PHENOTYPIC, GENOTYPIC AND PROTEOMIC TYPING OF INVASIVE GROUP B *STREPTOCOCCUS* ISOLATED FROM HUMANS AND TILAPIA (*Oreochromis* spp. PISCES) IN MALAYSIA

By

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

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Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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March 2023

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Streptococcus agalactiae, also called Group B *Streptococcus* (GBS), is a major cause of several infectious diseases in humans and fish. However, the likelihood of GBS transmission between different host species leading to a potential zoonotic problem is less well studied. This study aims to determine the phenotype, antimicrobial susceptibility, serotype, virulence and pili gene profiles, sequence type (ST) and proteomic profiles of GBS isolated from humans and cultured fish (tilapia) in Malaysia for comparison between both hosts for understanding its zoonotic and virulence potential. Considering the sporadic pattern of invasive GBS cases, particularly in humans, a total of 227 invasive GBS isolated from humans (n = 113) and tilapia (n = 114) were subjected to phenotyping, serotyping, antimicrobial susceptibility testing and detection of GBS virulence and pilus genes to allow comparison between two origins. Multilocus sequence typing (MLST), phylogenetic analysis and proteomic analysis were also performed for selected GBS isolates. All GBS isolated from humans and fish showed grey to white colonies with β haemolysis on blood agar, pink colonies on CHROMAgar and GBS brilliance agar, a positive CAMP test, a catalase-negative, and a positive GBS latex agglutination test. The most common serotype among human GBS strains was V (23%), followed by Ia (19.5%), II (18.6%), VI (15.9%), III (10.6%), VII (4.4%), Ib and IV, (3.5% each) and IX (0.9%), while all the fish isolates have serotype III (100%). Human isolates had a higher frequency of resistance to erythromycin (15%), azithromycin (13.3%), clindamycin (8.8%), chloramphenicol (2.7%) and ofloxacin (0.9%). However, the tetracycline resistance rate was higher in fish (98.5%) than in human isolates (75.3%). In the evaluation of the virulence and pili gene profiles, there were significant differences between the human and fish isolates in the genes *rib*, *scpB*, *lmb*, *bac*, PI -2a and PI -2b, but there were similarities in the genes *cfb*, *cylE*, *hylB*, *fbsA*, *fbsB*, *spb1*, *bca* and PI -1. Nineteen different sequence types (ST) were found among human isolates, where ST1 was the most predominant; interestingly, three novel sequence types, ST1668, ST1669 and ST1670, were also found. In addition, an unusual finding of the fish-adapted serotype III/ST283 was found in human isolates. On the other

hand, all the randomly selected 15 fish isolates were ST283. In the phylogenetic analysis, there is a genetic linkage between both human and fish isolates sharing a similar lineage of CC283 in clade I. A total of 1405 proteins were identified by LCMS/MS in five human GBS and three fish strains belonging to ST283, ST1668, ST1669 and ST1670. A total of 1162 proteins were identified in the core proteome (with 82.5% similarity), 140 proteins were present in the human isolates, and 107 proteins were identified in the fish isolates. Proteins involved in stress response and gene expression regulation, metabolism, transcription and pathogenicity were also detected, reflecting the adaptability of GBS strains. This study suggests that human and fish GBS have similar phenotypic characteristics but differ in terms of virulence and pili gene profiles, antimicrobial susceptibility, serotype and sequence type. In addition, the proteomes of human and fish GBS isolates were found to be highly similar in this study.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

FENOTIP, GENOTIP DAN JENIS PROTEOMIK TERHADAP KUMPULAN INVASIF *STREPTOCOCCUS* GROUP B YANG DIASINGKAN DARIPADA MANUSIA DAN TILAPIA (*Oreochromis* spp. PISCES) DI MALAYSIA

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Streptococcus agalactiae, juga dikenali sebagai *Streptococcus* Kumpulan B (GBS), adalah merupakan penyebab utama kepada kebanyakkan penyakit berjangkit terhadap manusia dan ikan. Walau bagaimanapun, penghantaran GBS di antara spesies perumah berbeza, yang berkemungkinan telah menyebabkan masalah kepada potensi zoonosis kurang dikaji dengan baik. Tujuan kajian ini adalah untuk menentukan kerentanan antimikrob, serotype, virulens dan profil gen pili, jenis jujukan (ST) dan profil proteomik GBS yang diasingkan daripada manusia dan ikan ternakan (tilapia) di Malaysia bagi tujuan perbandingan di antara kedua-dua pencilan dalam memahami potensi zoonosis dan virulennya. Memandangkan corak kes terhadap GBS invasive yang sporadik, terutamanya pada manusia, sejumlah 227 isolat GBS invasif daripada manusia (n = 113) dan tilapia (n = 114) telah tertakluk kepada fenotaip, serotipe, ujian kerentanan antimikrob dan pengesanan gen GBS virulensi dan pilus bagi tujuan perbandingan di antara kedua-dua asal usul. Penaipan jujukan multilocus (MLST), analisis filogenetik dan analisis proteomik juga telah dilakukan untuk pencilan GBS terpilih. Kesemua GBS yang diasingkan daripada manusia dan ikan telah menunjukkan koloni kelabu hingga putih dengan hemolisis β pada agar darah, koloni merah jambu pada agar CHROMAgar dan agar GBS brilliance, ujian CAMP positif, catalase-negatif, dan ujian aglutinasi lateks GBS positif. Serotaip yang paling biasa di kalangan strain GBS manusia adalah V (23%), diikuti oleh Ia (19.5%), II (18.6%), VI (15.9%), III (10.6%), VII (4.4%), Ib dan IV, (3.5% setiap satu) dan IX (0.9%), manakala kesemua pencilan ikan mempunyai serotype III (100%). Pecilan manusia mempunyai frekuensi rintangan yang lebih tinggi terhadap eritromisin (15%), azitromisin (13.3%), klindamisin (8.8%), kloramfenikol (2.7%) dan ofloksasin (0.9%). Walau bagaimanapun, kadar rintangan tetrasiklin lebih tinggi di kalangan ikan (98.5%) berbanding di kalangan pencilan manusia (75.3%). Dalam penilaian virulensi dan profil gen pili, terdapat perbezaan yang ketara antara pengasingan manusia dan ikan dalam gen rusuk, *scpB*, *lmb*, *bac*, PI -2a dan PI -2b, tetapi terdapat persamaan dalam gen *cfb*, *cylE*, *hylB*, *fbsA*, *fbsB*, *spb1*, *bca* dan PI -1. Sembilan belas jenis jujukan (ST) berbeza ditemui di kalangan pencilan manusia, dimana ST1 adalah yang paling dominan; menariknya, tiga jenis urutan novel, ST1668, ST1669 dan ST1670 telah turut ditemui. Di samping itu, penemuan luar biasa serotype III/ST283 yang disesuaikan dengan ikan telah ditemui dalam pencilan manusia. Sebaliknya, kesemua 15 pencilan ikan yang dipilih secara rawak adalah ST283. Dalam analisis filogenetik, terdapat kaitan genetik antara kedua-dua pencilan manusia dan ikan yang berkongsi garis keturunan CC283 yang serupa dalam klad I. Sebanyak 1405 protein telah dikenal pasti oleh LCMS/MS dalam lima GBS manusia dan tiga strain ikan iaitu ST283, ST1668, ST1669 dan ST1670. Sejumlah 1162 protein telah dikenal pasti dalam proteom teras (dengan 82.5% persamaan), 140 protein terdapat dalam pencilan manusia dan 107 protein telah dikenal pasti dalam pencilan ikan. Protein yang terlibat dalam tindak balas tekanan dan peraturan ekspresi gen, metabolisme, transkripsi dan patogenik turut dikesan, mencerminkan kebolehsuaian strain GBS. Kajian ini mencadangkan bahawa GBS manusia dan ikan mempunyai ciri-ciri fenotip yang serupa tetapi berbeza dari segi profil gen virulens dan gen pili, kerentanan antimikrob, serotype dan jenis jujukan. Di samping itu, proteome GBS pencilan manusia dan ikan di dapati sangat serupa dalam kajian ini.

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- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

AMP	Ampicillin
AMR	Antimicrobial Resistance
AST	Antibiotic Susceptibility Test
ATCC	American Type Culture Collection
ATCC	American Type Culture Collection
AZM	Azithromycin
βH/C	β-hemolysin/Cytolysin
bac	Gene Encoding β-subunit of C Protein
bca	Gene Encoding α-subunit of C Protein
BGG	bovine Gamma Globulin
BHI	Brain Heart Infusion
BLAST	Basic Local Alignment Search Tool
BSA	Bovine Serum Albumin
C	Chloramphenicol
CAMP	Christie–Atkins–Munch-Petersen
CC	Clonal Complexes
CDC	Centers for Control Disease
cfb	Gene Encoding CAMP Factor
CFU	Colony-forming Unit
CLSI	Clinical and Laboratory Standards Institutes
CPS	capsular polysaccharide
CRO	Ceftriaxone
CSF	Cerebrospinal Fluid
CspA	Cell Surface-associated Protein

CTX	Cefotaxime
cylE	Gene encoding β-hemolysin/cytolysin toxin
DA	Clindamycin
DNA	Deoxyribonucleic Acid
DTT	Dithiothreitol
E	Erythromycin
EOD	Early Onset Disease
fbsA	Fibrinogen-binding Proteins A
fbsB	Fibrinogen-binding Proteins B
FDR	False Discovery Rate
FEP	Cefepime
GBS	Group B *streptococcus*
HM	Hospital Melaka
HS	Hospital Serdang
HSA	Hospital Sultanah Aminah
HSB	Hospital Sungai Buloh
HTJ	Hospital Tuanku Ja'afar
hylB	Hyaluronidase
IAP	Intrapartum Antibiotic Prophylaxis
IMR	IMR Institute for Medical Research
LC MS/MS	Liquid Chromatography–Mass Spectrometry
Lmb	laminin-binding Protein
LOD	Late Onset Disease
LZD	Linezolid
MDR	Multidrug-Resistant
MIC	Minimal Inhibitory Concentrations

MLST	Multilocus Sequence Typing
MS	Mass spectrometry
NC	Negative Control
NT	Non-typeable
OFX	Ofloxacin
P	Penicillin
PBS	Phosphate-buffered saline
PC	Positive Control
PFGE	Pulsed-Field Gel Electrophoresis
rib	Gene encoding Rib Protein
RNA	Ribonucleic Acid
S	Susceptible
SBA	Sheep Blood Agar
scpB	Gene encoding C5a Peptidase
SDS-PAGE	Sodium Dodecyl Sulphate–Polyacrylamide Gel Electrophoresis
ST	Sequence Type
TE	Tetracycline
TG-SDS	Tris-Glycine-Sodium Dodecyl Sulfate
TPP	Trans-Proteomic Pipeline
UKMMC	Universiti Kebangsaan Malaysia Medical Centre
UPM	Universiti Putra Malaysia
V	Vancomycin
WHO	World Health Organization

CHAPTER 1

INTRODUCTION

1.1 Background of the Study

Streptococcus agalactiae (also known as Group B *Streptococcus* or GBS) belongs to group B of the Rebecca Lancefield classification of β-haemolytic streptococci. GBS is an opportunistic commensal Gram-positive diplococci bacterium that occurs in 17-30% of healthy human adults without symptomatic disease worldwide (Shabayek & Spellerberg, 2018). Nonetheless, during pregnancy, GBS colonization in the genitourinary tract can be clinically significant as it is associated with certain illnesses such as urinary tract infection, chorioamnionitis, endometritis in the mother, and meningitis and septicemia in the neonate when it is transmitted vertically from the mother during labour. Moreover, GBS can induce labour and lead to premature delivery and miscarriage (Watkins et al., 2019). GBS contributes significantly to perinatal mortality, including stillbirths, with an estimated 147,000 fatal cases (0.41 cases per 1000 live births) annually worldwide and 127,000 fatal cases (0.32 cases per 1000 live births) in Asia (Madrid et al., 2017; Hasperhoven et al., 2020). An investigation in a teaching hospital in Malaysia reported that GBS vaginal rate was 9.7% among the pregnant women (Eskandarian et al., 2013). Recently, the incidence of invasive GBS infection has increased among immunocompromised individuals and those with underlying medical conditions such as diabetes, heart disease, malignancies, and ageing. GBS infections may result from hospital-acquired infection or, more likely, from preexisting colonization of the skin or mucous membrane, which causes numerous and varied clinical manifestations, including tissue and skin infections, septicemia, meningitis and others (Barshak, 2019).

Furthermore, GBS is an important pathogenic bacterium causing infections in cultured fishes worldwide, including economically important cultured fishes such as tilapia (*Oreochromis* species), channel catfish (*Ictalurus punctatus*) and rainbow trout (*Oncorhynchus mykiss*) (Zamri-Saad et al., 2014). The disease is commonly affecting various tilapia-producing countries in Southeast Asia, including Malaysia, Indonesia, Vietnam and Thailand, where the mortality can be as high as 70% that leading to significant economic losses (approximately 250 million USD annually) and posing a threat to the aquaculture industry's development in this region (Anshary et al., 2014; Kayansamruaj et al., 2019; Syuhada et al., 2020). Streptococcosis manifests in clinical manifestations in fish such as exophthalmia, erratic swimming, pale gills, the opaque cornea, external hemorrhages, enlarged spleens, ascites of the abdominal cavity, and yellowed liver (Syuhada et al., 2020).

To elucidate the GBS population structure in relation to disease outbreaks in humans and fish, several phenotypic and genotypic techniques have been developed (Shabayek & Spellerberg, 2018). GBS virulence is determined by the capsular polysaccharide (CPS), which promotes adherence to epithelial surfaces of the host and play role in the escape from host defenses that determined by *cps* gene type. GBS can be subtyped into 10 different capsular serotypes, including Ia, Ib, and II to IX, and each serotype possesses a significant virulent capability (Imperi et al., 2010). Serotypes Ia, II, III and V have been characterized as the major strains associated with invasive disease in pregnant women, neonates and non-pregnant adults, while serotypes Ia, Ib and III are commonly associated with fish infection (Eskandarian et al., 2015; Suhaimi et al., 2017; Shabayek & Spellerberg, 2018; Syuhada et al., 2020) However, the distribution and predominance of certain serotypes varies over time and differ with a geographical area (Imperi et al., 2010). As a result of information about capsular serotypes, disease and vaccine-related surveillance can be conducted in human and fish isolates (Imperi et al., 2010).

Additionally, GBS, provided with a comprehensive virulence gene profiles, are determined by genotypic characterization based on virulence regiment, including capsular polysaccharides, surface proteins, toxins and pili that are found in human and fish isolates, which can play a role in immune evasion, adhesion and invade the host cells (Shabayek & Spellerberg, 2018; Bobadilla et al., 2021). The major GBS adhesins that facilitate adherence and contact between the bacterial cell and the host cells include the fibrinogen-binding proteins (Fbs), the laminin-binding protein (Lmb), the group B streptococcal C5a peptidase (ScpB) and pili, while β-hemolysin/cytolysin (βH/C), hyaluronidase (HylB), Rib protein (Rib), (α and β-subunit of C protein) and Christie–Atkins–Munch-Petersen (CAMP) plays a role in invasion the host cells, evasion from the immune system and transmission to invasive infections (Shabayek & Spellerberg, 2018). A variation of genetic profiles has been observed between human and fish GBS (Springman et al., 2009; Chen, 2019).

