser, R.B., & Scheerlinck, J.Y. (2014). Techniques for the diagnosis of *Fasciola* infections in animals: Room for improvement. *Advances in Parasitology, 85*, 65-105.

Alves, D.P., Carneiro, M.B., Martins, I.V.F., Bernando, C.C., Donatele, D.M., Pereira-Junior, O.S., Almelda, B.R., Avelar, B.R., & Leao, A.G.C. (2011). Distribution and factors associated with *Fasciola hepatica* infection in cattle in the south of Espirito Santo State, Brazil. *The Journal of Venomous Animals and Toxins including Tropical Diseases, 17*(3), 271-276.

Anisur Rahman, A.K.M., Shaheenur Islam, S.K., Hasanuzzaman Talukder, M., Kumruk Hassan, M., Dhand, N.K., & Ward, M.P. (2017). Fascioliasis risk factors and space-time clusters in domestic ruminants in Bangladesh. *Parasites & Vectors, 10*, 228.

© COPYRIGHT UPM

Anucherngchai, S., Chontananarth, T., Tejangkura, T., & Wongsawad, C. (2020). Molecular classification of rumen fluke eggs in fecal specimens from Suphanburi Province, Thailand, based on cytochrome C oxidase subunit 1. *Veterinary parasitology, regional studies and reports*, *20*, 100382.

Aragaw, K., & Tilahun, H. (2019). Coprological study of trematode infections and associated host risk factors in cattle during the dry season in and around Bahir Dar, northwest Ethiopia. *Veterinary and Animal Science, 7*, 100041.

Azima Laili, H., Azizah D., Nurulaini, R., Adnan, M., Lily Rozita, M.H., Debbra, M., Erwanas, A.I., & Chee, W.K. (2020). Occurrence of parasitic infection in small ruminants from various farms in Perak, Malaysia. *Malaysian Journal of Veterinary Research, 11*(1), 18-25.

Barbosa, R., Pinto, C., Garcia, P., & Rodrigues, A. (2019). Prevalence of fasciolosis in slaughtered dairy cattle from São Miguel Island, Azores, Portugal. *Veterinary Parasitology: Regional Studies and Reports, 17*, 100319.

Bennema, S.C., Ducheyne, E., Vercruysse, J., Claerebout, E., Hendrickx, E., & Charlier, J. (2011). Relative importance of management, meteorological and environmental factors in the spatial distribution of *Fasciola hepatica* in dairy cattle in a temperate climate zone. *International Journal for Parasitology, 41*(2), 225-233.

Bishop, S.C. (2012). Possibilities to breed for resistance to nematode parasite infections in small ruminants in tropical production systems. *Animal, 6*(5), 741-7.

Bishop, S.C., & Stear, M.J. (1999). Genetic and epidemiological relationships between productivity and disease resistance: gastrointestinalparasite infection in growing lambs. *Animal Science Journal, 69*, 515–525.

Boray, J.C. (1969). Experimental fascioliasis in Australia. *Advances in Parasitology, 7*, 95–210.

Boray, J.C., & Love, S. (2007). Liver fluke disease in sheep and cattle. *Department of Primary Industries, Primefact*, 1-10.

Breiman, L. (2001). Random Forests. *Machine Learning, 45*, 5-32.

Brockwell, Y.M., Spithill, T.W., Anderson, G.R., Grillo, V., & Sangster, N.C. (2013). Comparative kinetics of serological and coproantigen ELISA and faecal egg count in cattle experimentally infected with *Fasciola hepatica* and following treatment with triclabendazole. *Veterinary Parasitology, 196*(3–4), 417–26.

Bui, T.D., Doanh, P.N., Saegerman, C., & Losson, B. (2016). Current status of fasciolosis in Vietnam: An update and perspective. *Journal of Helminthology, 90*(5), 511-522.

Calvani, N.E.D., & Slapeta, J. (2020). *Fasciola* species introgression: just a fluke or something more?. *Trends in Parasitology, 37*(1), 25-34.

© COPYRIGHT UPM

Celias, D.P., Corvo, I., Silvane, L., Tort, J.F., Chiapello, L.S., Fresno, M., Arranz, A., Motran, C.C., & Cervi, L. (2019). Cathepsin L3 from *Fasciola hepatica* induces NLRP3 inflammasome alternative activation in murine dendritic cells. *Frontiers in Immunology, 10*, 552.

Centers for Disease Control and Prevention. (2020). Fascioliasis. Retrieved on 20 January 2020 from https://www.cdc.gov/dpdx/fascioliasis/index.html.

Charlier, J., Bennema, S.C., Caron, Y., Counotte, M., Ducheyne, E., Hendrickx, G., & Vercryusse, J. (2011). Towards assessing fine-scale indicators for the spatial transmission risk of *Fasciola hepatica* in cattle. *Geospatial Health, 5*(2), 239–45.

Conray, R. (2016). The Royal College of Surgeons in Ireland (RCSI) Sample Size Handbook.

Correa, A.C., Escobar, J.S., Noya, O., Velasquez, L.E., Gonzales-Ramirez, C., Hurtrez-Bousses, S., & Pointier, J.P. (2011). Morphological and molecular characterization of Neotropic Lymnaeidae (Gastropoda: Lymnaeoidea), vectors of fasciolosis. *Infection, Genetics and Evolution, 11*(8), 1978-1988.

Cwiklinski, K., O'neill, S.M., Donnelly, S., & Dalton, J.P. (2016). A prospective view of animal and human fasciolosis. *Parasite Immunology*, *38*, 558-568.

