FARMERS’ INTENTION TO ADOPT IMPROVED TECHNOLOGIES FOR DISEASE PREVENTION IN SHRIMP FARMING IN PENINSULAR 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 Master of Science

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DEDICATION

I dedicate this hard work to both of my parents

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

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May 2023

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Two marine shrimp species namely, native giant tiger prawn (*Penaeus monodon*) and non-native white shrimp (*Penaeus vannamei*) are mostly farmed in Malaysia. Diseases are undeniably the most important encounters confronted by the shrimp industry caused by bacterial, viral, fungus, and protozoa, significantly affecting the giant tiger prawn and white shrimp production. Shrimp farming should have a greater need for antibiotics and antimicrobial treatments to treat the diseases as well as to increase its production and productivity. Nevertheless, overuse of antibiotics and antimicrobial drugs had caused antimicrobial resistance (AMR) problems in shrimp farming which can cause an effect on human health and the environment in the long term. Hence, improved technologies for solving the AMR problems by eliminating the heavy usage of antibiotics in shrimp farming are needed. The main objective of this study was to determine shrimp farmers' intention to adopt improved technologies for disease prevention in shrimp farming in Peninsular Malaysia.

Using the stratified random sampling method, a total of 123 shrimp farmers located in Peninsular Malaysia were selected based on four (4) regions, and a structured questionnaire was used to obtain responses from the shrimp farmers. Several statistical analyses were carried out to analyse the data such as descriptive analysis, Pearson correlation analysis, Chi-square analysis, factor analysis, and logistics regression analysis.

The results showed that most of the shrimp farmers have adequate knowledge (63.4%, n=78) of the improved technologies – probiotic, antibody, and green water systems, whereas the remaining 36.6% (n=45) of the shrimp farmers have inadequate knowledge. Most shrimp farmers have a favourable attitude (78.0%, n=96) towards adopting the improved technologies in their farm, while 22.0% (n=27) have an unfavourable attitude. Most of the shrimp farmers (74.0%, n= 91) have a high intention to adopt improved technologies while 26.0% (n=32) of shrimp farmers have a low intention. There was a moderately significant positive relationship between the shrimp farmers' knowledge and their attitude to adopt improved technologies for disease prevention in shrimp farming. Educational level, farmers' experience, farm size, training, and monthly revenue were significantly associated with shrimp farmers' intention to adopt the improved technologies. Four (4) factors were extracted from factor analysis namely attitude, perceived behavioural control, subjective norm, and perceived resources and these factors were further measured in logistic regression analysis. Farmers' educational level, farmers' experience, attitude, subjective norm, and perceived resources were identified as the factors that influenced shrimp farmers' intention to adopt improved technologies. Further, farmers' attitude was revealed as the most influential factor that influenced shrimp farmers' intention to adopt improved technologies for disease prevention in their farming.

The study indicated that the majority of shrimp farmers had a high intention to adopt improved technologies. Attending relevant training programs can increase the farmers' knowledge and having a good and strong collaboration with a few shrimp farms can promote the benefits of improved technologies on a broad scale. Government should provide relevant training programs, webinars, hands-on workshops, and financial incentives to motivate the farmers in spreading their knowledge of the importance of adopting these technologies.

Keywords: Attitude, Improved technologies, Disease prevention, Shrimp Farming, Peninsular Malaysia

SDG: Goal 12: Responsible Consumption and Production

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

NIAT PETANI UNTUK MENGGUNAKAN TEKNOLOGI DIPERBAHARUI UNTUK PENCEGAHAN PENYAKIT DALAM PENTERNAKAN UDANG DI SEMENANJUNG MALAYSIA

Oleh

AMIRA HANANI BINTI AZALI @ SAZALI

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Dua spesies udang marin iaitu udang harimau raksasa asli (*Penaeus monodon*) dan udang putih bukan asli (*Penaeus vannamei*) kebanyakannya diternak di Malaysia. Penyakit adalah masalah utama yang dihadapi oleh industri udang disebabkan oleh bakteria, virus, kulat, dan protozoa yang mempengaruhi pengeluaran udang harimau dan udang putih. Penternakan udang memerlukan antibiotik dan rawatan antimikrobial yang lebih besar untuk merawat penyakit serta meningkatkan pengeluaran dan produktiviti. Namun, penggunaan antibiotik dan ubat antimikrobial secara berlebihan telah menyebabkan masalah ketahanan antimikrobial (AMR) dalam penternakan udang yang boleh memberi kesan kepada kesihatan manusia dan alam sekitar dalam jangka masa panjang. Justeru, teknologi yang lebih baik diperlukan untuk menyelesaikan masalah AMR dengan menghapuskan penggunaan antibiotik yang berlebihan dalam penternakan udang. Objektif utama kajian ini adalah untuk menentukan niat penternak udang untuk menggunakan teknologi diperbaharui untuk pencegahan penyakit dalam penternakan udang di Semenanjung Malaysia.

Dalam kajian ini, kaedah persampelan rawak berstrata digunakan untuk memilih 123 penternak udang di Semenanjung Malaysia berdasarkan empat (4) kawasan dan satu borang soal selidik berstruktur digunakan untuk mendapatkan respons daripada penternak udang. Beberapa analisis statistik telah dijalankan untuk menganalisis data seperti analisis deskriptif, analisis korelasi Pearson, analisis chi-square, analisis faktor, dan analisis regresi logistik.