Multilocus sequence typing (MLST) is a genotypic method that provides GBS strains' genetic characterization of both the sequence type (ST) and the clonal complex (CC) based on a nucleotide sequence of seven housekeeping genes (Jones et al., 2003). MLST data revealed that certain GBS strains of certain clonal complexes are more likely to cause invasive disease, whereas others harbour primarily colonizing strains (Kayansamruaj et al., 2019). MLST revealed to GBS consists of at least 2,105 sequence types (ST) worldwide (Jones et al., 2003; Jolley et al., 2018). Most human GBS strains cluster into four clonal complexes (CCs), including CC1, CC17, CC19, and CC23, which are recognized as human-adapted lineages, while fish GBS strains cluster into CC7 and CC283 (Ezhumalai et al., 2020; Syuhada et al., 2020).

In 2015, a rare outbreak of invasive disease due to the GBS serotype III, ST283, occurred in Singapore due to consuming contaminated raw fish salad (yusheng) typically made from two freshwater fish species. The outbreak has infected 238 people and caused septic arthritis, meningitis, and septicemia among a very different group of non-pregnant adults. This was the first documented case of invasive GBS associated with foodborne transmission (Chau et al., 2017).

Penicillin or ampicillin is the first line of antibiotics recommended to treat GBS infection by international and local guidelines, where GBS isolates remain susceptible primarily to penicillin and ampicillin, as observed in some studies in the local setting (Eskandarian et al., 2015; Suhaimi et al., 2017; Chen, 2019). Erythromycin or clindamycin are the alternatives if the patient is allergic to penicillin. Consequently, the increasing use of these drugs, consumed by around 20% of all GBS carriers, resulted in elevated clindamycin and erythromycin resistance rates. In addition, GBS is sensitive to cephalosporins, rifampin, vancomycin and resistant to tetracycline (Eskandarian et al., 2015; Suhaimi et al., 2017). In Malaysia, according to the Institute for Medical Research (IMR), the resistance of GBS isolates to erythromycin was 6.8% and clindamycin resistance (7.2%) is the same as in 2016 compared to 2015. The resistance to tetracycline has markedly increased to 70%, and the penicillin resistance rate was 0.2% among GBS isolates (Ministry of Health Malaysia, 2019). Among fish GBS isolates, the resistance rate to erythromycin, clindamycin, and azithromycin was less than in human isolates, while the resistance of tetracycline was around 85% (Nhung, et al., 2016).

Proteomics provides a systems perspective, viewing the protein synthesis, abundance, structure and post-translational modifications, as well as physical or functional interaction partners, to map the proteome all at once (Nesvizhskii, 2014). Proteomics is used for prevention, diagnosis and treatment of disease and precision medicine, creating treatment groups based on GBS proteomics profile or even designing drugs to act on a specific biomarker (Nesvizhskii, 2014).

Zoonoses comprise a large percentage of all newly identified infectious diseases as well as existing infectious diseases. Cross-sectoral collaboration is key to understanding and managing public health risks at the human-animal-environment interface and improving global health security (World Health Organization, 2019). The Malaysian Ministry of Health cooperates with WHO in fostering cross-sectoral collaboration at the human-animal-environment interface among the different relevant sectors at international, regional, and national levels and in developing capacity and promoting practical, evidence-based, and cost-effective tools and mechanisms for zoonoses prevention, surveillance and detection, reporting, epidemiological and laboratory investigation, risk assessment, and control, and assisting countries in their implementation to prevent and reduce risks and manage outbreaks (Ministry of Health Malaysia, 2016).

1.2 Problem Statement

GBS has recently been associated with invasive infections in humans and fish (Cho et al., 2019; Chen et al., 2019). Globally, GBS infections are a growing problem in older adults, pregnant women and those with chronic medical conditions, particularly immunocompromised patients such as diabetes mellitus (Shabayek & Spellerberg, 2018). In Malaysia, literary research on GBS infection in humans has identified a low number of articles since the 1980s (Eskandarian et al., 2015; Suhaimi et al., 2017). Available studies described GBS infection and associated risk factors only at a specific location and point in time (Eskandarian et al., 2013; Khalid et al., 2018). This may not represent the real incidence of GBS infection in Malaysia, where actual cases could not have been reported. Moreover, the GBS infection rate increased among farmed fish, including tilapia species, globally and in Southeast Asian countries, including Malaysia, causing significant economic losses to the aquaculture industry (Amal & Zamri-Saad, 2011; Syuhada et al., 2020).

GSB has long been associated with transmission from mother to baby (human to human) rather than fish to human (or vice versa), although fish may be the reservoir for GBS as well, where GBS strains that cause disease in humans are usually biochemically, phenotypically, genetically or serologically different than those causing disease in animals (Botelho et al., 2018). However, the Singaporean GBS fish-borne outbreak has sparked its zoonotic potential. The Singapore GBS outbreak was associated with sequence type (ST) 283 and contaminated raw fish salad consumption. This outbreak was unique because it affected non-pregnant and younger adults with fewer co-morbidities, suggesting more prominent virulence (Chau et al., 2017). Another study of genome analysis involving GBS isolates collected from six Southeast Asian countries hypothesized that the ST283 human infections could be possibly acquired from fish (Barkham et al., 2019). This is considering that GBS ST283 and its variants were primarily found in invasive GBS infection in fish. GBS ST283 has been rarely reported in human infection but is commonly found in diseased fish. This creates a new perspective on GBS potential as a newly emerging zoonotic threat rather than being confined to humans only (Chau et al., 2017).

GBS has been studied in multiple contexts, including human health, veterinary medicine, and agriculture, to determine the antimicrobial susceptibility pattern, serotypes, virulence genes and genotypes in Malaysia. However, GBS transmission from fish to humans is unknown. Beyond the proximal questions of how GBS colonizes and causes specific diseases in specific hosts, GBS is an intriguing case study for the larger questions of how a broad host range at the species level is maintained despite evidence of variation at the subspecies level. These larger evolutionary questions are again made more urgent by convincing evidence of ongoing adaptation and emergence of pathogenicity and resistance in GBS. A study suggested that genetic linkage is not a prerequisite for GBS to cross the host-specific barrier (Pereira et al., 2010). However, due to limited studies on GBS, wide surveillance is needed to understand the genetic linkage and the crossing of the host-specific barrier of GBS from different origins.

Current studies realized that the genome alone was not always enough to give useful information as genes can be translated into a myriad of proteins depending on the environment the organism experiences, among other factors (Tavares et al., 2018; Tavares et al., 2019; Abril et al., 2020;). Proteomic studies make it possible to identify and quantify sets of proteins that are expressed by microorganisms under specific culture conditions (Zhang et al., 2014). Proteomics can be used to compare the qualitative and quantitative proteome across strains, allowing interpretation of bacterial physiology and promoting knowledge of the genetic variation of each isolate (Tavares et al., 2019). Previous studies have been conducted on the expression of proteins using GBS strains, with a particular emphasis on the analysis of surface proteins (Hughes et al., 2002; Doro et al., 2009; Liu et al., 2013; Li et al., 2016), secretory proteins (Papasergi et al., 2013; Li et al., 2016) and the comparative proteome (Li et al., 2014). There is still a lack of studies that compare the whole proteomic properties of GBS involving different origins, particular in human and fish settings. Thus, a proteomic study of GBS strains that infect humans and fish would permit the analysis of protein variability within the strains belonging to the genotypes among humans and fish, increase scientific knowledge about the adaptation and pathogenesis of the GBS infections in humans and fish, and insight on the potential interspecies transmission between human and fish hosts. Additionally, this approach could identify antigenic proteins that can be used as targets for vaccine development.

In view of the increasing incidence of treatment failure for GBS infection by antimicrobial therapy due to its concurrent emerging resistance, an understanding of the phenotypes and genotypes of GBS from human and fish settings is warranted. Furthermore, antimicrobial resistance leads to increased morbidity and mortality since resistance increases the risk of inappropriate therapy (Andersson et al., 2016). The risk is that the patients who do not receive appropriate therapy will have a longer period of disease or fatal effect; therefore, morbidity and transmission of the microorganism will increase due to the patients remaining infectious for an extended period (CDC, 2019). Also, the increasing trend of antimicrobial resistance is a serious challenge in countries at all economic levels (Ventola, 2015).

The findings of this study will improve health protection in Malaysia through productive partnerships for the preparedness, planning, prevention, prompt detection, characterization, and the containment and control of emerging diseases and to provide risk assessment data to support outbreak control and prevention measures. Comparative proteomics of GBS for understanding its zoonotic and virulent potential can expand knowledge on the genetic for future manipulation. Data will serve as reference for comparative analysis with other studies worldwide on the genetic properties and population. The shared knowledge will be useful for prospective risk, diagnostic and prevention strategy.

1.3 Research Objectives

1.3.1 General Objective

This study aims to compare the phenotype, antimicrobial susceptibility patterns, serotype, virulence and pili gene profiles, sequence type (ST) and proteomic of GBS isolated from humans and tilapia fish in Malaysia.

1.3.2 Specific Objectives

a. To determine the antimicrobial susceptibility patterns of human and fish GBS isolates.

b. To determine the serotypes distribution of human and fish GBS isolates.

c. To determine the distribution of the virulence genes (*cfb, cylE, lmb, scpB, hylB, rib, fbsA, fbsB, spb1, bca* and *bac*) and pili genes (PI-1, PI-2a and PI-2b) of human and fish GBS isolates.

d. To determine the sequence type (ST) and clonal complex (CC) of selected human and fish GBS isolates using the MLST technique.

e. To describe and compare the proteomic profiles of selected representative human and fish GBS isolates using the LCMS/MS technique.

1.4 Research Hypothesis

There are variations with respect to phenotype, antimicrobial susceptibility pattern, serotype distribution, virulence and pili genes distribution, genotypes and proteomic profiling between GBS isolated from humans and tilapia fish in Malaysia.

REFERENCES

Abdallah, N. G., Ali, F. M., Adel, L. A., Elkotb, A. M., & Ibrahim, W. A. (2021). Prevalence, resistance profile and virulence genes of *Streptococcus agalactiae* colonizing near-term pregnant women attending ain shams university hospital. *Journal of Pure and Applied Microbiology*, *15*(3), 1490–1500.

Abril, A. G., Carrera, M., Böhme, K., Barros-Velázquez, J., Cañas, B., Rama, J. L., ... & Calo-Mata, P. (2020). Characterization of bacteriophage peptides of pathogenic *Streptococcus* by LC-ESI-MS/MS: bacteriophage phylogenomics and their relationship to their host. *Frontiers in Microbiology*, *11*, 1-15.

Abril, A. G., Carrera, M., Böhme, K., Barros-Velázquez, J., Rama, J.-L. R., Calo-Mata, P., … Villa, T. G. (2020). Proteomic characterization of antibiotic resistance, and production of antimicrobial and virulence factors in streptococcus species associated with bovine mastitis. Could enzybiotics represent novel therapeutic agents against these pathogens? *Antibiotics*, *9*(6), 1–24.

Absalon, J., Simon, R., Radley, D., Giardina, P. C., Koury, K., Jansen, K. U., & Anderson, A. S. (2022). Advances towards licensure of a maternal vaccine for the prevention of invasive group B streptococcus disease in infants: a discussion of different approaches. *Human Vaccines and Immunotherapeutics*, *18*(1), 1–13.

Adhisivam, B. (2022). Maternal colonization of group B streptococcus and neonatal sepsis. *Indian Journal of Pediatrics*, *89*(1), 5–6.

Adile, M., Gergova, R., & Mitov, I. (2020). Virulence profile of Bulgarian clinical isolates *Streptococcus agalactiae*-PCR determination. *Journal of IMAB–Annual Proceeding Scientific Papers*, *26*(2), 3203–3207.

Akkaneesermsaeng, W., Petpichetchian, C., Yingkachorn, M., & Sasithorn, S. (2019). Prevalence and risk factors of group B streptococcus colonisation in intrapartum women: a cross-sectional study. *Journal of Obstetrics and Gynaecology*, *39*(8), 1093–1097.

Al Safadi, R., Amor, S., Hery-Arnaud, G., Spellerberg, B., Lanotte, P., Mereghetti, L., … Rosenau, A. (2010). Enhanced expression of *lmb* gene encoding laminin-binding protein in *Streptococcus agalactiae* strains harboring IS1548 in *scpB-lmb* intergenic region. *PLoS ONE*, *5*(5), 1–10.

Alhhazmi, A. (2018). *Molecular characterization of Streptococcus agalactiae isolates from human cases of invasive disease collected in Alberta, Canada: 2003-2013*. University of Alberta.

Alhhazmi, A., Hurteau, D., & Tyrrell, G. J. (2017). Epidemiology of invasive group B streptococcal disease in Alberta, Canada, from 2003 to 2013. *Journal of Clinical Microbiology*, *55*(1), 342–343.

Al-Saeedi, M., & Al-Hajoj, S. (2017). Diversity and evolution of drug resistance mechanisms in *Mycobacterium tuberculosis*. *Infection and Drug Resistance*, *10*, 333–342.

Alvim, D. C. S. S., Ferreira, A. F. M., Leal, M. A., Oliveira, L. M. A., Botelho, A. M. N., Botelho, A. C. N., … Pinto, T. C. A. (2019). Biofilm production and distribution of pilus variants among *Streptococcus agalactiae* isolated from human and animal sources. *Biofouling*, *35*(8), 938–944.

Amal, M. N. A., & Zamri-Saad, M. (2011). Streptococcosis in Tilapia (*Oreochromis niloticus*): A Review. *Journal of Tropical Agricultural Science Journal*, *34*(21), 195–281.

Amal, M. N. A., & Zulkafli, A. R. (2013). Molecular characterization of *Streptococcus agalactiae* strains isolated from fishes in Malaysia. *Journal of Applied Microbiology*, *115*(1), 20–29.

Amal, M. N. A., Zamri-Saad, M., Zulkafli, A. R., Siti-Zahrah, A., Misri, S., Ramley, B., … Sabri, M. Y. (2010). Water thermocline confirms susceptibility of tilapia cultured in lakes to *Streptococcus agalactiae*. *Journal of Animal and Veterinary Advances*, *9*(22), 2811–2817.

Amaral, E., Ratner, A. J., Kulkarni, R., Randis, T. M., Antala, S., & Wang, A. (2013). Β-Hemolysin / Cytolysin of group B streptococcus enhances host inflammation but is dispensable for establishment of urinary tract infection. *PloS One*, *8*(3), 8–12.

American College of Obstetricians and Gynecologists, A. (2020). Prevention of group B Streptococcal early-onset disease in newborns: ACOG committee opinion, number 797. *Obstetrics and Gynecology*, *135*(2), e51–e72.

Amir, S. H., Yuswan, M. H., Aizat, W. M., Mansor, M. K., Desa, M. N. M., Yusof, Y. A., … Mustafa, S. (2021). Comparative database search engine analysis on massive tandem mass spectra of pork-based food products for halal proteomics. *Journal of Proteomics*, *241*(2020), 104-240.

Andersson, D. I., Hughes, D., & Kubicek-Sutherland, J. Z. (2016). Mechanisms and consequences of bacterial resistance to antimicrobial peptides. *Drug Resistance Updates*, *26*, 43–57.