Dalton, J.P., Neill, S.O., Stack, C., Collins, P., Walshe, A., Sekiya, M., Doyle, S., Mulcahy, G., Hoyle, D., Khaznadji, E., Moiré, N., Brennan, G., Mousley, A., Kreshchenko, N., Maule, A.G., & Donnelly, S.M. (2003). *Fasciola hepatica* cathepsin L-like proteases: biology, function, and potential in the development of first generation liver fluke vaccines. *International journal for parasitology*, *33*(11), 1173–1181.

Devos, J., Vassilogloup, B., Amenna-Bernard, N., & Marcotty, T. (2013). Paramphistomosis in sheep; natural infection of lambs by *Calicophoron daubneyi*. *Revue de Medecine Veterinaire, 164*, 528–535.

Diyana, N.A.J., Lokman, I.H., Nur Fazila, S.H., Latiffah, H., Ibitoye, E.B., Noor Hazfalinda, H., Chandrawathani, P., Juriah, K., & Nur Mahiza, M.I. (2019). A retrospective study on bovid fascioliasis in Veterinary Regional Laboratories in Peninsular Malaysia. *Journal of Parasitology Research*, 1-5.

Diyana, N.A.J., Nur Mahiza, M.I., Latiffah, H., Nur Fazila, S.H., Lokman, I.H., Noor Hazfalinda, H., Chandrawathani, P., Ibitoye, E.B., & Juriah, K. (2020). Occurrence, morphometric, and molecular investigation of cattle and buffalo liver adult fluke in Peninsular Malaysia main abattoirs. *Journal of Parasitology Research*, 1-6.

Dreyfuss, G., Abrous, M., Vignoles, P., & Rondelaud, D. (2004). *Fasciola hepatica* and *Paramphistomum daubneyi*: Vertical distribution of metacercariae on plants under natural conditions. *Parasitology Research, 94*(1), 70-73.

Dung, B.T., Doanh, P.N., The, D.T., Loan, H.L., Losson, B., & Caron, Y. (2013). Morphological and molecular characterization of lymnaeid snails and their

© COPYRIGHT UPM

potential role in transmission of *Fasciola* in Vietnam. *Korean Journal of Parasitology, 51*(6), 657-562.

Duthaler, U., Rinaldi, L., Maurelli, M., Vargas, M., Utzinger, J., Cringoli, G., & Keiser, J. (2010). *Fasciola hepatica*: comparison of the sedimentation and FLOTAC techniques for the detection and quantification of faecal egg counts in rats. *Experimental Parasitology, 126*(2), 161-166.

Dutra, L.H., Molento, M.B., Naumann, C.R.C., Fortes, F.S., & Malone, J. (2010). Mapping risk of bovid fasciolosis in the South of Brazil using geographic information systems. *Veterinary Parasitology, 169*(1), 76-81.

Edmonson, A.J., Lean, I.J., Weaver, L.D., Farver, T., & Webster, G. (1989). A body condition scoring chart for Holstein dairy cows. *Journal of Dairy Science, 72*(1), 68-78.

Elelu, N., Ambali, A., Coles, G.C., & Eisler, M.C. (2016). Cross-sectional study of *Fasciola gigantica* and other trematode infections of cattle in Edu Local Government Area, Kwara State, north-central Nigeria. *Parasites & Vectors, 9*, 470–480.

Fatin Fazira, I. (2018). Prevalence of fascioliasis among cattle and goats slaughtered in Shah Alam abattoir. Unpublished thesis. Faculty of Veterinary Medicine. Universiti Putra Malaysia. Malaysia.

Faria, R.N., Cury, M.C., & Lima, W.S. (2008). Evaluation of two available methods to detect eggs of *Fasciola hepatica* in cattle faeces. *Arquivo Brasileiro de Medicina Veterinaria e Zootecnia, 60*, 1023–1025.

Fazly Ann, Z., Muhamad Syamsul Naim, N.A., Wan Normaziah, W.O.B., Geethamalar, S., & Mohd Iswadi. (2015). Screening for zoonotic fascioliasis in slaughtered large ruminants in abattoirs in Perak, Malaysia. *Tropical Life Sciences Research, 26*, 121-124.

Fionna, V.B. (2018). *Fasciola*sis in Tuaran, Sabah: A case report. *Borneo Journal of Medical Sciences, 1*, 35-36.

Flanagan, A., Edgar, H.W.J., Gordon, A., Hanna, R.E.B., Brennan, G.P., & Fairweather, I. (2011). Comparison of two assays, a faecal egg count reduction test (FECRT) and a coproantigen reduction test (CRT), for the diagnosis of resistance to triclabendazole in *Fasciola hepatica* in sheep. *Veterinary Parasitology, 176*, 170–176.

Fox, N.J., Marion, G., Davidson, R.S., White, P.C.L., & Hutchings, M.R. (2013). Modelling parasite transmission in a grazing system: The importance of host behaviour and immunity. *PLos ONE, 8*(11), e77996.

Fox, N.J., White, P.C.L., McClean, C.J., Marion, G., Evans, A., & Hutchings, M.R. (2011). Predicting impacts of climate change on *Fasciola hepatica* risk. *PLos ONE, 6*(1): e16126.

© COPYRIGHT UPM

Fuertes, M., Perez, V., Benavides, J., Gonzalez-Lanza, M.C., Mezo, M., Gonzalez-Warleta, M., Giraldez, F.J., Fernandez, M., Manga-Gonzalez, M.Y., & Ferreras, M.C. (2015). Pathological changes in cattle naturally infected by *Calicophoron daubneyi* adult flukes. *Veterinary Parasitology, 209*, 188-196.