Anshary, H., Kurniawan, R. A., Sriwulan, S., Ramli, R., & Baxa, D. V. (2014). Isolation and molecular identification of the etiological agents of streptococcosis in Nile tilapia (*Oreochromis niloticus*) cultured in net cages in Lake Sentani, Papua, Indonesia. *SpringerPlus*, *3*(1), 1–11.

Arias, B., Kovacec, V., Vigliarolo, L., Suárez, M., Tersigni, C., Lopardo, H., … Bonofiglio, L. (2022). Epidemiology of invasive infections caused by *Streptococcus agalactiae* in Argentina. *Microbial Drug Resistance*, *28*(3), 322–329.

Arnold, B. J., Huang, I., & Hanage, W. P. (2022). Horizontal gene transfer and adaptive evolution in bacteria. *Nature Reviews Microbiology*, *20*(4), 206–218.

Arzanlou, M., Jannati, E., Roshani, M., Habibzadeh, S., Rahimi, G., & Shapuri, R. (2012). Capsular serotype and antibiotic resistance of group B streptococci isolated from pregnant women in Ardabil, Iran. *Iranian Journal of Microbiology*, *4*(3), 130–135.

Azmai, M. N. A., Zamri-saad, M., Siti-Zahrah, A., Zulkafli, R., Misri, S., Nur-Nazifah, M., & Shahidan, H. (2010). Prevalence of *Streptococcus agalactiae* in tilapia kept in different water bodies. *Online Journal of Veterinary Research*, *11*(2), 153–162.

Back, E. E., O'Grady, E. J., & Back, J. D. (2012). High rates of perinatal group B streptococcus clindamycin and erythromycin resistance in an Upstate New York Hospital. *Antimicrobial Agents and Chemotherapy*, *56*(2), 739–742.

Bahez, A. (2019). *Serotyping of group B streptococcus (GBS) isolated from symtomatic pregnant women in Hospital Tengku Ampuan Afzan (HTAA) and the detection of associated virulence-genes rib and bca* (Master's thesis, International Islamic University Malaysia, Malaysia).

Bahez, A., Mahmud, M. I. A.-D. M., Hamzah, H. A., & Wahid, H. H. (2021). Virulence-genes *rib* and *bca* in serotypes of group B streptococcus (GBS) isolated from symptomatic pregnant women in east coast Malaysia. *IIUM Medical Journal Malaysia*, *20*(3), 118–126.

Balasubramanian, S., Kannan, T. R., & Baseman, J. B. (2008). The surface-exposed carboxyl region of Mycoplasma pneumoniae elongation factor Tu interacts with fibronectin. *Infection and Immunity*, *76*(7), 3116–3123.

Ballard, M. B., Mercado-Evans, V., Marunde, M. G., Nwanosike, H., Zulk, J., & Patras, K. A. (2021). Group B streptococcus CAMP factor does not contribute to interactions with the vaginal epithelium and is dispensable for vaginal colonization in mice. *Microbiology Spectrum*, *9*(3),1–10.

Barkham, T. I. D., Zadoks, R. N., Azmai, M. N. A., Baker, S., Bich, V. T. N., Chalker, V., … Chen, S. L. I. D. (2019). One hypervirulent clone, sequence type 283, accounts for a large proportion of invasive *Streptococcus agalactiae* isolated from humans and diseased tilapia in Southeast Asia. *PLOS Neglected Tropical Diseases*, *13*(6), 1–20.

Barkham, T., Dance, D. A. B., Vongsouvath, M., Newton, P., & Chen, S. (2018). *Streptococcus agalactiae* ST283 has been present in Laos for over 18 years. *International Journal of Infectious Diseases*, *73*(2018), 189–190.

Baron, M. J., Bolduc, G. R., Goldberg, M. B., Aupérin, T. C., & Madoff, L. C. (2004). Alpha C protein of group B streptococcus binds host cell surface glycosaminoglycan and enters cells by an actin-dependent mechanism. *Journal of Biological Chemistry*, *279*(23), 24714–24723.

Barro, C., Salloum, M., Lim, S., Delputte, P., & Doare, K. Le. (2021). Simultaneous carriage of multiple serotypes of group B streptococcus : a systematic review. *Vaccine*, *11*(2), 1–2.

Barshak, M. B. (2019). Group B streptococcus , an a-list pathogen in nonpregnant adults. *JAMA Internal Medicine*, *179*(4), 488–489.

Bergmann, S., Fulde, M., & Siemens, N. (2022). Editorial: Streptococci in infectious diseases – pathogenic mechanisms and host immune responses. *Frontiers in Microbiology*, *13*(1), 1–3.

Bergseng, H., Bevanger, L., Rygg, M., & Bergh, K. (2007). Real-time PCR targeting the sip gene for detection of group B streptococcus colonization in pregnant women at delivery Printed in Great Britain. *Journal of Medical Microbiology*, *56*(2), 223–228.

Blancas, D., Santin, M., Olmo, M., Alcaide, F., Carratala, J., & Gudiol, F. (2004). Group B streptococcal disease in nonpregnant adults: incidence, clinical characteristics, and outcome. *European Journal of Clinical Microbiology and Infectious Diseases*, *23*(3), 168–173.

Bobadilla, F. J., Novosak, M. G., Cortese, I. J., Delgado, O. D., & Laczeski, M. E. (2021). Prevalence , serotypes and virulence genes of *Streptococcus agalactiae* isolated from pregnant women with 35 – 37 weeks of gestation. *BMC Infectious Diseases*, *21*(1), 1–11.

Boonsilp, S., Nealiga, M. J., Wangchuk, K., Homkaew, A., Wongsuk, T., Thuncharoon, H., … Dubbs, P. (2022). Differential interaction between invasive Thai group B streptococcus sequence type 283 and caco-2 cells. *Microorganisms*, *10*(10), 1–16.

Boonyayatra, S., Wongsathein, D., & Tharavichitkul, P. (2020). Genetic relatedness among *Streptococcus agalactiae* isolated from cattle, fish, and humans. *Foodborne Pathogens and Disease*, *17*(2), 137–143.

Botelho, A. C., Ferreira, A. F., Fracalanzza, S. EL, Teixeira, L. M., & Pinto, T. C. (2018). A Perspective on the potential zoonotic role of *Streptococcus agalactiae* searching for a missing link in alternative transmission routes. *Frontiers in Microbiology*, *9*, 608.

Bramugy, J., Mucasse, H., Massora, S., Vitorino, P., Aerts, C., Mandomando, I., … Bassat, Q. (2021). Short- and long-term outcomes of group B streptococcus invasive disease in mozambican children: results of a matched cohort and retrospective observational study and implications for future vaccine introduction. *Clinical Infectious Diseases*, *74*(1), 14–23.

Brittan, J. L., & Nobbs, A. H. (2015). Group B streptococcus pili mediate adherence to salivary glycoproteins. *Microbes and Infection*, *17*(5), 360–368.

Brokaw, A., Furuta, A., Dacanay, M., Rajagopal, L., & Adams Waldorf, K. M. (2021). Bacterial and host determinants of Group B Streptococcal vaginal colonization and ascending infection in pregnancy. *Frontiers in Cellular and Infection*

Microbiology, *11*(9), 1–19.

Brown, T. A. (2020). Understanding a Genome Sequence. In *Genomes* (Oxford: Wiley-Liss).

Burcham, L. R., Spencer, B. L., Keeler, L. R., Runft, D. L., Patras, K. A., Neely, M. N., & Doran, K. S. (2019). Determinants of Group B streptococcal virulence potential amongst vaginal clinical isolates from pregnant women. *PLoS ONE*, *14*(12), 1–16.

Buurman, E. T., Timofeyeva, Y., Gu, J., Kim, J. H., Kodali, S., Liu, Y., … Anderson, A. S. (2019). A novel hexavalent capsular polysaccharide conjugate vaccine (GBS6) for the prevention of neonatal group B streptococcal infections by maternal immunization. *Journal of Infectious Diseases*, *220*(1), 105–115.

Bwalya, P., Simukoko, C., Hang'ombe, B. M., Støre, S. C., Støre, P., Gamil, A. A. A., … Mutoloki, S. (2020). Characterization of streptococcus-like bacteria from diseased *Oreochromis niloticus* farmed on Lake Kariba in Zambia. *Aquaculture*, *523*(1), 1–9

Carl, M. A., Ndao, I. M., Springman, A. C., Manning, S. D., Johnson, J. R., Johnston, B. D., … Tarr, P. I. (2014). Sepsis from the gut: The enteric habitat of bacteria that cause late-onset neonatal bloodstream infections. *Clinical Infectious Diseases*, *58*(9), 1211–1218.

Centers for Disease Control and Prevention, C. (2020). Prevention of group B streptococcal early-onset disease in newborns: ACOG committee opinion summary, Number 797. *Obstetrics and Gynecology*, *135*(2), 489–492.

Centers for Disease Control and Prevention. (2019). Antibiotic resistance threats in the United States 2019. In *Atlanta, GA: U.S. Department of Health and Human Services*.

Chand, Y., Alam, M. A., & Singh, S. (2020). Pan-genomic analysis of the species Salmonella enterica: Identification of core essential and putative essential genes. *Gene Reports*, *20*(1), 1–3

Chau, M. L., Chen, S. L., Yap, M., Hartantyo, S. H. P., Chiew, P. K. T., Fernandez, C. J., … Ng, L. C. (2017). Group B streptococcus infections caused by improper sourcing and handling of fish for raw consumption, Singapore, 2015–2016. *Emerging Infectious Diseases*, *23*(12), 2002–2010.

Cheesbrough, M. (2008). District laboratory practice in tropical countries. *Part 2*. Cambridge university press.

Chen, J., Li, B., Huang, B., Yang, G., Mo, F., Weng, T., … Lu, Y. (2020). Immunogenicity and efficacy of two DNA vaccines encoding antigenic PspA and TerD against Nocardia seriolae in hybrid snakehead. *Fish and Shellfish Immunology*, *106*, 742–754.

Chen, M., Wang, R., Luo, F. G., Huang, Y., Liang, W. W., Huang, T., … Li, L. P. (2015).

Streptococcus agalactiae isolates of serotypes Ia, III and V from human and cow are able to infect tilapia. *Veterinary Microbiology*, *180*(1–2), 129–135.

Chen, S. L. (2019). Genomic insights into the distribution and evolution of group B streptococcus. *Frontiers in Microbiology*, *10*, 1–15.

Cho, C. Y., Tang, Y. H., Chen, Y. H., Wang, S. Y., Yang, Y. H., Wang, T. H., … Jeng, M. J. (2019). Group B Streptococcal infection in neonates and colonization in pregnant women: An epidemiological retrospective analysis. *Journal of Microbiology, Immunology and Infection*, *52*(2), 265–272.

Clinical and Laboratory Standards Institute (CLSI). (2020). *Performance standards for antimicrobial susceptibility testing. (30th ed.) CLSI supplement M100.* Wayne.

Cobo-angel, C. G., Jaramillo-jaramillo, A. S., Palacio-aguilera, M., Jurado-vargas, L., Calvo-villegas, E. A., Ospina-loaiza, D. A., … Ceballos-marquez, A. (2019). Potential group B streptococcus interspecies transmission between cattle and people in Colombian dairy farms. *Comparative Immunology, Microbiology and Infectious Diseases*, *1*(8), 1–9.

Collineau, L., Boerlin, P., Carson, C. A., Chapman, B., Fazil, A., Hetman, B., … Smith, B. A. (2019). Integrating whole-genome sequencing data into quantitative risk assessment of foodborne antimicrobial resistance: A review of opportunities and challenges. *Frontiers in Microbiology*, *10*(3), 1–18.

Crespo-Ortiz, M. D. P., Burbano, M. E., & Barreto, M. (2020). Pathogenesis and in vivo interactions of human *Streptococcus agalactiae* isolates in the Galleria mellonella invertebrate model. *Microbial Pathogenesis*, *147*,1–6.

Da Cunha, V., Davies, M. R., Douarre, P. E., Rosinski-Chupin, I., Margarit, I., Spinali, S., … Efstratiou, A. (2014). *Streptococcus agalactiae* clones infecting humans were selected and fixed through the extensive use of tetracycline. *Nature Communications*, *5*, 1–12.

Dangwetngam, M., Suanyuk, N., Kong, F., & Phromkunthong, W. (2016). Serotype distribution and antimicrobial susceptibilities of *Streptococcus agalactiae* isolated from infected cultured tilapia (*Oreochromis niloticus*) in Thailand Nine-year perspective. *Journal of Medical Microbiology*, *65*(3), 247–254.

de Gaetano, G. V., Lentini, G., Galbo, R., Coppolino, F., Famà, A., Teti, G., & Beninati, C. (2021). Invasion and trafficking of hypervirulent group B streptococci in polarized enterocytes. *PLoS ONE*, *16*(6), 1–14.

De Gaetano, G. V., Pietrocola, G., Romeo, L., Galbo, R., Lentini, G., Giardina, M., … Beninati, C. (2018). The *Streptococcus agalactiae* cell wall-anchored protein PbsP mediates adhesion to and invasion of epithelial cells by exploiting the host vitronectin/αvintegrin axis. *Molecular Microbiology*, *110*(1), 82–94.

de Oliveira, T. F., Queiroz, G. A., Teixeira, J. P., Figueiredo, H. C. P., & Leal, C. A. G. (2018). Recurrent Streptoccoccus agalactiae infection in Nile tilapia (*Oreochromis* *niloticus*) treated with florfenicol. *Aquaculture*, *493*, 51–60.

Delannoy, C. M.J., Zadoks, R. N., Crumlish, M., Rodgers, D., Lainson, F. A., Ferguson, H. W., … Fontaine, M. C. (2016). Genomic comparison of virulent and non-virulent *Streptococcus agalactiae* in fish. *Journal of Fish Diseases*, *39*(1), 13–29.

Delannoy, Christian M.J., Crumlish, M., Fontaine, M. C., Pollock, J., Foster, G., Dagleish, M. P., … Zadoks, R. N. (2013). Human *Streptococcus agalactiae* strains in aquatic mammals and fish. *BMC Microbiology*, *13*(1), 1–9.

Deng, Lishuang, Li, Y., Geng, Y., Zheng, L., Rehman, T., Zhao, R., … Lai, W. (2019). Molecular serotyping and antimicrobial susceptibility of *Streptococcus agalactiae* isolated from fish in China. *Aquaculture*, *510*(211), 84–89.

Deng, Liwen, Spencer, B. L., Holmes, J. A., Mu, R., Rego, S., Weston, T. A., … Doran, K. S. (2019). The group B streptococcal surface antigen I/II protein, BspC, interacts with host vimentin to promote adherence to brain endothelium and inflammation during the pathogenesis of meningitis. *PLoS Pathogens*, *15*(6), 1–30.

Department of Statistics Malaysia. (2021). Press release state socioeconomic report 2021. *The office of Chief Statistician. July*.

Dhanoa, A., Karunakaran, R., & Puthucheary, S. D. (2010). Serotype distribution and antibiotic susceptibility of group B streptococci in pregnant women. *Epidemiology and Infection*, *138*(7), 979–981.

Di Palo, B., Rippa, V., Santi, I., Brettoni, C., Muzzi, A., Metruccio, M. M. E., … Soriani, M. (2013). Adaptive response of group B streptococcus to high glucose conditions: New insights on the CovRS regulation network. *PLoS ONE*, *8*(4), 1–11.

Dmitriev, A., Suvorov, A., Shen, A. D., & Yang, Y. H. (2004). Clinical diagnosis of group B streptococci by *scpB* gene based PCR. *Indian Journal of Medical Research, Supplement*, *119*(5), 233–236.

Dobrut, A., & Brzychczy-Włoch, M. (2022). Immunogenic proteins of group B streptococcus—potential antigens in immunodiagnostic assay for GBS detection. *Pathogens*, *11*(1), 1–20.

Dobrut, A., Ochońska, D., Brzozowska, E., Górska, S., Kaszuba-Zwoinska, J., Gołda-Cępa, M., … Brzychczy-Wloch, M. (2022). Molecular characteristic, antibiotic resistance, and detection of highly immunoreactive proteins of group B streptococcus strains isolated from urinary tract infections in Polish adults. *Frontiers in Microbiology*, *13*(3), 1–13.

Dominguez, K., & Randis, T. M. (2022). Toward the development of a protein-based group B streptococcus vaccine. *Cell Reports Medicine*, *3*(2), 100536.

Dong, Y., Ma, K., Cao, Q., Huang, H., Nie, M., Liu, G., … Liu, Y. (2021). CRISPR-dependent endogenous gene regulation is required for virulence in piscine

Streptococcus agalactiae. *Emerging Microbes and Infections*, *10*(1), 2113–2124.

Doran, K. S., Engelson, E. J., Khosravi, A., Maisey, H. C., Fedtke, I., Equils, O., … Nizet, V. (2005). Blood-brain barrier invasion by group B streptococcus depends upon proper cell-surface anchoring of lipoteichoic acid. *Journal of Clinical Investigation*, *115*(9), 2499–2507.

Doro, F., Liberatori, S., Rodríguez-ortega, M. J., Rinaudo, C. D., Rosini, R., Mora, M., … Grandi, G. (2009). Surfome analysis as a fast track to vaccine identification of a novel protective antigen for group B streptococcus hypervirulent. *Molecular & Cellular Proteomics*, *8*(7), 1728–1737.

Duarte, R. S., Bellei, B. C., Miranda, P., Brito, M. A. V. P., & Teixeira, M. (2005). Distribution of antimicrobial resistance and virulence-related genes among Brazilian group B streptococci recovered from bovine and human sources. *Antimicrobial Agents and Chemotherapy*, *49*(1), 97–103.

Durat, G., Çulhacik, G. D., Doğu, Ö., Turan, Z., Atasoy, I., & Toker, E. (2018). The development of an anxiety assessment scale for pregnant women in labor. *Saudi Medical Journal*, *39*(6), 609–614.

Dy, R. L., Przybilski, R., Semeijn, K., Salmond, G. P. C., & Fineran, P. C. (2014). A widespread bacteriophage abortive infection system functions through a type IV toxin-antitoxin mechanism. *Nucleic Acids Research*, *42*(7), 4590–4605.

Edwards MS, B. C. (2015). *Streptococcus agalactiae (Group B streptococcus), in bennett JEDR, blaser MJ (ed), mandell, douglas, and bennett's principles and practice of infectious diseases,* updated edition, 8th ed Saunders, Philadelphia.

Edwards, J. M., Watson, N., Focht, C., Wynn, C., Todd, C. A., Walter, E. B., … Swamy, G. K. (2019). Group B streptococcus (GBS) colonization and disease among pregnant women: A historical cohort study. *Infectious Diseases in Obstetrics and Gynecology*, *2019*(1),1–7.

Edwards, M. S., & Gonik, B. (2013). Preventing the broad spectrum of perinatal morbidity and mortality through group B streptococcal vaccination. *Vaccine*, *31*(4), 66–71.

Enright, M. C., & Brian, G. S. (1999). Multilocus sequence typing. *Trends in Microbiolog*, *7*(12), 482–487.

Eskandarian, N., Ismail, Z., Neela, V. K., Van Belkum, A., Desa, M. N. M., & Nordin, S. A. (2015). Antimicrobial susceptibility profiles, serotype distribution and virulence determinants among invasive, non-invasive and colonizing *Streptococcus agalactiae* (group B streptococcus) from Malaysian patients. *European Journal of Clinical Microbiology & Infectious Diseases*, *34*(3), 579–584.

Eskandarian, N., Neela, V., Ismail, Z., Puzi, S. M., Hamat, R. A., Desa, M. N. M., & Nordin, S. A. (2013). Group B streptococcal bacteremia in a major teaching hospital in Malaysia : a case series of eighteen patients. *International Journal of Infectious Diseases*, *17*(9), 777–780.

Evans, J. J., Bohnsack, J. F., Klesius, P. H., Whiting, A. A., Garcia, J. C., Shoemaker, C. A., & Takahashi, S. (2008). Phylogenetic relationships among *Streptococcus agalactiae* isolated from piscine, dolphin, bovine and human sources: A dolphin and piscine lineage associated with a fish epidemic in Kuwait is also associated with human neonatal infections in Japan. *Journal of Medical Microbiology*, *57*(11), 1369–1376.

Evans, J. J., Klesius, P. H., Pasnik, D. J., & Bohnsack, J. F. (2009). Human *Streptococcus agalactiae* isolate in nile tilapia (*Oreochromis niloticus*). *Emerging Infectious Diseases*, *15*(5), 774–776.

Ezhumalai, M., Muthanna, A., Suhaili, Z., Dzaraly, N. D., Amin-Nordin, S., Amal, M. N. A., & Desa, M. N. M. (2020). Multilocus sequence typing analysis of invasive and non-invasive group B streptococcus of hospital origin in Malaysia. *Malaysian Journal of Medical Sciences*, *27*(1), 134–138.

Faralla, C., Metruccio, M. M., De Chiara, M., Mu, R., Patras, K. A., Muzzi, A., … Janulczyk, R. (2014). Analysis of two-component systems in group B streptococcus shows that RgfAC and the novel FspSR modulate virulence and bacterial fitness. *MBio*, *5*(3), 1–12.

Flores, A. R., Galloway-Peña, J., Sahasrabhojane, P., Saldaña, M., Yao, H., Su, X., … Shelburne, S. A. (2015). Sequence type 1 group B streptococcus, an emerging cause of invasive disease in adults, evolves by small genetic changes. *Proceedings of the National Academy of Sciences*, *112*(20), 6431–6436.

Florindo, C., Damiao, V., Silvestre, I., Farinha, C., Rodrigues, F., Nogueira, F., … Group for the Prevention of Neonatal GBS Infection. (2014). Epidemiological surveillance of colonising group B streptococcus epidemiology in the Lisbon and Tagus Valley regions, Portugal (2005 to 2012): emergence of a new epidemic type IV/clonal complex 17 clone. *European Communicable Disease Bulletin*, *19*(23), 10–13.

Florindo, Carlos, Barroco, C. A., Silvestre, I., Damião, V., Gomes, J. P., Spellerberg, B., … Borrego, M. J. (2018). Capsular type, sequence type and microbial resistance factors impact on DNase activity of *Streptococcus agalactiae* strains from human and bovine origin . *European Journal of Microbiology and Immunology*, *8*(4), 149–154.

Foysal, M. J., Alam, M., Momtaz, F., Chaklader, M. R., Siddik, M. A. B., Cole, A., … Rahman, M. M. (2019). Dietary supplementation of garlic (Allium sativum) modulates gut microbiota and health status of tilapia (*Oreochromis niloticus*) against *Streptococcus iniae* infection. *Aquaculture Research*, *50*(8), 2107–2116.

Francisco, A. P., Vaz, C., Monteiro, P. T., Melo-Cristino, J., Ramirez, M., & Carriço, J. A. (2012). PHYLOViZ: Phylogenetic inference and data visualization for sequence based typing methods. *BMC Bioinformatics*, *13*(1), 1–15.

Francois Watkins, L. K., McGee, L., Schrag, S. J., Beall, B., Jain, J. H., Pondo, T., … Langley, G. E. (2019). Epidemiology of invasive group B streptococcal infections among nonpregnant adults in the United States, 2008-2016. *JAMA Internal Medicine*, *179*(4), 479–488.

Franken, C., Haase, G., Brandt, C., Weber-Heynemann, J., Martin, S., Lämmler, C., … Spellerberg, B. (2001). Horizontal gene transfer and host specificity of beta-haemolytic streptococci: The role of a putative composite transposon containing *scpB* and *lmb*. *Molecular Microbiology*, *41*(4), 925–935.

Franza, T., Rogstam, A., Thiyagarajan, S., Sullivan, M. J., Derré-Bobillot, A., Bauer, M. C., … Gaudu, P. (2021). NAD+ pool depletion as a signal for the Rex regulon involved in *Streptococcus agalactiae* virulence. *PLoS Pathogens*, *17*(8), 1–27.

Fuchs, T. M., Eisenreich, W., Heesemann, J., & Goebel, W. (2012). Metabolic adaptation of human pathogenic and related nonpathogenic bacteria to extra- and intracellular habitats. *FEMS Microbiology Reviews*, *36*(2), 435–462.

Furfaro, L. L., Chang, B. J., & Payne, M. S. (2018). Perinatal *streptococcus agalactiae* epidemiology and surveillance targets. *Clinical Microbiology Reviews*, *31*(4), 1–18.

Galperin, M. Y., Makarova, K. S., Wolf, Y. I., & Koonin, E. V. (2015). Expanded microbial genome coverage and improved protein family annotation in the COG database. *Nucleic Acids Research*, *43*(1), 261–269.

Ge, Y., Pan, F., Bai, R., Mao, Y., Ji, W., Wang, F., & Tong, H. (2021). Prevalence of group B streptococcus colonization in pregnant women in Jiangsu, East China. *BMC Infectious Diseases*, *21*(1), 4–8.

Geng, Y., Wang, K., Huang, X., Chen, D., Li, C., Ren, S., … Lai, W. (2012). *Streptococcus agalactiae*, an emerging pathogen for cultured Ya-Fish, schizothorax prenanti, in China. *Transboundary and Emerging Diseases*, *59*(4), 369–375.

Genovese, C., D'Angeli, F., Di Salvatore, V., Tempera, G., & Nicolosi, D. (2020). *Streptococcus agalactiae* in pregnant women: serotype and antimicrobial susceptibility patterns over five years in Eastern Sicily (Italy). *European Journal of Clinical Microbiology and Infectious Diseases*, *39*(12), 2387–2396.

Gizachew, M., Tiruneh, M., Moges, F., Adefris, M., Tigabu, Z., & Tessema, B. (2020). Molecular characterization of *Streptococcus agalactiae* isolated from pregnant women and newborns at the University of Gondar Comprehensive Specialized Hospital, Northwest Ethiopia. *BMC Infectious Diseases*, *20*(1), 1–9.

Glaser, P., Rusniok, C., Buchrieser, C., Chevalier, F., Frangeul, L., Msadek, T., … Kunst, F. (2002). Genome sequence of *Streptococcus agalactiae*, a pathogen causing invasive neonatal disease. *Molecular Microbiology*, *45*(6), 1499–1513.

Glatter, T., Ludwig, C., Ahrné, E., Aebersold, R., Heck, A. J. R., & Schmidt, A. (2012).

Large-scale quantitative assessment of different in-solution protein digestion protocols reveals superior cleavage efficiency of tandem Lys-C/trypsin proteolysis over trypsin digestion. *Journal of Proteome Research*, *11*(11), 5145–5156.

Godoy, D. T., Carvalho-Castro, G. A., Leal, C. A. G., Pereira, U. P., Leite, R. C., & Figueiredo, H. C. P. (2013). Genetic diversity and new genotyping scheme for fish pathogenic *Streptococcus agalactiae*. *Letters in Applied Microbiology*, *57*(6), 476–483.

Granato, D., Bergonzelli, G. E., Pridmore, R. D., Marvin, L., Rouvet, M., & Corthésy-Theulaz, I. E. (2004). Cell surface-associated elongation factor Tu mediates the attachment of lactobacillus johnsonii NCC533 (La1) to human intestinal cells and mucins. *Infection and Immunity*, *72*(4), 2160–2169.

Graux, E., Hites, M., Martiny, D., Maillart, E., Delforge, M., Melin, P., & Dauby, N. (2021). Invasive group B streptococcus among non-pregnant adults in Brussels-Capital Region, 2005–2019. *European Journal of Clinical Microbiology and Infectious Diseases*, *40*(3), 515–523.

Gründling, A. (2013). Potassium uptake systems in *Staphylococcus aureus*: new stories about ancient systems. *MBio*, *4*(4), 1–3.

Guo, D., Xi, Y., Wang, S., & Wang, Z. (2019). Is a positive Christie-Atkinson-Munch-Peterson (CAMP) test sensitive enough for the identification of *Streptococcus agalactiae*? *BMC Infectious Diseases*, *19*(1), 3–7.

Guo, H., Fu, M., Peng, Q., Chen, Z., Liu, J., Qiu, Y., & Huang, Y. (2019). Antimicrobial resistance and molecular characterization of *Streptococcus agalactiae* from pregnant women in southern China. *Journal of Infection in Developing Countries*, *13*(9), 802–809.

Haeusler, I. L., Daniel, O., Isitt, C., Watts, R., Cantrell, L., Feng, S., … Le Doare, K. (2022). Group B streptococcus (GBS) colonization is dynamic over time, whilst GBS capsular polysaccharides-specific antibody remains stable . *Clinical and Experimental Immunology*, *209*(2), 188–200.

Hanh, T. Q., Van Du, V., Hien, P. T., Chinh, D. D., Loi, C. B., Dung, N. M., … Anh, T. T. K. (2020). Prevalence and capsular type distribution of group B streptococcus isolated from vagina of pregnant women in Nghe an Province, Vietnam. *Iranian Journal of Microbiology*, *12*(1), 11–17.

Hannoun, A., Shehab, M., Khairallah, M. T., Sabra, A., Abi-Rached, R., Bazi, T., … Matar, G. M. (2009). Correlation between group B streptococcal genotypes, their antimicrobial resistance profiles, and virulence genes among pregnant women in Lebanon. *International Journal of Microbiology*, *2009*(1), 1–6.

Harnisz, M., Korzeniewska, E., & Gołaś, I. (2015). The impact of a freshwater fish farm on the community of tetracycline-resistant bacteria and the structure of tetracycline resistance genes in river water. *Chemosphere*, *128*, 134–141.

Hasperhoven, G. F., Al-Nasiry, S., Bekker, V., Villamor, E., & Kramer, B. W. W. (2020). Universal screening versus risk-based protocols for antibiotic prophylaxis during childbirth to prevent early-onset group B streptococcal disease: a systematic review and meta-analysis. *BJOG: An International Journal of Obstetrics & Gynaecology*, *127*(6), 680–691.

Hayes, K., O'Halloran, F., & Cotter, L. (2020). A review of antibiotic resistance in group B streptococcus: the story so far. *Critical Reviews in Microbiology*, *46*(3), 253–269.

Heberle, H., Meirelles, G. V., Silva, F. R., Telles, G. P., & Minghim, R. (2015). InteractiVenn : a web-based tool for the analysis of sets through Venn diagrams. *BMC Bioinformatics*, *16*(1), 1–7.