Ganga, G., Varshney, J.P., & Sharma R.L. (2004). Effect of *F. gigantica* excretory-secretary antigen on rat hematological indices. *Journal of Veterinary Science, 7*, 123-125.

Ghanimatdan, M., Chalechale, A., Rezaei, F., Rokni, M.B., & Shahrokhi, S.R. (2019). Bioclimatic analysis and spatial distribution of livestock fascioliasis in Iran. *Iranian Journal of Parasitology, 14*(1): 41–51.

Gordon, D.K., Roberts, L.C.P., Lean, N., Zadoks, R.N., Sargison, N.D., & Skuce, P.J. (2013). Identification of the rumen fluke, *Calicophoron daubneyi*, in GB livestock: possible implications for liver fluke diagnosis. *Veterinary Parasitology, 1296*(1-2), 65-71.

Gordon, D.K., Zadoks, R.N., Stevenson, H., Sargison, N.D., & Skuce, P.J. (2012). On farm evaluation of the coproantigen ELISA and coproantigen reduction test in Scottish sheep naturally infected with *Fasciola hepatica*. *Veterinary Parasitology, 187*, 436–444.

Gueguen, E., Leperre, P., Petit, H., Merlin, A., & Chartier, C. (2016). A coproscopical study of helminthosis in domestic ruminants (cattle, buffalo, goat) in Khammouane Province (Lao PDR). *Revue de Medecine Veterinaire, 167*(11-12), 310-315.

Halimi, M., Farajzadeh, M., Delavari, M., & Arbabi, M. (2015). Developing a climate-based risk map of fascioliasis outbreaks in Iran. *Journal of Infection and Public Health, 8*(5): 481–86.

Hansen, D.S., Clery, D.G., Estuningsih, S.E., Widjajanti, S., Partoutomo, S., & Spithill, T.W. (1999). Immune responses in Indonesian Thin Tail and Merino sheep during a primary infection with *Fasciola gigantica*: lack of a specific IgG2 antibody response is associated with increased resistance to infection in Indonesian sheep. *International Journal for Parasitology, 29*(7), 1027–35.

Hochachka, W.M., & Dhondt, A.A. (2000). Density-dependent decline of host abundance resulting from a new infectious disease. *Proceedings of the National Academy of Sciences of the United States of America, 97* (10), 5303-5306.

Howell, A., Baylis, M., Smith, R., Pinchbeck, G., & Williams, D. (2015). Epidemiology and impact of *Fasciola hepatica* exposure in high-yielding dairy herds. *Preventive Veterinary Medicine, 121*(1–2): 41–48.

Huson, K.M., Oliver, N.A.M., & Robinson, M.W. (2017). Paramphistomosis of ruminants: an emerging parasitic disease in Europe. *Trends in Parasitology, 33*(11), 836-844.

© COPYRIGHT UPM

Hussein, A.N.A., Hassan, I.M., & Khalifa, R.M.A. (2010). Description of eggs and larval stages of *Fasciola*, light and scanning electron microscopic studies. *Research Journal of Parasitology, 5*(1), 1-12.

Iffah Laila, F.H. (2019). Prevalence of liver fluke in buffaloes in a farm in Larut and Matang (Taiping), Perak. Unpublished thesis. Faculty of Veterinary Medicine. Universiti Putra Malaysia. Malaysia.

Jaja, I.F., Mushonga, B., Green, E., & Muchenje, V. (2017). Seasonal prevalence, body condition score and risk factors of bovid fasciolosis in South Africa. *Veterinary and Animal Science, 4*, 1–7.

Japa, O., Siriwechviriya, P., & Prakhammin, K. (2020). Occurrence of fluke infection in beef cattle around Phayao Lake, Phayao, Thailand. *Veterinary World, 13*(2), 334-337.

John, B.C., Davies, D.R., Williams, D.J.L., & Hodgkinson, J.E. (2019). A review of our current understanding of parasite survival in silage and stored forages, with a focus on *Fasciola hepatica* metacercariae. *Grass and Forage Science, 74*(2), 211-217.

Jones, R.A., Williams, H.W., Dalesman, S., Ayodeji, S., Thomas, R.K., & Brophy, P.M. (2017). The prevalence and development of digenean parasites within their intermediate snail host, *Galba truncatula*, in a geographic area where the presence of *Calicophoron daubneyi* has recently been confirmed. *Veterinary Parasitology, 240*, 68–74.

Kajugu, P.E., Hanna, R.E.B., Edgar, H.W., McMahob, C., Cooper, M., Gordon, A., Barley, J.P., Malone, F.E., Brenna, G.P., & Fairweather, I. (2015). *Fasciola hepatica*: specificity of a coproantigen ELISA test for diagnosis of fasciolosis in faecal samples from cattle and sheep concurrently infected with gastrointestinal nematodes, coccidians and/or rumen flukes (Paramphistomes), under field conditions. *Veterinary Parasitology, 212*(3–4), 181–87.

Karvonen, A., Jokela, J., & Laine, A.L. (2019). Importance of sequence and timing in parasite coinfections. *Trends in Parasitology, 35*(2), 109-118.

Kassai, T. (1999). *Veterinary Helminthology*. London, United Kingdom: Elsevier Health Sciences. Pp. 3-13.