Hendriksen, R. S., Mevius, D. J., Schroeter, A., Teale, C., Jouy, E., Butaye, P., … Aarestrup, F. M. (2008). Occurrence of antimicrobial resistance among bacterial pathogens and indicator bacteria in pigs in different European countries from year 2002 - 2004: The ARBAO-II study. *Acta Veterinaria Scandinavica*, *50*(1), 1–10.

Hernandez, L., Cadona, J., Traverso, F., Altamiranda, S., Bustamante, A., & Sanso, A. (2022). Virulence profiles and antimicrobial resistance of *Streptococcus agalactiae* infective and colonizing strains from Argentina. *Current Microbiology*, *79*(12), 1–10.

Herold, R., Schroten, H., & Schwerk, C. (2019). Virulence factors of meningitis-causing bacteria: Enabling brain entry across the blood–brain barrier. *International Journal of Molecular Sciences*, *20*(21), 1–28.

Hillier, S. L., Ferrieri, P., Edwards, M. S., Ewell, M., Ferris, D., Fine, P., … Baker, C. J. (2019). A phase 2, randomized, control trial of group B streptococcus (GBS) type III capsular polysaccharide-tetanus toxoid (GBS III-TT) vaccine to prevent vaginal colonization with GBS III. *Clinical Infectious Diseases*, *68*(12), 2079–2086.

Hirai, N., Kasahara, K., Nakano, R., Ogawa, Y., Suzuki, Y., Ogawa, M., … Yoshikawa, M. (2020). Clinical characteristics and molecular epidemiology of invasive *Streptococcus agalactiae* infections between 2007 and 2016 in Nara, Japan. *PLoS ONE*, *15*(10), 1–14.

Hiriote, W., Tor-Udom, S., & Tor-Udom, P. (2017). Maternal to child group B streptococcus transmission rate at Thammasat University hospital, Thailand. *Southeast Asian Journal of Tropical Medicine and Public Health*, *48*(4), 841–849.

Ho, C., Chi, C., Ho, M., Chen, C., Liao, W., Liu, Y., … Wang, J. (2006). Clinical characteristics of group B streptococcus bacteremia in non-pregnant adults. *Journal of Microbiology, Immunology, and Infection*, *39*(5), 396–401.

Hsu, J. F., Tsai, M. H., Lin, L. C., Chu, S. M., Lai, M. Y., Huang, H. R., … Lu, J. J. (2021). Genomic characterization of serotype III/ST-17 group B streptococcus strains with antimicrobial resistance using whole genome sequencing. *Biomedicines*, *9*(10), 1–13.

Huang, J., Zheng, L., Su, Y., Wang, F., Kong, H., Chang, Y., & Xin, H. (2021). Effects of group B streptococcus infection on vaginal micro-ecology and pregnancy outcomes of pregnant women in late pregnancy. *European Journal of Obstetrics & Gynecology and Reproductive Biology*, *267*(1), 274–279.

Huang, P. Y., Lee, M. H., Yang, C. C., & Leu, H. S. (2006). Group B streptococcal bacteremia in non-pregnant adults. *Journal of Microbiology, Immunology, and Infection*, *39*(3), 237–241.

Hughes, M. J. G., Moore, J. C., Lane, J. D., Wilson, R., Pribul, P. K., Younes, Z. N., … Santangelo, J. D. (2002). Identification of major outer surface proteins of *Streptococcus agalactiae*. *Infection and Immunity*, *70*(3), 1254–1259.

Imperi, M., Pataracchia, M., Alfarone, G., Baldassarri, L., Ore, G., & Creti, R. (2010). A multiplex PCR assay for the direct identification of the capsular type (Ia to IX) of *Streptococcus agalactiae*. *Journal of Microbiological Methods*, *80*(2), 212–214.

Ip, M., Ang, I., Fung, K., Liyanapathirana, V., Luo, M. J., & Lai, R. (2016). Hypervirulent clone of group B streptococcus serotype III sequence type 283, Hong Kong, 1993–2012. *Emerging Infectious Diseases*, *22*(10), 1800–1803.

Jamrozy, D., Bijlsma, M. W., de Goffau, M. C., van de Beek, D., Kuijpers, T. W., Parkhill, J., … Bentley, S. D. (2020). Increasing incidence of group B streptococcus neonatal infections in the Netherlands is associated with clonal expansion of CC17 and CC23. *Scientific Reports*, *10*(1), 1–13.

Jhingan, G. D., Kumari, S., Jamwal, S. V., Kalam, H., Arora, D., Jain, N., … Nandicoori, V. K. (2016). Comparative proteomic analyses of avirulent, virulent, and clinical strains of *Mycobacterium tuberculosis* identify strain-specific patterns. *Journal of Biological Chemistry*, *291*(27), 14257–14273.

Jiang, H., Chen, M., Li, T., Liu, H., Gong, Y., Li, M., & Li, M. (2016). Molecular Characterization of *Streptococcus agalactiae* Causing Community- and Hospital-Acquired Infections in Shanghai , China. *Frontiers in Microbiology*, *7*, 1308.

Jiang, S., Park, S. E., Yadav, P., Paoletti, L. C., & Wessels, M. R. (2012). Regulation and function of pilus island 1 in group B streptococcus. *Journal of Bacteriology*, *194*(10), 2479–2490.

Jin, T., Brefo-Mensah, E., Fan, W., Zeng, W., Li, Y., Zhang, Y., & Palmer, M. (2018). Crystal structure of the *Streptococcus agalactiae* CAMP factor provides insights into its membrane-permeabilizing activity. *Journal of Biological Chemistry*, *293*(30), 11867–11877.

Jin, Z., Li, J., Zhou, H., Wang, Z., Yi, L., Liu, N., … Ji, W. (2022). Serotype distribution , virulence determinants and antimicrobial susceptibility of *Streptococcus agalactiae* isolated from young infants. *Pathogens*, *11*(1), 1–13.

Jisuvei, S. C., Osoti, A., & Njeri, M. A. (2020). Prevalence, antimicrobial susceptibility patterns, serotypes and risk factors for group B streptococcus rectovaginal isolates among pregnant women at Kenyatta National Hospital, Kenya; A cross-sectional study. *BMC Infectious Diseases*, *20*(1), 1–9.

Jolley, K., Bray, J., & Maiden, M. C. J. J. (2018). Open-access bacterial population genomics: BIGSdb software, the PubMLST. org website and their applications. *Wellcome open research*, *3*(124), 1–20.

Jones, N., Bohnsack, J. F., Takahashi, S., Oliver, K. A., Chan, M. S., Kunst, F., ... & Spratt, B. G. (2003). Multilocus sequence typing system for group B streptococcus. *Journal of Clinical Microbiology*, *41*(6), 2530–2536.

Jump, R. L. P., Wilson, B. M., Baechle, D., Briggs, J. M., Banks, R. E., Song, S., … Perez, F. (2019). Risk factors and mortality rates associated with invasive group B streptococcus infections among patients in the US veterans health administration. *JAMA Network Open*, *2*(12), e1918324.

Kailasam, S. (2022). LC-MS – What is LC-MS, LC-MS analysis and LC-MS/MS? Retrieved from https://www.technologynetworks.com/analysis/articles/lc-ms-what-is-lc-ms-lc-ms-analysis-and-lc-msms-348238

Kalimuddin, S., Chen, S. L., Lim, C. T. K., Koh, T. H., Tan, T. Y., Kam, M., … Barkham, T. (2017). 2015 Epidemic of severe *Streptococcus agalactiae* sequence type 283 infections in Singapore associated with the consumption of raw freshwater fish: A detailed analysis of clinical, epidemiological, and bacterial sequencing data. *Clinical Infectious Diseases*, *64*(2), S145–S152.

Kannika, K., Pisuttharachai, D., Srisapoome, P., Wongtavatchai, J., Kondo, H., Hirono, I., … Areechon, N. (2017). Molecular serotyping, virulence gene profiling and pathogenicity of *Streptococcus agalactiae* isolated from tilapia farms in Thailand by multiplex PCR. *Journal of Applied Microbiology*, *122*(6), 1497–1507.

Kao, Y., Tsai, M. H., Lai, M. Y., Chu, S. M., Huang, H. R., Chiang, M. C., … Hsu, J. F. (2019). Emerging serotype III sequence type 17 group B streptococcus invasive infection in infants: The clinical characteristics and impacts on outcomes. *BMC Infectious Diseases*, *19*(1), 1–8.

Karunakaran, R., Raja, N. S., Hafeez, A., & Puthucheary, S. D. (2009). Group B streptococcus infection: Epidemiology, serotypes, and antimicrobial susceptibility of selected isolates in the population beyond infancy (excluding females with genital tract- and pregnancy-related isolates) at the University Malaya Medical Centre. *Japanese Journal of Infectious Diseases*, *62*(3), 192–194.

Kawasaki, M., Delamare-Deboutteville, J., Bowater, R. O., Walker, M. J., Beatson, S., Ben Zakour, N. L., & Barnes, A. C. (2018). Microevolution of *Streptococcus agalactiae* ST-261 from Australia indicates dissemination via imported tilapia and ongoing adaptation to marine hosts or environment. *Applied and Environmental Microbiology*, *84*(16), 1–17.

Kayansamruaj, P., Pirarat, N., Katagiri, T., Hirono, I., & Rodkhum, C. (2014). Molecular characterization and virulence gene profiling of pathogenic *Streptococcus* *agalactiae* populations from tilapia (*Oreochromis* sp.) farms in Thailand. *Journal of Veterinary Diagnostic Investigation*, *26*(4), 488–495.

Kayansamruaj, P., Soontara, C., Unajak, S., & Thanh, H. (2019). Genomics Comparative genomics inferred two distinct populations of piscine pathogenic *Streptococcus agalactiae* , serotype Ia ST7 and serotype III ST283 , in Thailand and Vietnam. *Genomics*, *111*(6), 1657–1667.

Keenleyside, W. J., Clarke, A. J., & Whitfield, C. (2001). Identification of residues involved in catalytic activity of the inverting glycosyl transferase WbbE from *Salmonella enterica* serovar borreze. *Journal of Bacteriology*, *183*(1), 77–85.

Kekic, D., Gajic, I., Opavski, N., Kojic, M., Vukotic, G., Smitran, A., … Ranin, L. (2021). Trends in molecular characteristics and antimicrobial resistance of group B streptococci: a multicenter study in Serbia, 2015–2020. *Scientific Reports*, *11*(1), 1–10.

Kerdsin, A., Hatrongjit, R., Hamada, S., Akeda, Y., & Gottschalk, M. (2017). Development of a multiplex PCR for identification of β-hemolytic streptococci relevant to human infections and serotype distribution of invasive *Streptococcus agalactiae* in Thailand. *Molecular and Cellular Probes*, *36*, 10–14.

Khalid, N., Zainun, K. A., Hisham, S., Mazan, N. I., & Amin Nordin, S. (2018). Group B streptococcus infection in a sudden unexpected death of infancy – The importance of microbiological investigation at post-mortem. *Tropical Biomedicine*, *35*(3), 604–609.

Khare, B., & V. L. Narayana, S. (2017). Pilus biogenesis of Gram-positive bacteria: Roles of sortases and implications for assembly. *Protein Science*, *26*(8), 1458–1473.

Khodaei, F., Najafi, M., Hasani, A., Kalantar, E., Sharifi, E., Amini, A., & Aghazadeh, M. (2018). Pilus–encoding islets in S. agalactiae and its association with antibacterial resistance and serotype distribution. *Microbial Pathogenesis*, *116*, 189–194.

Kim, Y.-J., Yoon, Y. M., Kim, Y. R., Heo, S. T., Yoo, J. R., Lee, K. H., & Choi, J. H. (2020). Group B streptococcal transmission via a prolonged colonizer in a neonatal intensive care unit. *Journal of Microbiology, Immunology and Infection*, *53*(1), 179–182.

Kolar, M., Cermak, P., Hobzova, L., Bogdanova, K., Neradova, K., Mlynarcik, P., & Bostik, P. (2020). Antibiotic resistance in nosocomial bacteria isolated from infected wounds of hospitalized patients in Czech Republic. *Antibiotics*, *9*(6), 1–8.

Kolter, J., & Henneke, P. (2017). Codevelopment of microbiota and innate immunity and the risk for group B streptococcal disease. *Frontiers in Immunology*, *8*(11), 1–13.

Kong, F., Gowan, S., Martin, D., James, G., & Gilbert, G. L. (2002). Serotype identification of group B streptococci by PCR and sequencing. *Journal of Clinical*

Microbiology, *40*(1), 216–226.

Kong, Fanrong, Ma, L., Gilbert, G. L., & Gilbert, G. L. (2005). Simultaneous detection and serotype identification of *Streptococcus agalactiae* using multiplex PCR and reverse line blot hybridization. *Journal of Medical Microbiology*, *54*(12), 1133–1138.

Kovavisarach, E., Sa-adying, W., & Kanjanahareutai, S. (2007). Comparison of combined vaginal-anorectal, vaginal and anorectal cultures in detecting of group B streptococci in pregnant women in labor. *Journal of the Medical Association of Thailand*, *90*(9), 1710–1714.

Kumar, S., Stecher, G., & Tamura, K. (2016). MEGA7 : Molecular evolutionary genetics analysis version 7 . 0 for Bigger datasets brief communication. *Molecular Biology and Evolution*, *33*(7), 1870–1874.

Kwatra, G., Madhi, S. A., Cutland, C. L., Buchmann, E. J., & Adrian, P. V. (2013). Evaluation of trans-vag broth, colistin-nalidixic agar, and CHROMagar StrepB for detection of group B streptococcus in vaginal and rectal swabs from pregnant women in South Africa. *Journal of Clinical Microbiology*, *51*(8), 2515–2519.

Lacasse, M., Valentin, A.-S., Corvec, S., Bémer, P., Jolivet-Gougeon, A., Plouzeau, C., … Lartigue, M.-F. (2022). Genotypic characterization and biofilm production of group B streptococcus strains isolated from bone and joint infections. *Microbiology Spectrum*, *10*(2), 1–8.

Lai, L., Dai, J., Tang, H., Zhang, S., Wu, C., Qiu, W., … Wu, Z. (2017). *Streptococcus suis* serotype 9 strain GZ0565 contains a type VII secretion system putative substrate EsxA that contributes to bacterial virulence and a vanZ-like gene that confers resistance to teicoplanin and dalbavancin in *Streptococcus agalactiae*. *Veterinary Microbiology*, *205*(1), 26–33.

Lambiase, A., Agangi, A., Del Pezzo, M., Quaglia, F., Testa, A., Rossano, F., … Catania, M. R. (2012). In vitro resistance to macrolides and clindamycin by group B streptococcus isolated from pregnant and nonpregnant women. *Infectious Diseases in Obstetrics and Gynecology*, *2012*(1), 1–6.

Larppanichpoonphol, P Watanakunakorn, C. (2001). Group B streptococcal bacteremia in nonpregnant adults at a community teaching hospital. *Southern Medical Journal*, *94*(12), 1206–1212.

Le Guennec, L., Coureuil, M., Nassif, X., & Bourdoulous, S. (2020). Strategies used by bacterial pathogens to cross the blood–brain barrier. *Cellular Microbiology*, *22*(1), 1–12.