Kato, M., Murakami, Y., Shimizu, M., Yamamoto, H., Yonemoto, Y., Ishii, K., & Kira, S. (2005). Survey of cattle fascioliasis in Tsuyama Abattoir. *Environmental health and preventive medicine*, *10*(3), 162–165. https://doi.org/10.1007/BF02900810

Keyyu, J.D., Monrad, J., Kyvsgaard, N.C., & Kassuku, A.A. (2005). Epidemiology of *Fasciola gigantica* and amphistomes in cattle on traditional, small-scale dairy and large-scale dairy farms in the Southern Highlands of Tanzania." *Tropical Animal Health and Production, 37*(4), 303–14.

© COPYRIGHT UPM

Khadijah, S., & Norlin Atikah, A. (2017). Availability of *Lymnaea rubiginosa* and other snails around cattle grazing areas. Poster presented at 26th International Conference of the World Association for the Advancement of Veterinary Parasitology, Abstract number 5612, 2017 September 4-8: Kuala Lumpur, Malaysia.

Khadijah, S., Ariff, Z., Nurlaili, M.R., Sakiinah, A., Izzudin, A.H., Mursyidah, A.K., Rita, N., & Nur Aida, H. (2017). *Fasciola* and *Paramphistomum* infection in large ruminants. *International Journal of Agronomy and Agricultural Research, 10*, 19-26.

Khadijah, S., Nik Izzudin, A.H., Rita, N., Veronica, S., Nur Aida, H., & Wahab, A.R. (2015). Endo- and ectoparasite infections in two cattle farms located in Kuala Terengganu, Peninsular Malaysia. *Asian Journal of Agriculture and Food Sciences, 3*, 667-674.

Khan, M.K., Sajid, M.S., Khan, M.N., Iqbal, Z., & Iqbal, M.U. (2009). Bovid fasciolosis: prevalence, effects of treatment on productivity and cost benefit analysis in five districts of Punjab, Pakistan. *Research in Veterinary Science, 87*, 70–75.

Kimura, K., & Chiba, S. (2009). Interspecific interference competition alters habitat use patterns in two species of land snails. *Evolutionary Ecology, 24*, 815-825.

Lemoinne, S., Cadoret, A., Mourabit, H.E., Thabut, D., & Housset, C. (2013). Origins and functions of liver myofibroblasts. *Biochimica et Bioophysica Acta, 1832*, 948-954.

Liang, J.B., & Paengkoum, P. (2019). Current status, challenges and the way forward for dairy goat production in Asia - conference summary of dairy goats in Asia. *Asian-Australian Journal of Animal Sciences, 32*(8), 1233-1243.

Loeurng, V., Ichikawa-Seki, M., Wannasan, A., Sothyra, T., Chaisowwong, W., & Tiwananthagorn, S. (2019). Genetic characterization of Cambodian *Fasciola gigantica* and dispersal direction of the species in Asia. *Veterinary Parasitology, 273*, 45-51.

Lu, X.T., Gu, Q.Y., Limpanont, Y., Song, L.G., Wu, Z.D., Okanurak, K., & Lv, Z.Y. (2018). Snail-borne parasitic diseases: an update on global epidemiological distribution, transmission interruption and control methods. *Infectious Diseases of Poverty, 7*(1), 1–16.

Lueng, V., Ichikawa-Seki, M., Wannasan, A., Sothyra, T., Chaisowwong, W., & Tiwananthagorn S. (2019). Genetic charazterization of Cambodian *Fasciola gigantica* and direction of the species in Asia. *Veterinary Parasitology, 273*, 45-51.

Madsen, H., & Hung, N.M. (2015). An overview of freshwater snails in Asia with main focus on Vietnam. *Acta Tropica, 141*, 372-384.

© COPYRIGHT UPM

Magaji, A.A., Ibrahim, K., Salihu, M.D., Saulawa. M.A., Mohammed, A.A., & Musawa, A.1. (2014). Prevalence of fascioliasis in cattle slaughtered in Sokoto metropolitan abattoir, Sokoto, Nigeria. *Advances in Epidemiology*. No ID 247258.

Mahato, S.N., & Harrison, L.J.S. (2005). Control of fasciolosis in stall-fed buffaloes by managing the feeding of rice straw. *Tropical Animal Health and Production, 37*, 285-291.

Malaysian Department of Meteorology. (2020). *Buletin Cuaca Bulanan* [Montly Weather News]. Retrieved on 15 October 2020 from https://www.met.gov.my/

Malaysian Department of Statistics. (2019). *Chosen Agriculture Indicator, Malaysia*. Retrieved on 26 December 2019 from https://www.dosm.gov.my/v1/index.php?r=column/cthemeByCat&cat=72&bul_id=SEUxMEE3VFdBcDJhdUhPZVUxa2pKdz09&menu_id=Z0VTZGU1UHBUT1 VJMFlpaXRRR0xpdz09

Malaysian Department of Veterinary Services. (2018). *Livestock Statistics 2017/2018*. Retrieved on 8 January 2020 from http://www.dvs.gov.my/index.php/pages/view/2234

Malaysian Ministry of Economic Affairs. (2019). *Shared Prosperity Vision 2030*. Selangor, Malaysia: Attin Press Sdn Bhd, Chapter 6.

Malone, J.B., Gommes, R., Hansen, J., Yilma, J.M., Slingenberg, J., Snijders, F., Nachtergaele, F., & Ataman, E. (1998). A geographic information system on the potential distribution and abundance of *Fasciola hepatica* and *F. gigantica* in East Africa based on Food and Agriculture Organization databases. *Veterinary Parasitology, 78*(2), 87–101.

Manuel, C., Mabel, G., Greta, M., William, C., Maritza, C., Richar, R., & Hiromu, S. (2018). Asymptomatic *Fasciola hepatica* infection presenting with hypereosinophilia. *Archives of Clinical Microbiology, 9*(1), 73.