Leal, C. A., Queiroz, G. A., Pereira, F. L., Tavares, G. C., & Figueiredo., H. C. (2019). *Streptococcus agalactiae* Sequence Type 283 in Farmed Fish, Brazil. *Emerging Infectious Diseases*, *25*(4), 776–779.

Lee, H. T., Kim, S. Y., Park, P. W., Ahn, J. Y., Kim, K. H., Seo, J. Y., … Seo, Y. H.

(2019). Detection and genomic analysis of genital group B streptococcus in pregnant Korean women. *Journal of Obstetrics and Gynaecology Research*, *45*(1), 69–77.

Lefebvre, N., Forestier, E., Mohseni-Zadeh, M., Remy, V., Lesens, O., Kuhnert, C., … Hansmann, Y. (2007). Invasive *Streptococcus agalactiae* infections in non-pregnant adults. *Medecine et Maladies Infectieuses*, *37*(12), 796–801.

Legario, F. S., Choresca, C. H., Turnbull, J. F., & Crumlish, M. (2020). Isolation and molecular characterization of streptococcal species recovered from clinical infections in farmed Nile tilapia (*Oreochromis niloticus*) in the Philippines. *Journal of Fish Diseases*, *43*(11), 1431–1442.

Li, C., Sapugahawatte, D. N., Yang, Y., & Wong, K. T. (2020). Multidrug-resistant *Streptococcus agalactiae* strains found in human and fish with high penicillin and cefotaxime non-susceptibilities. *Microorganisms*, *8*(7), 1–10.

Li, L., Shi, Y., Wang, R., Huang, T., Liang, W., Luo, H., … Chen, M. (2015). Proteomic analysis of tilapia *Oreochromis niloticus Streptococcus agalactiae* strains with different genotypes and serotypes. *Journal of Fish Biology*, *86*(2), 615–636.

Li, Li, Jr, C. J. S., & Roos, D. S. (2003). OrthoMCL : Identification of ortholog groups for eukaryotic genomes. *Genome Research*, *13*(9), 2178–2189.

Li, Liping, Wang, R., Huang, Y., Huang, T., Luo, F., Huang, W., … Gan, X. (2018). High incidence of pathogenic *Streptococcus agalactiae* ST485 strain in pregnant/puerperal women and isolation of hyper-virulent human CC67 strain. *Frontiers in Microbiology*, *9*(2), 1–14.

Li, S., Wen, G., Cao, X., Guo, D., Yao, Z., Wu, C., & Ye, X. (2018). Molecular characteristics of *Streptococcus agalactiae* in a mother-baby prospective cohort study: Implication for vaccine development and insights into vertical transmission. *Vaccine*, *36*(15), 1941–1948.

Li, W., Mao, R., Yue, X., Wu, J., Wu, R., Qiao, Y., … Du, Y. (2020). Competitive annealing mediated isothermal amplification (CAMP) for rapid and simple detection of Listeria monocytogenes in milk. *Food Control*, *117*(5), 107-347.

Li, W., Su, Y., Mai, Y., Li, Y., Mo, Z., & Li, A. (2014). Comparative proteome analysis of two *Streptococcus agalactiae* strains from cultured tilapia with different virulence. *Veterinary Microbiology*, *170*(1–2), 135–143.

Li, W., Wang, H., He, R., Li, Y., Su, Y., & Li, A. (2016). Fish & Shell fish Immunology Major surfome and secretome pro fi le of *Streptococcus agalactiae* from Nile tilapia (*Oreochromis niloticus*): Insight into vaccine development. *Fish and Shellfish Immunology*, *55*, 737–746.

Liakopoulos, A., Mavroidi, A., Vourli, S., Panopoulou, M., Zachariadou, L., Chatzipanagiotou, S., … Petinaki, E. (2014). Molecular characterization of *Streptococcus agalactiae* from vaginal colonization and neonatal infections: A 4-

year multicenter study in Greece. *Diagnostic Microbiology and Infectious Disease*, *78*(4), 487–490.

Lim, C., Thong, M., Parasakthi, N., & Ngeow, Y. (1997). Group B streptococcus: maternal carriage rate and early neonatal septicaemia. *Singapore*, *26*(4), 421–425.

Lin, F. P., Lan, R., Sintchenko, V., Gilbert, G. L., & Kong, F. (2011). Computational bacterial genome-wide analysis of phylogenetic profiles reveals potential virulence genes of *Streptococcus agalactiae*. *PLoS ONE*, *6*(4), e17964.

Liu, G., Zhang, W., & Lu, C. (2013a). Comparative genomics analysis of *Streptococcus agalactiae* reveals that isolates from cultured tilapia in China are closely related to the human strain A909. *BMC Genomics*, *14*(1), 1–10.

Liu, G., Zhang, W., & Lu, C. (2013b). Identification of immunoreactive proteins of *Streptococcus agalactiae* isolated from cultured tilapia in China. *Pathogens and Disease*, *69*(3), 223–231.

Lu, Y. J., & Rock, C. O. (2006). Transcriptional regulation of fatty acid biosynthesis in *Streptococcus pneumoniae. Molecular Microbiology*, *59*(2), 551–566.

Lusiastuti, A. M., Seeger, H., Indrawati, A., & Zschöck, M. (2013). The Comparison of *Streptococcus agalactiae* Isolated from Fish and Bovine using Multilocus Sequence Typing. *Institut Pertanian Bogor*, *20*(4), 157–162.

Lyhs, U., Kulkas, L., Katholm, J., Waller, K. P., Saha, K., Tomusk, R. J., & Zadoks, R. N. (2016). *Streptococcus agalactiae* serotype IV in humans and cattle, Northern Europe. *Emerging Infectious Diseases*, *22*(12), 2097–2103.

Łysakowska, M. E., Kalinka, J., Bigos, M., Prosniewska, M., & Wasiela, M. (2011). Occurrence of virulence genes among S. agalactiae isolates from vagina and anus of pregnant women - A pilot study. *Archives of Perinatal Medicine*, *17*(4), 229–234.

Madrid, L., Seale, A. C., Kohli-Lynch, M., Edmond, K. M., Lawn, J. E., Heath, P. T., ... & Schrag, S. (2017). Infant group B streptococcal disease incidence and serotypes worldwide: systematic review and meta-analyses. *Clinical Infectious Diseases*, *65*(2), 160-172.

Maggioni, A. P., Maseri, A., Fresco, C., Franzosi, M. G., Mauri, F., Santoro, E., … Spellerberg, B. (2017). Reliable Detection of group B streptococcus in the Clinical Laboratory. *Journal of Clinical Microbiology*, *55*(20), 2590–2598.

Magiorakos, A., Srinivasan, A., Carey, R. B., Carmeli, Y., Falagas, M. E., Giske, C. G., … Hindler, J. F. (2011). Bacteria : an international expert proposal for interim standard definitions for acquired resistance. *Clinical Microbiology and Infection*, *18*(3), 268–281.

Maiden, M. C. J., Bygraves, J. A., Feil, E., Morelli, G., Russell, J. E., Urwin, R., … Spratt, B. G. (1998). Multilocus sequence typing: A portable approach to the identification of clones within populations of pathogenic microorganisms. *Proceedings of the National Academy of Sciences of the United States of America*, *95*(6), 3140–3145.

Manage, P. M. (2018). Heavy use of antibiotics in aquaculture: Emerging human and animal health problems – A review. *Sri Lanka Journal of Aquatic Sciences*, *23*(1), 13–27.

Manning, S. D., Ki, M., Marrs, C. F., Kugeler, K. J., Borchardt, S. M., Baker, C. J., & Foxman, B. (2006). The frequency of genes encoding three putative group B isolates. *BMC Infectious Diseases*, *6*(1), 1–7.

Manning, S. D., Springman, A. C., Lehotzky, E., Lewis, M. A., Whittam, T. S., & Davies, H. D. (2009). Multilocus sequence types associated with neonatal group B streptococcal sepsis and meningitis in Canada. *Journal of Clinical Microbiology*, *47*(4), 1143–1148.

Manzer, H. S., Nguyen, D. T., Park, J. Y., Park, N., Seo, K. S., Thornton, J. A., … Doran, K. S. (2022). The group B streptococcal adhesin BspC interacts with host cytokeratin 19 to promote colonization of the female reproductive tract. *MBio*, *19*(5), e0178122.

Martins, E. R., Melo-Cristino, J., Ramirez, M., & Portuguese Group for the Study of Streptococcal Infections. (2012). Dominance of serotype Ia among group B streptococci causing invasive infections in nonpregnant adults in Portugal. *Journal of Clinical Microbiology*, *50*(4), 1219–1227.

McCabe, S. (2022). *The group B Streptococcus virulence factor C5a peptidase role in complement cleavage and vaccine protection*. (Doctoral dissertation, University of California San Diego, USA).

McGee, L., Chochua, S., Li, Z., Mathis, S., Rivers, J., Metcalf, B., … Beall, B. W. (2021). Multistate, population-Based distributions of candidate vaccine targets, clonal complexes, and resistance features of invasive group B Streptococci within the United States, 2015-2017. *Clinical Infectious Diseases*, *72*(6), 1004–1013.

Menagah, E. (2019). Genotyping of nvasive and non-invasive group B streptococcus of hospital origin in Malaysia. (Master’s thesis, Universiti Putra Malaysia, Malaysia).

Mereghetti, L., Sitkiewicz, I., Green, N. M., & Musser, J. M. (2008). Extensive adaptive changes occur in the transcriptome of *Streptococcus agalactiae* (Group B streptococcus) in response to incubation with human blood. *PLoS ONE*, *3*(9), 1–10.

Metcalf, B. J., Chochua, S., Gertz, R. E., Hawkins, P. A., Ricaldi, J., Li, Z., … Langley, G. (2017). Short-read whole genome sequencing for determination of antimicrobial resistance mechanisms and capsular serotypes of current invasive *Streptococcus agalactiae* recovered in the USA. *Clinical Microbiology and Infection*, *23*(8), 574.e7–574.e14.

Mian, G. F., Godoy, D. T., Leal, C. A. G., Yuhara, T. Y., Costa, G. M., & Figueiredo, H. C. P. (2009). Aspects of the natural history and virulence of S. agalactiae infection in Nile tilapia. *Veterinary Microbiology*, *136*(1–2), 180–183.

Milligan, T. W., Doran, T. I., Straus, D. C., & Mattingly, S. J. (1978). Growth and amino acid requirements of various strains of group B streptococci. *Journal of Clinical Microbiology*, *7*(1), 28–33.

Ministry of Health Malaysia. (2016). Malaysia–WHO Country Cooperation Strategy 2016–2020. Kuala Lumpur: Academy of Medicine Malaysia. Retrieved from http:// www.moh.gov.my/medical/htm

Ministry of Health Malaysia. (2019). National Surveillance of Antibiotic Resistance. Kuala Lumpur: Institute for Medical Research. Retrieved from http://www.imr.gov.my

Modak, J., Deckwer, W. D., & Zeng, A. P. (2002). Metabolic control analysis of eucaryotic pyruvate dehydrogenase multienzyme complex. *Biotechnology Progress*, *18*(6), 1157–1169.

Mohamed Sadaka, S., Abdelsalam Aly, H., Ahmed Meheissen, M., Orief, Y. I., & Mohamed Arafa, B. (2018). Group B streptococcal carriage, antimicrobial susceptibility, and virulence related genes among pregnant women in Alexandria, Egypt. *Alexandria Journal of Medicine*, *54*(1), 69–76.

Mohamed, A. M., Khan, M. A., Faiz, A., Ahmad, J., Khidir, E. B., Basalamah, M. A., & Aslam, A. (2020). Group B streptococcus colonization, antibiotic susceptibility, and serotype distribution among Saudi pregnant women. *Infection and Chemotherapy*, *52*(1), 70–81.

Morach, M., Stephan, R., Schmitt, S., Ewers, C., Zschöck, M., Reyes-Velez, J., … Daubenberger, C. (2018). Population structure and virulence gene profiles of *Streptococcus agalactiae* collected from different hosts worldwide. *European Journal of Clinical Microbiology & Infectious Diseases*, *37*(3), 527–536.

Morello, E., Mallet, A., Konto-Ghiorghi, Y., Chaze, T., Mistou, M. Y., Oliva, G., … Dramsi, S. (2015). Evidence for the sialylation of pilA, the PI-2a pilus-associated adhesin of *Streptococcus agalactiae* strain NEM316. *PLoS One*, *10*(9), 1–17.

Motallebirad, T., Fazeli, H., Ghahiri, A., Shokri, D., Jalalifar, S., Moghim, S., & Esfahani, B. N. (2021). Prevalence, population structure, distribution of serotypes, pilus islands and resistance genes among erythromycin-resistant colonizing and invasive *Streptococcus agalactiae* isolates recovered from pregnant and non-pregnant women in Isfahan, Iran. *BMC Microbiology*, *21*(1), 1–11.

Mu, R., Kim, B. J., Paco, C., Del Rosario, Y. D., Courtney, H. S., & Doran, K. S. (2014). Identification of a group B streptococcal fibronectin binding protein, SfbA, that contributes to invasion of brain endothelium and development of meningitis. *Infection and Immunity*, *82*(6), 2276–2286.

Mudzana, R., Mavenyengwa, R. T., & Gudza-Mugabe, M. (2021). Analysis of virulence factors and antibiotic resistance genes in group B streptococcus from clinical samples. *BMC Infectious Diseases*, *21*(1), 1–11.

Muthanna, A., Aziz, N. A., Desa, M. N. M., Dzaraly, N. D., Baharin, N. H. Z., Azmai, M. N. A., & Amin-Nordin, S. (2022a). An unusual Cause of tenosynovitis by group B streptococcus in the immunocompromised patient: A case report. *Pertanika Journal of Science and Technology*, *30*(3), 2071–2076.

Muthanna, A., Zakariah, S. Z., Rashid, A. A., Ghazali, S. S., Hamat, R. A., Mawardi, M., … Shamsuddin, N. H. (2022b). Antibiotic prescribing patterns for patients with pharyngitis in Malaysian public primary care clinics. *Malaysian Journal of Medical Sciences*, *29*(1), 91–100.

Nabavinia, M., Khalili, M. B., Sadeh, M., Eslami, G., Vakili, M., Azartoos, N., & Mojibiyan, M. (2020). Distribution of pilus island and antibiotic resistance genes in *streptococcus agalactiae* obtained from vagina of pregnant women in Yazd, Iran. *Iranian Journal of Microbiology*, *12*(5), 411–416.

Nadimpalli, M., Delarocque-Astagneau, E., Love, D. C., Price, L. B., Huynh, B. T., Collard, J. M., … Abdou, A. Y. (2018). Combating global antibiotic resistance: emerging one health concerns in lower-and middle-income countries. *Clinical Infectious Diseases*, *66*(6), 963–969.

Nair, S., Poyart, C., Beretti, J. L., Veiga-Fernandes, H., Berche, P., & Trieu-Cuot, P. (2003). Role of the *Streptococcus agalactiae* ClpP serine protease in heat-induced stress defence and growth arrest. *Microbiology*, *149*(2), 407–417.

Navarro-Torné, A., Curcio, D., Moïsi, J. C., & Jodar, L. (2021). Burden of invasive group B streptococcus disease in non-pregnant adults: A systematic review and meta-analysis. *PLoS ONE*, *16*(9), 1–18.