Marston, L. (2010). Introductory statistics for health and nursing using SPSS. London: SAGE Publications. 200-212.

Martinez-Sernandez, V., Orbegozo-Medina, R.A., Gonzalez-Warleta, M., Mezo, M., & Ubeira, F.M. (2016). Rapid enhanced MM3-COPRO ELISA for detection of *Fasciola* coproantigens. *PLos Neglected Tropical Diseases, 10*, 0004872.

Martins, I.V., de Avelar, B.R., Pereira, M.J., & da Fonseca, A.H. (2012). Application of a geographical information system approach for risk analysis of fascioliasis in southern Espírito Santo State, Brazil. *Geospatial Health, 6*(3), 87-93.

Mas-Coma, S. (2005). Epidemiology of fasciolosis in human endemic areas. *Journal of Helminthology*, *79*, 207-216.

Mason, C., Stevenson, H., Cox, A., & Dick, I. (2012). Disease associated with immature paramphistome infection in sheep. *Veterinary Record, 170*(13), 343-344.

© COPYRIGHT IPM

Masrin, A., Magendren, S., Chandrawathani, P., & Nurain Irzierah, I. (2015). Current status of fascioliasis in ruminants: cases diagnosed from 2004 to 2013 in VRI, Ipoh. Department Veterinary Services Malaysia. Pp. 1-4.

May, K., Brügemann, K., König, S., & Strube, C. (2019). Patent infections with *Fasciola hepatica* and paramphistomes (*Calicophoron daubneyi*) in dairy cows and association of fasciolosis with individual milk production and fertility parameters. *Veterinary Parasitology, 267*, 32-41.

McCann, C.M., Baylis, M., & Williams, D.J.L. (2010). The development of linear regression models using environmental variables to explain the spatial distribution of *Fasciola hepatica* infection in dairy herds in England and Wales. *International Journal for Parasitology, 40*(9), 1021–28.

Mehmood, K., Zhang, H., Sabir, A.J., Abbas, R.Z., Ijaz, M., Durrani, A.Z., Saleem, M.H., Rehman, M.U., Iqbal, M.K., Wang, Y., Ahmad, H.I., Abbas, T., Hussain, R., Ghori, M.T., Ali, S., Khan, A.U., & Li, J. (2017). A review on epidemiology, global prevalence and economical losses of fasciolosis in ruminants. *Microbial Pathogenesis, 109*, 253-262.

Mezo, M., González-Warleta, M., Carro, C., & Ubeira, F.M. (2004). An ultrasensitive capture ELISA for detection of *Fasciola hepatica* coproantigens in sheep and cattle using a new monoclonal antibody (MM3). *Journal of Parasitology, 90*(4), 845–52.

Moazeni, M., & Ahmadi, A. (2016). Controversial aspects of the life cycle of *Fasciola hepatica*. *Experimental Parasitology,* 169, 81–89.

Mochankana, M.E., & Robertson, I.D. (2018). Cross-sectional prevalence of *Fasciola gigantica* infections in beef cattle in Botswana. *Tropical Animal Health and Production, 50*(6), 1355–1363.

Mohd Ridzuan, N., Mohd Zamri, S., & Rehana, A.S. (2012). Status and effect of fascioliasis in buffaloes kept extensively in a farm in Sabah, Malaysia. 7th Proceedings of the Seminar in Veterinary Sciences.

Molina-Hernández, V., Mulcahy, G., Perez, J., Martinez-Moreno, A., Donnelly, S., O'Neill, S.M., Dalton, J.P., & Cwiklinski, K. (2015). *Fasciola hepatica* vaccine: we may not be there yet but we're on the right road. *Veterinary Parasitology, 208*(1–2), 101–11.

Munita, M.P., Rea, R., Martinez-Ibeas, A.M., Byrne, N., McGrath, G., Munita-Corbalan, L.E., Sekiya, M., Mulcahy, G., & Sayers, R.G. (2019). Liver fluke in Irish sheep: prevalence and associations with management practices and co-infection with rumen fluke. *Parasites and Vectors, 12*(1), 1–14.

Mursyidah, A.K., Khadijah, S., & Rita, N. (2017). *Fasciola* and *Paramphistomum* infections in small ruminants (Sheep and goat) in Terengganu. *Malaysian Journal of Veterinary Research, 8*, 8-12.

© COPYRIGHT UPM

Naim C.K., Muhammad Ali I.R., Busayo I.E., Noor Hazfalinda H., Lokman Hakim I., & Nur Mahiza M.I. (2021). The first report of ruminant fascioliasis in Sabah, east Malaysia. *Journal of Parasitology Research*, article ID 6691483, 1-5.

Naranjo-Lucena, A., Corbalán, M.P.M., Martínez-Ibeas, A.M., McGrath, G., Murray, G., Casey, M., Good, B., Sayers, R., Mulcahy, G., & Zintl, A. (2018) Spatial patterns of *Fasciola hepatica* and *Calicophoron daubneyi* infections in ruminants in Ireland and modeling of *C. daubneyi* infection. *Parasites & Vectors, 11*(1), 531-531.

Narisetty, N.N. (2020). Chapter 4 – Bayesian model selection for high-dimensional data. *Handbook of Statistics*, 43, 207-248.

Nguyen, T., De, N. V., Nguyen, T., Quang, H. H., Doan, H., Agatsuma, T., & Le, T. H. (2018). Distribution status of hybrid types in large liver flukes, *Fasciola* species (digenea: Fasciolidae), from ruminants and humans in Vietnam. *The Korean journal of parasitology*, *56*(5), 453–461.