Neagu, A.-N., Jayathirtha, M., Baxter, E., Donnelly, M., Petre, B. A., & Darie, C. C. (2022). Applications of tandem mass spectrometry (MS/MS) in protein analysis for biomedical research. *Molecules*, *27*(1), 1–29.

Neijssel, O. M. (1997). Regulation of energy source metabolism in streptococci. *Journal of Applied Microbiology Symposium Supplement*, *83*(1), 12–19.

Nesvizhskii, A. I. (2014). Proteogenomics: concepts, applications and computational strategies. *Nature Methods*, *11*, 1114–1125.

Nhung, N. T., Cuong, N. V, Thwaites, G., & Carrique-mas, J. (2016). Antimicrobial usage and antimicrobial resistance in animal production in Southeast Asia : A review. *Antibiotics*, *5*(4), 1–24.

Niu, G., Khattiya, R., Zhang, T., Boonyayatra, S., & Wongsathein, D. (2020). Phenotypic and genotypic characterization of *Streptococcus* spp. isolated from tilapia (*Oreochromis* spp.) cultured in river-based cage and earthen ponds in Northern Thailand. *Journal of Fish Diseases*, *43*(3), 391–398.

Noble, K., Lu, J., Guevara, M. A., Doster, R. S., Chambers, S. A., Rogers, L. M., … Gaddy, J. A. (2021). Group B streptococcus cpsE Is required for serotype v capsule production and aids in biofilm formation and ascending infection of the reproductive tract during pregnancy. *ACS Infectious Diseases*, *7*(9), 2686–2696.

Noor, Z., Mohamedali, A., & Ranganathan, S. (2019). Identification of proteins from proteomic analysis. *Encyclopedia of Bioinformatics and Computational Biology*, *3*(1), 855–870.

Nyvard, B., & Fejerskov, O. (1987). Scanning electron microscopy of early microbial colonization of human enamel and root surfaces in vivo. *European Journal of Oral Sciences*, *95*(4), 287–296.

Ong, S. W., Barkham, T., Kyaw, W. M., Ho, H. J., & Chan, M. (2018). Characterisation of bone and joint infections due to Group B streptococcus serotype III sequence type 283. *European Journal of Clinical Microbiology & Infectious Diseases*, *37*(7), 1313–1317.

Papasergi, S., Galbo, R., Lanza-cariccio, V., Domina, M., Signorino, G., Biondo, C., … Beninati, C. (2013). Analysis of the *Streptococcus agalactiae* exoproteome. *Journal of Proteomics*, *89*(1), 154–164.

Park, S. E., Jiang, S., & Wessels, M. R. (2012). CsrRS and environmental pH regulate group B streptococcus adherence to human epithelial cells and extracellular matrix. *Infection and Immunity*, *80*(11), 3975–3984.

Paveenkittiporn, W., Ungcharoen, R., & Kerdsin, A. (2020). *Streptococcus agalactiae* infections and clinical relevance in adults, Thailand. *Diagnostic Microbiology and Infectious Disease*, *97*(1),11–15.

Pereira, U. P., Mian, G. F., Oliveira, I. C. M., Benchetrit, L. C., Costa, G. M., & Figueiredo, H. C. P. (2010). Genotyping of *Streptococcus agalactiae* strains isolated from fish , human and cattle and their virulence potential in Nile tilapia. *Veterinary Microbiology*, *140*(1–2), 186–192.

Petrovski, K. R., Laven, R. A., & Lopez-Villalobos, N. (2011). A descriptive analysis of the antimicrobial susceptibility of mastitis-causing bacteria isolated from samples submitted to commercial diagnostic laboratories in New Zealand (2003-2006). *New Zealand Veterinary Journal*, *59*(2), 59–66.

Phares, C. R., Lynfield, R., Farley, M. M., Mohle-Boetani, J., Harrison, L. H., Petit, S., … Schrag, S. J. (2008). Epidemiology of invasive group B streptococcal disease in the United States, 1999-2005. *JAMA*, *299*(17), 2056–2065.

Phuoc, N. N., Linh, N. T. H., Crestani, C., & Zadoks, R. N. (2021). Effect of strain and enviromental conditions on the virulence of *Streptococcus agalactiae* (Group B streptococcus; GBS) in red tilapia (*Oreochromis* sp.). *Aquaculture*, *534*, 736256.

Poyart, C., Pellegrini, E., Gaillot, O., Boumaila, C., Baptista, M., & Trieu-Cuot, P. (2001). Contribution of Mn-cofactored superoxide dismutase (SodA) to the virulence of *Streptococcus agalactiae*. *Infection and Immunity*, *69*(8), 5098–5106.

Pragya, P., Kaur, G., Ali, S. A., Bhatla, S., Rawat, P., Lule, V., … Behare, P. (2017). High-resolution mass spectrometry-based global proteomic analysis of probiotic strains Lactobacillus fermentum NCDC 400 and RS2. *Journal of Proteomics*, *152*, 121–130.

Puopolo, K. M., Lynfield, R., & Cummings, J. J. (2019). Management of infants at risk for group B streptococcal disease. *Pediatrics*, *144*(2),1–7.

Quan, V., Verani, J. R., Cohen, C., Von Gottberg, A., Meiring, S., Cutland, C. L., … Madhi, S. A. (2016). Invasive group B streptococcal disease in South Africa: Importance of surveillance methodology. *PLoS ONE*, *11*(4), 1–10.

Raabe, V. N., & Shane, A. L. (2019). Group B streptococcus (*streptococcus agalactiae*). *Microbiology Spectrum*, *7*(2), 228–238.

Raj, M., Razali, N., & Sulaiman, S. (2009). Screening of antenatal mothers and prevention of perinatal Group B streptococcal infection. *Journal of Health and Translational Medicine*, *12*(1), 27–30.

Rajaei, A. (2022). *The CPSA and PSR proteins of Streptococcus agalactiae provide a united front to protect against the host immune system*. (Doctoral dissertation, University of Maine, USA).

Rajagopal, L. (2009). Understanding the regulation of Group B Streptococcal virulence factors. *Future Microbiology*, *4*(2), 201–221.

Rajendram, P., Kyaw, W. M., Leo, Y. S., Ho, H., Chen, W. K., Lin, R., … Chow, A. (2016). Group B streptococcus sequence type 283 disease linked to consumption of raw fish, Singapore. *Emerging Infectious Diseases*, *22*(11), 11–14.

Rakocy, J. (2019). Cultured aquatic species information programme (*Oreochromis niloticus*). Retrieved from https://www.fao.org/fishery/en/culturedspecies/oreochromis_niloticus?lang=en

Rato, M. G., Bexiga, R., Florindo, C., Cavaco, L. M., Vilela, C. L., & Santos-Sanches, I. (2013). Antimicrobial resistance and molecular epidemiology of streptococci from bovine mastitis. *Veterinary Microbiology*, *161*(3–4), 286–294.

Reyes, A. T., Raymundo, A. K., Baldrias, L. R., Paller, V. G., & Dalmacio, I. F. (2021). Occurrence of Streptococcus spp. on farmed nile tilapia (*Oreochromis niloticus L.*) in Lubao, Pampanga, Philippines. *International Journal of Agricultural Technology*, *17*(3), 1041–1060.

Rojo-Bezares, B., Azcona-Gutiérrez, J. M., Martin, C., Jareño, M. S., Torres, C., & Sáenz, Y. (2016). *Streptococcus agalactiae* from pregnant women: Antibiotic and heavy-metal resistance mechanisms and molecular typing. *Epidemiology and Infection*, *144*(15), 3205–3214.

Rosinski-Chupin, I., Sauvage, E., Mairey, B., Mangenot, S., Ma, L., Da Cunha, V., … Glaser, P. (2013). Reductive evolution in *Streptococcus agalactiae* and the emergence of a host adapted lineage. *BMC Genomics*, *14*(1), 1–15.

Rottenstreich, M., Rotem, R., Srebnik, N., Farkash, R., Samueloff, A., & Grisaru-Granovsky, S. (2020). The recurrence risk of group B streptococcus in consecutive deliveries. *Journal of Maternal-Fetal and Neonatal Medicine*, *33*(13), 2263–2268.

Ruegg, P. L. (2017). A 100-Year Review: Mastitis detection, management, and prevention. *Journal of Dairy Science*, *100*(12), 10381–10397.

Safari, D., Gultom, S. M., Tafroji, W., Azzahidah, A., Soesanti, F., Khoeri, M. M., … Putri, N. D. (2021). Prevalence, serotype and antibiotic susceptibility of group B streptococcus isolated from pregnant women in Jakarta, Indonesia. *PLoS ONE*, *16*(5), 1–9.

Sakap, H. S., Hassan, J. S., & Razak, S. H. A. (2020). Molecular detection of C5a peptidase (*scpB*) gene in group B streptococcus isolated from pregnant women and the correspondence with adverse pregnancy outcome. *Indian Journal of Public Health Research & Development*, *11*(1), 1144–1149.

Salloum, M., Van Der Mee-Marquet, N., Domelier, A. S., Arnault, L., & Quentin, R. (2010). Molecular characterization and prophage dna contents of *Streptococcus agalactiae* strains isolated from adult skin and osteoarticular infections. *Journal of Clinical Microbiology*, *48*(4), 1261–1269.

Samant, S., Lee, H., Ghassemi, M., Chen, J., Cook, J. L., Mankin, A. S., & Neyfakh, A. A. (2008). Nucleotide biosynthesis is critical for growth of bacteria in human blood. *PLoS Pathogens*, *4*(2),1–10.

Santi, I., Scarselli, M., Mariani, M., Pezzicoli, A., Masignani, V., Taddei, A., … Soriani, M. (2007). BibA: A novel immunogenic bacterial adhesin contributing to group B streptococcus survival in human blood. *Molecular Microbiology*, *63*(3), 754–767.

Sapugahawatte, D. N., Li, C., Dharmaratne, P., Zhu, C., Yeoh, Y. K., Yang, J., … Ip, M. (2022). Prevalence and characteristics of *Streptococcus agalactiae* from freshwater fish and pork in Hong Kong wet markets. *Antibiotics*, *11*(3), 1–15.

Schaumburg, J., Diekmann, O., Hagendorff, P., Bergmann, S., Rohde, M., Hammerschmidt, S., … Kärst, U. (2004). The cell wall subproteome of *Listeria monocytogenes*. *Proteomics*, *4*(10), 2991–3006.

Schrag, S. J., Zell, E. R., Lynfield, R., Roome, A., Arnold, K. E., Craig, A. S., … Schuchat, A. (2003). A Population-Based Comparison of Strategies to Prevent Early-Onset Group B Streptococcal Disease in Neonates. *Obstetrical & Gynecological Survey*, *58*(1), 6–8.

Schuchat, A., & Wenger, J. D. (1994). Epidemiology of Group B Streptococcal Disease: Risk Factors, Prevention Strategies, and Vaccine Development. *Epidemiologic Reviews*, *16*(2), 374–402.

Seger, C., & Salzmann, L. (2020). After another decade: LC–MS/MS became routine in clinical diagnostics. *Clinical Biochemistry*, *82*(1), 2–11.

Shabayek, S., & Spellerberg, B. (2018). Group B streptococcal colonization, molecular characteristics, and epidemiology. *Frontiers in Microbiology*, *9*(1), 1–14.

Shabayek, S., Abdalla, S., & Abouzeid, A. M. H. (2010). Comparison of *scpB* gene and *cfb* gene polymerase chain reaction assays with culture on Islam medium to detect Group B streptococcus in pregnancy. *Indian Journal of Medical Microbiology*, *28*(4), 320–325.

Silva, W. M., Folador, E. L., Soares, S. C., Souza, G. H. M. F., Santos, A. V., Sousa, C. S., … Azevedo, V. (2017). Label-free quantitative proteomics of *Corynebacterium pseudotuberculosis* isolates reveals differences between Biovars ovis and equi strains. *BMC Genomics*, *18*(1), 1–14.

Silvestre, I., Borges, V., Duarte, S., Nunes, A., Sobral, R., Vieira, L., … Ricardo Jorge, D. (2020). Global gene expression analysis of *Streptococcus agalactiae* at exponential growth phase. *BioRxiv*, *14*(11), 1–19.

Simões, L. C., Silva, A. C. P., Santos, C. M., Alvim, D. C. S. S., Nery, D. C. M., Oliveira, L. M. A., … Pinto, T. C. A. (2021). Unusual finding of the human - adapted hypervirulent serotype III / ST17 clone in a historical bovine Group B streptococcus isolate from Brazil. *Brazilian Journal of Microbiology*, *52*(3), 1631–1635.

Si-Tuan, N., Ngoc, H. M., Nhat, L. D., Nguyen, C., Pham, H. Q., & Huong, N. T. (2020). Genomic features, whole-genome phylogenetic and comparative genomic analysis of extreme-drug-resistant ventilator-associated-pneumonia Acinetobacter baumannii strain in a Vietnam hospital. *Infection, Genetics and Evolution*, *80*(1), 1–7.

Six, A., Firon, A., Plainvert, C., Caplain, C., Touak, G., Dmytruk, N., … Poyart, C. (2016). Molecular characterization of nonhemolytic and nonpigmented group B streptococci responsible for human invasive infections. *Journal of Clinical Microbiology*, *54*(1), 75–82.

Skoff, T. H., Farley, M. M., Petit, S., Craig, A. S., Schaffner, W., Gershman, K., … Schrag, S. J. (2009). Increasing burden of invasive group B Streptococcal disease in nonpregnant adults, 1990-2007. *Clinical Infectious Diseases*, *49*(1), 85–92.

Song, J. Y., Lim, J. H., Lim, S., Yong, Z., & Seo, H. S. (2018). Progress toward a group B streptococcal vaccine. *Human Vaccines and Immunotherapeutics*, *14*(11), 2669–2681.

Soto, E., Wang, R., Wiles, J., Green, C., Plumb, J., Hawke, J., & Soto, E. (2015). Characterization of isolates of *Streptococcus agalactiae* from diseased farmed and wild marine fish from the U.S. Gulf coast, Latin America, and Thailand. *Journal of Aquatic Animal Health*, *27*(2), 123–134.

Springman, A. C., Lacher, D. W., Wu, G., Milton, N., Whittam, T. S., Davies, H. D., & Manning, S. D. (2009). Selection , recombination , and virulence gene diversity among group B streptococcal genotypes. *191*(17), 5419–5427.

Steer, P. J., Russell, A. B., Kochhar, S., Cox, P., Plumb, J., & Gopal Rao, G. (2020). Group B streptococcal disease in the mother and newborn—A review. *European Journal of Obstetrics and Gynecology and Reproductive Biology*, *252*, 526–533.

Stefańska, I., Kwiecień, E., Kizerwetter-Świda, M., Chrobak-Chmiel, D., & Rzewuska, M. (2022). Tetracycline, Macrolide and lincosamide resistance in *streptococcus canis* strains from companion animals and its genetic determinants. *Antibiotics*, *11*(8), 1–14.

Stoll, B. J., Puopolo, K. M., Hansen, N. I., Sánchez, P. J., Bell, E. F., Carlo, W. A., … Higgins, R. D. (2020). Early-onset neonatal sepsis 2015 to 2017, the rise of *Escherichia coli*, and the need for novel prevention strategies. *JAMA Pediatrics*, *174*(7), 1–12.

Suanyuk, N., Kong, F., Ko, D., Gilbert, G. L., & Supamattaya, K. (2008). Occurrence of rare genotypes of *Streptococcus agalactiae* in cultured red tilapia *Oreochromis* sp. and Nile tilapia *O. niloticus* in Thailand-relationship to human isolates? *Aquaculture*, *284*(1–4), 35–40.

Suhaimi, M. E., Desa, M. N. M., Eskandarian, N., Pillay, S. G., Ismail, Z., Neela, V. K., … Nordin, S. A. (2017). Characterization of a group B streptococcus infection based on the demographics, serotypes, antimicrobial susceptibility and genotypes of selected isolates from sterile and non-sterile isolation sites in three major hospitals in Malaysia. *Journal of Infection and Public Health*, *10*(1), 14–21.

Sukhnanand, S., Dogan, B., Ayodele, M. O., Zadoks, R. N., Craver, M. P. J., Dumas, N. B., … Wiedmann, M. (2005). Molecular subtyping and characterization of bovine and human *Streptococcus agalactiae* isolates. *Journal of Clinical Microbiology*, *43*(3), 1177–1186.

Sulung, F., Hussin, A., & Hassan, S. A. (2020). Group B streptococcus bacteremia among non-pregnant adults in Kelantan: Description on clinical presentations, serotypes and virulence genes. *International Journal of Infectious Diseases*, *101*, 146.

Suwannasang, A., Dangwetngam, M., Issaro, A., Phromkunthong, W., & Suanyuk, N. (2014). Pathological manifestations and immune responses of serotypes Ia and III *Streptococcus agalactiae* infections in Nile tilapia (*Oreochromis niloticus*). *Songklanakarin Journal of Science and Technology*, *36*(5), 499–506.

Syuhada, R., Zamri-saad, M., Ina-salwany, M. Y., Mustafa, M., Nasruddin, N. N., & Desa, M. N. M. (2020). Molecular characterization and pathogenicity of *Streptococcus agalactiae* serotypes Ia ST7 and III ST283 isolated from cultured red hybrid tilapia in Malaysia. *Aquaculture*, *515*(7), 1–21.

Takang, W. A., Obichemti, E. T., Florent, F. Y., Ujambeng, U. V., & Forlemu, A. A.

(2022). Prevalence, antimicrobial susceptibility pattern and factors associated with GBS colonization in pregnant women at the Regional Hospital Bamenda (RHB). *Open Journal of Obstetrics and Gynecology*, *12*(8), 887–906.

Tan, S., Lin, Y., Foo, K., Ang, L. W., Cui, L., & Badaruddin, H. (2016). Sequence Type 283 bacteremia associated with consumption of raw fish, Singapore. *Emerging Infectious Diseases*, *22*(11), 1970–1973.

Tavares, Guilherme C, Carvalho, A. F., Pereira, F. L., & Rezende, C. P. (2018). Transcriptome and proteome of fish-pathogenic *Streptococcus agalactiae* are modulated by temperature bacterial strains and growth conditions. *Food Technology and Biotechnology*, *9,* 2639.

Tavares, Guilherme Campos, Pereira, F. L., Barony, G. M., Rezende, C. P., Marques, W., Henrique, G., … Figueiredo, P. (2019). Delineation of the pan-proteome of fish- pathogenic *Streptococcus agalactiae* strains using a label-free shotgun approach. *BMC Genomics*, *20*(1), 1–22.

Teatero, S., Athey, T. B. T., Van Caeseele, P., Horsman, G., Alexander, D. C., Melano, R. G., … Fittipaldi, N. (2015). Emergence of serotype IV group B streptococcus adult invasive disease in Manitoba and saskatchewan, Canada, is driven by clonal sequence type 459 strains. *Journal of Clinical Microbiology*, *53*(9), 2919–2926.

Teatero, S., Lemire, P., Dewar, K., Wasserscheid, J., Calzas, C., Mallo, G. V., … Fittipaldi, N. (2016). Genomic recombination leading to decreased virulence of group B streptococcus in a mouse model of adult invasive disease. *Pathogens*, *5*(3), 1–11.

Tenenbaum, T., Spellerberg, B., Adam, R., Vogel, M., Kim, K. S., & Schroten, H. (2007). *Streptococcus agalactiae* invasion of human brain microvascular endothelial cells is promoted by the laminin-binding protein. *Microbes and Infection*, *9*(6), 714–720.

The ASEAN Secretariat Jakarta. (2016). *ASEAN Food Safety Policy*. 1–16. Retrieved from www.asean.org

Tien, N., Ho, C. M., Lin, H. J., Shih, M. C., Ho, M. W., Lin, H. C., … Lu, J. J. (2011). Multilocus sequence typing of invasive group B streptococcus in central area of Taiwan. *Journal of Microbiology, Immunology and Infection*, *44*(6), 430–434.

Tor-Udom, S., Tor-Udom, P., & Hiriote, W. (2006). The prevalence of *Streptococcus agalactiae* (group B) colonization in pregnant women at Thammasat Hospital. *Journal of the Medical Association of Thailand*, *89*(4), 411–414.

Tsai, I. A., Su, Y., Wang, Y. H., & Chu, C. (2022). Alterations in Genes *rib*, *scpB* and pilus island decrease the prevalence of predominant serotype V, Not III and VI, of *Streptococcus agalactiae* from 2008 to 2012. *Pathogens*, *11*(10), 1–10.

Tsai, M. H., Hsu, J. F., Lai, M. Y., Lin, L. C., Chu, S. M., Huang, H. R., … Lu, J. J. (2019). Molecular characteristics and antimicrobial resistance of group B streptococcus strains causing invasive disease in neonates and adults. *Frontiers in Microbiology*, *10*(2), 1–9.

Tuasikal, B. J., Wibawan, I. W. T., Pasaribu, F. H., & Estuningsih, S. (2017). Bacterial protein characterization of *Streptococcus agalactiae* by SDS-page method for subclinical mastitis irradiated vaccine materials in dairy cattle. *Atom Indonesia*, *38*(2), 66–70.

Tulyaprawat, O., Pharkjaksu, S., Shrestha, R. K., & Ngamskulrungroj, P. (2021). Emergence of multi-drug resistance and its association with uncommon serotypes of *Streptococcus agalactiae* isolated from non-neonatal patients in Thailand. *Frontiers in Microbiology*, *12*(9), 1–11.

Turner, C., Turner, P., Po, L., Maner, N., De Zoysa, A., Afshar, B., … Nosten, F. (2012). Group B streptococcal carriage, serotype distribution and antibiotic susceptibilities in pregnant women at the time of delivery in a refugee population on the Thai-Myanmar border. *BMC Infectious Diseases*, *12*.

Turrentine, M. A., King, T. L., & Silverman, N. S. (2020). Penicillin allergy in pregnancy: moving from "rash" decisions to accurate diagnosis. *Obstetrics and Gynecology*, *135*(2), 401–408.

Uchiyama, S., Sun, J., Fukahori, K., Ando, N., Wu, M., Schwarz, F., … Nizet, V. (2019). Dual actions of group B streptococcus capsular sialic acid provide resistance to platelet-mediated antimicrobial killing. *Proceedings of the National Academy of Sciences of the United States of America*, *116*(15), 7465–7470.

Van Der Mee-Marquet, N., Domelier, A. S., Salloum, M., Violette, J., Arnault, L., Gaillard, N., … Quentin, R. (2009). Molecular characterization of temporally and geographically matched *Streptococcus agalactiae* strains isolated from food products and bloodstream infections. *Foodborne Pathogens and Disease*, *6*(10), 1177–1183.

Van Doan, H., Hoseinifar, S. H., Hung, T. Q., Lumsangkul, C., Jaturasitha, S., Ehab El-Haroun, & Paolucci, M. (2020). Dietary inclusion of chestnut (Castanea sativa) polyphenols to Nile tilapia reared in biofloc technology: Impacts on growth, immunity, and disease resistance against *Streptococcus agalactiae*. *Fish and Shellfish Immunology*, *105*, 319–326.

Van Doan, H., Soltani, M., Leitão, A., Shafiei, S., Asadi, S., Lymbery, A. J., & Ringø, E. (2022). Streptococcosis a re-emerging disease in aquaculture: significance and phytotherapy. *Animals*, *12*(18), 1–32.

Van Kassel, M. N., Janssen, S. W. C. M., Kofman, S., Brouwer, M. C., van de Beek, D., & Bijlsma, M. W. (2021). Prevalence of group B streptococcal colonization in the healthy non-pregnant population: a systematic review and meta-analysis. *Clinical Microbiology and Infection*, *27*(7), 968–980.

Van Sorge, N. M., Cole, J. N., Kuipers, K., Henningham, A., Aziz, R. K., Kasirer-Friede, A., … Nizet, V. (2014). The classical lancefield antigen of group A streptococcus is a virulence determinant with implications for vaccine design. *Cell Host and Microbe*, *15*(6), 729–740.

Ventola, C. L. (2015). The antibiotic resistance crisis: part 1: causes and threats. *Pharmacy and Therapeutics*, *40*(4), 277–283.

Villanueva-Uy, M. E. sterlit., Wongsiridej, P., Sangtawesin, V., Chiu, V., Tallo, V., Nazaire-Bermal, N., … Boudville, I. (2015). The burden of invasive neonatal group B streptococcal (GBS) disease in Thailand and the Philippines. *The Southeast Asian Journal of Tropical Medicine and Public Health*, *46*(4), 728–737.

Villareal, K., Goslin, A., & Bajracharya, H. (2021). Group B streptococcus meningitis associated with acute otitis media in an adult patient. *American Journal of Case Reports*, *22*(1), 7–9.

Wang, C.-H., Kung, W.-J., Lee, C.-H., Lee, C.-F., Kao, C.-L., Chen, H.-C., … Lin, C.-C. (2022). High rates of colonization and antimicrobial resistance of group B streptococcus highlight the need for vaccination even after implementation of guidelines for intrapartum antibiotic prophylaxis. *Vaccine*, *40*(2), 282–287.

Wang, H. Y., Li, W. C., Huang, K. Y., Chung, C. R., Horng, J. T., Hsu, J. F., … Lee, T. Y. (2019). Rapid classification of group B streptococcus serotypes based on matrix-assisted laser desorption ionization-time of flight mass spectrometry and machine learning techniques. *BMC Bioinformatics*, *20*(19), 1–17.

Wang, R., Li, L. P., Huang, T., Lei, A. Y., Huang, Y., Luo, F. G., … Huang, J. (2017). Genomic comparison of virulent and non-virulent serotype V ST1 *Streptococcus agalactiae* in fish. *Veterinary Microbiology*, *207*(1), 164–169.

Wang, R., Li, L., Huang, T., Huang, W., Lei, A., & Chen, M. (2018). Capsular switching and ICE transformation occurred in human *Streptococcus agalactiae* ST19 with high pathogenicity to fish. *Frontiers in Veterinary Science*, *5*(11), 1–8.

Wang, S., Li, L., Wu, B., & Wu, W. (2018). Serotype, genotype, and clinical manifestations of group B streptococcus (GBS) isolated from neonates in China. *Iranian Journal of Pediatrics*, *28*(1), 1–6.

Watkins, L. K. F., Mcgee, L., Schrag, S. J., Beall, B., Jain, J. H., Pondo, T., … Langley, G. E. (2019). Epidemiology of invasive group B streptococcal infections among nonpregnant adults in the United States, 2008-2016. *30329*(4), 479–488.

Wichgers Schreur, P. J., Rebel, J. M. J., Smits, M. A., van Putten, J. P. M., & Smith, H. E. (2011). Troa of *Streptococcus suis* is required for manganese acquisition and full virulence. *Journal of Bacteriology*, *193*(19), 5073–5080.

Wong, S. S., Tsui, K., Liu, Q. D., Lin, L. C., Tsai, C. R., Chen, L. C., & Huang, C. H. (2011). Serotypes, surface proteins, and clinical syndromes of invasive group B streptococcal infections in northern Taiwan, 1998-2009. *Journal of Microbiology, Immunology and Infection*, *44*(1), 8–14.

World Health Organization. (2019). Manag ing public health risks at the human-animal environment interface. Geneva: Department of Essential Medicines and Health Products. Retrieved from https://www.who.int/zoonoses/en/

Wu, B., Su, J., Li, L., Wu, W., Wu, J., Lu, Y., … Liang, X. (2019). Phenotypic and genetic differences among group B Streptococcus recovered from neonates and pregnant women in Shenzhen, China: 8-year study. *BMC Microbiology*, *19*(1), 1–9.

Xu, Z., Lu, Z., Soteyome, T., Chen, L., Liang, Y., Bai, C., … Kjellerup, B. V. (2020). Resistome and virulome study on pathogenic *Streptococcus agalactiae* Guangzhou-SAG036. *Microbial Pathogenesis*, *147*(1), 104258.

Yadeta, T. A., Worku, A., Egata, G., Seyoum, B., Marami, D., & Berhane, Y. (2018). Vertical transmission of group B streptococcus and associated factors among pregnant women: A cross-sectional study, Eastern Ethiopia. *Infection and Drug Resistance*, *11*, 397–404.

Yamamoto, Y., Pargade, V., Lamberet, G., Gaudu, P., Thomas, F., Texereau, J., … Poyart, C. (2006). The group B streptococcus NADH oxidase Nox-2 is involved in fatty acid biosynthesis during aerobic growth and contributes to virulence. *Molecular Microbiology*, *62*(3), 772–785.

Yanagawa, R., Otsuki, K., & Tokui, T. (1968). Electron microscopy of fine structure of Corynebacterium renale with special reference to pili. *Japanese Journal of Veterinary Research*, *16*, 31–37.

Yang, Q., Yu, X., Du, C., Ni, X., Li, W., Yao, W., & Wu, Z. (2021). Bacterial challenge undermines the innate immune response in *Hyriopsis cumingii*. *Aquaculture*, *530*.

Yao, K., Poulsen, K., Maione, D., Rinaudo, C. D., Baldassarri, L., & Telford, J. L. (2013). Capsular gene typing of *Streptococcus agalactiae* compared to serotyping by latex agglutination. *Journal of Clinical Microbiology*, *51*(2), 503–507.

Yin, X., Mu, L., Wu, H., Han, K., Guo, Z., & Ye, J. (2020). Expression and functional analysis of Nile tilapia transferrin receptors (TfRs) in host resistance to pathogenic bacteria and iron ion metabolism. *Fish and Shellfish Immunology*, *100*, 407–417.

Yuan, X.-Y., Liu, H.-Z., Liu, J.-F., Sun, Y., & Song, Y. (2021). Pathogenic mechanism, detection methods and clinical significance of group B streptococcus. *Future Microbiology*, *16*(9), 671–685.

Yura, T. H. N., & Mori, H. (1993). Regulation of the heat-shock response in bacteria. *Annual Review of Microbiology(*, *47*(1), 321–351.

Zamri-Saad, M., Amal, M. N. A., Siti-Zahrah, A., & Zulkafli, A. (2014). Control and prevention of Streptococcosis in cultured tilapia in Malaysia : A review. *Pertanika Journal of Tropical Agricultural Science*, *37*(4), 390–410.

Zhang, L., Kang, W. J., Zhu, L., Xu, L. J., Guo, C., Zhang, X. H., … Ma, L. (2021).