Novobilský, A., Engstrom, A., Sollenberg, S., Gustafsson, K., Morrison, D.A., & Hoglung, J. (2014). Transmission patterns of *Fasciola hepatica* to ruminants in Sweden. *Veterinary Parasitology*, *203*(3-4), 276-286.

Nurhanim, R., 2019. Morphological and molecular characterization of *Fasciola* species in ruminant slaughtered at Shah Alam and Banting abattoirs. Unpublished thesis. Faculty of Veterinary Medicine. Universiti Putra Malaysia. Malaysia.

Nurhidayah, N., Satrija, F., Retnani, E.B., Astuti, D.A., & Murtini, S. (2020). Prevalence and risk factors of trematode infection in swamp buffaloes reared under different agro-climatic conditions in Java Island of Indonesia. *Veterinary World, 13*(4), 687–94.

Nyirenda, S.S., Sakala, M., Moonde, L., Kayesa, E., Fandamu, P., Banda, F., & sinkala, Y. (2019). Prevalence of bovid fascioliasis and economic impact associated with liver condemnation in abattoirs in Mongu District of Zambia. *BMC Veterinary Research, 15*(1), 1–8.

Nzalawahe, J. Kassuku, A.A., Stothard, J.R., Coles, G.C., & Eisler, M.C. (2015). Associations between trematode infections in cattle and freshwater snails in highland and lowland areas of Iringa rural district, Tanzania. *Parasitology, 142*(11), 1430–39.

Ollerenshaw, C.B., & Rowlands, W.T. (1959). A method of forecasting the incidence of fascioliasis in Anglesey. *Veterinary Record, 71*, 591–598.

Phalee, A., Wongsawad, C., Rojanapaibul, A., & Chai, J.Y. (2015). Experimental life history and biological characteristics of *Fasciola gigantica* (Digenea: Fasciolidae). *The Korean Journal of Parasitology, 53*, 59-64.

Phiri, A.M., Phiri, I.K., & Monrad, J. (2006). Prevalence of amphistomiasis and its association with *Fasciola gigantica* infections in Zambian cattle from communal grazing areas. *Journal of Helminthology, 80*(1), 65–68.

© COPYRIGHT UPM

Piedrafita, D., Raadsma, H.W., Gonzalez, J., & Meeusen, E. (2010). Increased production through parasite control: can ancient breeds of sheep teach us new lessons?. *Trends in Parasitology, 26*(12), 568–73.

Pinilla, J.C., Florez, A.A., Orlandoni, G., Tobon, J.C., & Ortiz, D. (2020). Current status of prevalence and risk factors associated with liver fluke *Fasciola hepatica* in cattle raised in different altitudinal regions of Colombia. *Veterinary Parasitology: Regional Studies and Reports, 22*, 100487.

Pleasance, J., Wiedosari, E., Raaddsma, H.W., Meeusen, E., & Piedrafita, D. (2011). Resistance to liver fluke infection in the natural sheep host is correlated with a type-1 cytokine response. *Parasite Immunology, 33*(9), 495–505.

Poulin, R., Besson, A.A., Morin, M.B., & Randhawa, H.S. (2016). Missing links: testing the completeness of host-parasite checklists. *Parasitology, 143*, 114–22.

Qureshi, A.W., Tanveer, A., Maqbool, A., & Niaz, S. (2015). Prevalence and trematode infection of freshwater snails with emphasis on fasciolosis in Punjab, Pakistan. *Asian Journal of Agriculture and Biology, 3*, 130-139.

Rajamanickam, C., Cheah, T.S., Chandrawathani, P., Hasnah, Y., & Adnan, M. (1996). *Fasciola* infection in Peninsular Malaysia. Ministry of Agriculture Malaysia. Pp. 1-20.

Rajamanickam, C., Muniandy, N., Yahya, M., Cheah, T.S., & Paramasvaran, S. (1987). Haematological and biochemical parameters of cattle naturally infested with *Fasciola gigantica* in Perak, Malaysia. *Kajian Veterinar, 19*, 143-151.

Rapsch, C., Dahinden, T., Heinzmann, D., Torgerson, P.R., Braun, U., Deplazes, P., Hurni, L., Bar, H., & Knubben-Schweizer, G. (2008). An interactive map to assess the potential spread of *Lymnaea truncatula* and the free-living stages of *Fasciola hepatica* in Switzerland. *Veterinary Parasitology, 154*(3–4), 242–49.

Rapsch, C., Schweizer, G., Grimm, F., Kohler, L., Bauer, C., Deplazes, P., Braun, U., & Torgerson, P. R. (2006). Estimating the true prevalence of Fasciola hepatica in cattle slaughtered in Switzerland in the absence of an absolute diagnostic test. *International journal for parasitology*, *36*(10-11), 1153–1158. https://doi.org/10.1016/j.ijpara.2006.06.001

Reddington, J.J., Wes Leid, R., & Wescott, R.B. (1984). A review of the antigens of *Fasciola hepatica*. *Veterinary Parasitology, 14*, 209-229.

Rinaldi, L., Amadesi, A., Dufourd, E., Bosco, A., Gadanho, M., Lehebel, A., Maurelli, M.P., Chauvin, A., Charlier, J., Cringoli, G., Ravinet, N., & Chartier, C. (2019). Rapid assessment of faecal egg count and faecal egg count reduction through composite sampling in cattle. *Parasites Vectors, 12*, 353.

Rita, N., Mursyidah, A.K., & Khadijah, S. (2017). The prevalence of helminthiasis in cattle, Terengganu, Peninsular Malaysia. *Tropical Biomedicine, 34*, 324-331.

© COPYRIGHT UPM

Robertson, I.D. (2020). Disease control, prevention and on-farm biosecurity: the role of veterinary epidemiology. *Engineering, 6*(1), 20-25.

Rosilawati, K., Ramli, S., & Saipul Bahari, A.R. (2017). Fascioliasis in an adult draught buffalo in Malaysia: A case report. *Malaysian Journal of Veterinary Research, 8*, 169-172.

Ruiz-Campillo, M.T., Hernandez, V.M., Escamilla, A., Stevenson, M., Perez, J., Martinez-Moreno, A., Donnelly, S., Dalton, J.P., & Cwiklinski, K. (2017). Immune signatures of pathogenesis in the peritoneal compartment during early infection of sheep with *Fasciola hepatica*. *Scientific Reports, 7*, 2782.

Saleha, A.A. (1991). Liver fluke disease (fasciolosis): epidemiology, economic impact and public health significance. *Southeast Asian Journal of Tropical Medicine Public health*, *22*, 361-364.

Sargeant, J.M., O'Connor, A.M., Dohoo, I.R., Erb, H.N., Cevallos, M., Egger, M., Ersboll, A.K., Martin, S.W., Nielsen, L.R., Pearl D.L., Pfeiffer, D.U., Sanchez, J., Torrence, M.E., Vigre, H., Waldner, C., & Ward, M.P. (2016). Methods and processes of developing the strengthening the reporting of observational studies in epidemiology – veterinary (STROBE-Vet) statement. *Preventive Veterinary Medicine, 134*, 188-196.

Sargison, N., Francis, E., Davison, C., Bronsvoort, B.M.d., Handel, I., & Mazeri, S. (2016). Observations on the biology, epidemiology and economic relevance of rumen flukes (Paramphistomidae) in cattle kept in a temperate environment. *Veterinary Parasitology, 219*, 7-16.

Sarmah, P.C., Laha, R., Bhattacharjee, K., Goswami, A., Raquib, M., & Kakati, P. (2014). Human consumption of rumen flukes of cattle in India. *Southeast Asian Journal of Tropical Medicine Public health*, *45*, 26–30.

Sato, M.O., Sato, M., Chaisiri, K., Maipanich, W., Yoonuan, T., Sanguankiat, S., Pongvongsa, T., Boupha, B., Moji, K., & Waikagul, J. (2014). Nematode infection among ruminants in monsoon climate (Ban-Lahanam, Lao PDR) and its role as food-borne zoonosis. *Brazilian Journal of Veterinary Parasitology, 23*(1), 80-84.

Schweizer, G., Meli, M.L., Torgerson, P. R., Lutz, H., Deplazes, P., & Braun, U. (2007). Prevalence of *Fasciola hepatica* in the intermediate host *Lymnaea truncatula* detected by real time TaqMan PCR in populations from 70 Swiss farms with cattle husbandry. *Veterinary Parasitology, 150*, 164-169.

Seid, U., & Melese, M. (2018). Review on prevalence, distribution and economic significance of liver fluke in Ethiopia. *ARC Journal of Animal and Veterinary Sciences, 4*(2), 38-48.

Selemetas, N., Ducheyne, E., Phelan, P., O'Kiely, P., Hendrickx, G., & Waal, T.D. (2015). Spatial analysis and risk mapping of *Fasciola hepatica* infection in dairy herds in Ireland. *Geospatial Health, 9*(2), 281–91.

© COPYRIGHT UPM

Shahudin, M.S., Ghani, A.A.A., Zamri Saad, M., Zuki, A.B., Abdullah, F.F.J., Wahid, H., & Hassim, H.A. (2018). The necessity of a herd health management programme for dairy goat farm in Malaysia. *Pertanika Journal of Tropical Agricultural Science, 41*, 1-18.

Sharma, R.L., Godara, R., & Thilagar, M.B. (2011). Epizootiology, pathogenesis and immunoprophylactic trends to control tropical bubaline fasciolosis: an overview. *Journal of Parasitic Diseases, 35*(1), 1-9.

Shi, W., Wei, Z.Y., Elsheikha, H.M., Zhang, F.K., Sheng, A.A., Lu, K.J., Wang, D.Y., Huang, W.Y., & Zhu, X.Q. (2013). Dynamic expression of cytokine and transcription factor genes during experimental *Fasciola* gigantica infection in buffaloes. *Parasites & Vectors, 10*, 602.

Shinggu, P.A., Olufemi, O.T., Nwuku, J.A., Baba-Onoja, E.B.T., & Iyawa, P.D. (2019). Liver flukes egg infection and associated risk factors in White Fulani cattle slaughtered in Wukari, Southern Taraba state, Nigeria. *Advances in Preventive Medicine,* 2671620.

Silverman, B. (1986). Density estimation for statistics and data analysis. In: Monographs on Statistics and Applied Probability. London: Chapman and Hall.

Siti Aqilah, Z.N. (2018). Prevalence of liver and rumen flukes in foster farms, Universiti Putra Malaysia. Unpublished thesis. Faculty of Veterinary Medicine. Universiti Putra Malaysia. Malaysia.

Stevenson, M. (2013). An R package for the analysis of epidemiological data. R package version 0.9-46, from http://www2.uaem.mx/r-mirror/web/packages/epiR/epiR.pdf

Suhaila, J., Mohd Deni, S., Wan Zin, W.Z., & Jemain, A.A. (2010). Trends in Peninsular Malaysia rainfall data during the southwest monsoon and northeast monsoon seasons: 1975-2004. *Sains Malaysiana, 39*, 533-542.

Suhardono, Roberts, J.A., & Copeman, D.B. (2006). Distribution of metacercariae of *Fasciola gigantica* on rice straw. *Tropical Animal Health and Production, 38*, 117-119.

Takeuchi-Storm, N., Denwood, M., Hansen, T.V.A., Halsa, T., Rattenborg, E., Boes, J., Enemak, H.L., & Thamsborg, S.M. (2017). Farm-level risk factors for *Fasciola hepatica* infection in Danish dairy cattle as evaluated by two diagnostic methods. *Parasites and Vectors, 10*(1), 1–11.

Taylor, M.A., Coop, R.L., & Wall, R.L. (2015). Veterinary Parasitology. Oxford, UK: Wiley-Blackwell. Pp. 483-484.

Tham, K.M., & Sheikh-Omar, A.R. (1981). A study on causes of condemnation of carcass and organs at Shah Alam abattoir. *Pertanika Journal of Tropical Agricultural Science, 4*, 43-46.

The Strait Times. (1959). Wettest town's water rationing (1959, April 2). Pp. 7.

© COPYRIGHT UPM

Thrusfield, M. (2007). Veterinary Epidemiology. Oxford, UK: Blackwell Science. 46-53.

Tolan, R.W. (2011). Fascioliasis due to *Fasciola hepatica* and *Fasciola gigantica* infection: an update on this "neglected" neglected tropical disease. Laboratory Medicine, 42(2), 107-116.

Toolan, D.P., Mitchell, G., Searle, K., Sheehan, M., Skuce, P.J., & Zadoks, R.N. (2015). Bovid and ovine rumen fluke in Ireland-prevalence, risk factors and species identity based on passive veterinary surveillance and abattoir findings. *Veterinary Parasitology, 212*(3–4), 168–74.

Tum, S., Puotinen, M.L., & Copeman, D.B. (2004). A geographic information systems model for mapping risk of fasciolosis in cattle and buffaloes in Cambodia. *Veterinary Parasitology, 122*(2), 141–49.

Ulayi, B.N., Umaru-Sule, B., & Adamu, S. (2007). Prevalence of *Dicrocoelium hospes* and *Fasciola gigantica* infections in cattle at slaughter in Zaria, Nigeria. *Journal of Animal and Veterinary Advances, 6*(9), 1112–1115.

Valero, M.A., Ubeira, F.M., Khoubbane, M., Artigas, P., Muino, L., Mezo, M., Perez-Crespo, I., Periago, M.V., & Mas-Coma, S. (2009). MM3-ELISA Evaluation of coproantigen release and serum antibody production in sheep experimentally infected with *Fasciola hepatica* and *F. gigantica*. *Veterinary Parasitology, 159*(1), 77–81.

Vaumourin, E., Vourc'h, E., Gasqui, P., & Vayssier-Taussat, M. (2015). The importance of multiparasitism: examining the consequences of co-infections for human and animal health. *Parasites and Vectors, 8*(1), 1–13.

Vignoles, P., Rondelaud, D., & Dreyfuss, G. (2017). Determination of zones at risk for fasciolosis in the Department of Haute-Vienne, Central France: a retrospective study on natural infections detected in 108,481 *Galba truncatula* for 37 years. *Parasite*, *24*, 55.

Villa-Mancera, A., & Reynoso-Palomar, A. (2019). High prevalence, potential economic impact, and risk factors of *Fasciola hepatica* in dairy herds in tropical, dry and temperate climate regions in Mexico. *Acta Tropica, 193*, 169–75.

Wang, C. R., Qiu, J. H., Zhu, X. Q., Han, X. H., Ni, H. B., Zhao, J. P., Zhou, Q. M., Zhang, H. W., & Lun, Z. R. (2006). Survey of helminths in adult sheep in Heilongjiang Province, People's Republic of China. *Veterinary parasitology*, *140*(3-4), 378–382. https://doi.org/10.1016/j.vetpar.2006.04.008

Wannasan, A., Khositharattanakool, P., Chaiwong, Piangjai, S., Uparanukraw, P., & Morakote, N. (2014). Identification of *Fasciola* species based on mitochondrial and nuclear DNA reveals the co-existence of intermediate *Fasciola* and *Fasciola gigantica* in Thailand. *Experimental Parasitology, 146*, 64-70.

© COPYRIGHT UPM

Yabe, J., Phiri, I.K., Phiri, A.M., Chembensofu, M., Dorny, P., & Vercruysse, J. (2008). Concurrent infections of *Fasciola*, *Schistosoma* and *Amphistomum* spp. in cattle from Kafue and Zambezi river basins of Zambia. *Journal of Helminthology, 82*(4), 373–76.

Yadav, S.C., Sharma, R.L., Kalicharan, Mehra, U.R., Dass, R.S., & Verma, A.K. (1999). Primary experimental infection of buffaloes with *F. gigantica*. *Veterinary Parasitology, 82*, 285-296.

Yuan, W., Liu, J.M., Lu, K., Duan, M.M., Feng, J.T., Hong, Y., Liu, Y.P., Zhou, Y., Tong, L.B., Zhu, C.G., Jin, Y.M., Cheng, G.F., & Lin, J.J. (2016). Molecular identification and seasonal infections of species of *Fasciola* in ruminants from two provinces in China. *Journal of Helminthology, 90*(3), 359-363.

© COPYRIGHT UPM