Hasil kajian menunjukkan bahawa kebanyakan penternak udang mempunyai pengetahuan yang mencukupi (63.4%, n=78) mengenai teknologi diperbaharui

- probiotik, antibodi, dan sistem air hijau, manakala 36.6% (n=45) lagi daripada penternak udang mempunyai pengetahuan yang tidak mencukupi. Kebanyakan penternak udang mempunyai sikap yang baik (78.0%, n=96) terhadap penggunaan teknologi diperbaharui dalam penternakan mereka, manakala 22.0% (n=27) mempunyai sikap yang tidak baik. Kebanyakan penternak udang (74.0%, n=91) mempunyai niat yang tinggi untuk menggunakan teknologi diperbaharui, manakala 26.0% (n=32) daripada penternak udang mempunyai niat yang rendah. Terdapat hubungan positif yang signifikan sederhana antara pengetahuan penternak udang dan sikap mereka untuk menggunakan teknologi diperbaharui untuk pencegahan penyakit dalam penternakan udang. Tahap pendidikan, pengalaman penternak, saiz ladang, latihan, dan pendapatan bulanan berkait rapat dengan niat penternak udang untuk menggunakan teknologi diperbaharui. Empat (4) faktor telah diekstrak daripada analisis faktor iaitu sikap, kawalan tingkah laku yang dirasai, norma subjektif, dan sumber yang dirasai. Faktor-faktor ini kemudiannya digunakan dalam analisis regresi logistik. Tahap pendidikan penternak, pengalaman penternak, sikap, norma subjektif, dan sumber yang dirasai dikenal pasti sebagai faktor yang mempengaruhi niat penternak udang untuk mengambil teknologi yang lebih baik. Selain itu, sikap penternak adalah faktor yang paling berpengaruh dalam mempengaruhi niat penternak udang untuk menggunakan teknologi diperbaharui untuk pencegahan penyakit dalam penternakan mereka.

Kajian menunjukkan bahawa majoriti penternak udang mempunyai niat yang tinggi untuk menggunakan teknologi diperbaharui. Menghadiri program latihan yang berkaitan dapat meningkatkan pengetahuan para penternak dan mempunyai kerjasama yang baik dan kukuh dengan beberapa penternakan udang juga boleh mempromosikan faedah teknologi diperbaharui pada skala yang luas. Kerajaan harus menyediakan program latihan yang berkaitan, webinar, bengkel praktikal, dan insentif kewangan untuk memotivasikan para penternak dalam menyebarkan pengetahuan mereka tentang kepentingan menggunakan teknologi ini.

Kata Kunci: Sikap, Teknologi diperbaharui, Pencegahan penyakit, Penternakan Udang, Semenanjung Malaysia

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LIST OF ABBREVIATIONS

AHPND	Acute Hepatopancreatic Necrosis Disease
AIZ	Aquaculture Industrial Zone
AMR	Antimicrobial Resistance
ARB	Antibiotic-Resistant Bacteria
ARGs	Antibiotic-Resistant Genes
ASEAN	Association of Southeast Asian Nations
BFT	Biofloc Technology
Ca-SP	Calcium Spirulan
DoF	Department of Fisheries
DoSM	Department of Statistics Malaysia
EMS	Early Mortality Syndrome
ETP	Malaysia Economic Transformation Programme
EU	European Union
FAO	Food and Agricultural Organisation of United Nations
FRI	Fisheries Research Institute Malaysia
GAqP	Good Aquaculture Practices
GDP	Gross Domestic Product
GFT	Green Fertiliser Technology
H_{01}, H_{02}, H_{03}	Null Hypothesis
H_{a1}, H_{a2}, H_{a3}	Alternative Hypothesis
HACCP	Hazard Analysis Critical Control Point
HFMD	Hand, Foot, and Mouth Disease

HGT	Horizontal Gene Transfer
HP	Hepatopancreas
IATs	Improved Agricultural Technologies
ICT	Information and Communications Technology
IPA	Intensive Pond Aquaculture
IPM	Integrated Pest Management
IZAQs	Integrated Aquaculture Model
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
MOA	Ministry of Agriculture and Agro-based Industry
MAFS	Ministry of Agriculture and Food Security
MRL	Maximum Residue Levels
NAFP	Malaysia's National Agrofood Policy
NAP	National Agrofood Policy
NPRA	National Pharmaceutical Regulatory Agency
PBC	Perceived Behaviour Control
PCC	Per Capita Consumption
PEMANDU	Performance Management and Delivery Unit
PPK	Pertubuhan Peladang Kawasan
PRP	Preliminary Farm Certification Program
QQ	Quorum Quenching
RAS	Recirculation Aquaculture Systems
R&D	Research and Development
SCS	Soil Organic Carbon Sequestration
SN	Subjective Norm
SPLAM	Skim Pensijilan Ladang Akuakultur Malaysia

SPSS	Statistical Package for the Social Science
SSL	Self-Sufficiency Level
SSR	Self-Sufficiency Ratio
TPB	Theory of Planned Behaviour
TRA	Theory of Reasoned Action
TSVD	Taura Syndrome Virus Disease
WHO	World Health Organization
WSD	White Spot Disease
WSS	White Spot Syndrome
WSSV	White Spot Syndrome Virus
YHV	Yellow Head Virus Disease

CHAPTER 1

INTRODUCTION

The first chapter of this thesis provides a brief description of the aquaculture industry and an overview of the fisheries industry in Malaysia. Types of aquaculture farming are outlined, followed by shrimp production, diseases in shrimp farming, and issues in shrimp farming. The chapter discusses issues and challenges related to the industry; the problem statement and research questions that motivated the study, which leads to the objectives of the study, and significance of the study. The chapter concludes with the organisation of the thesis.

1.1 Overview of Fisheries Sector in Malaysia

Seafood is one of the most traded food commodities in the world, providing livelihood and a source of income to people in many underdeveloped countries and supplying more than 15% of an individual's animal protein diet on average (El-Saadony et al., 2022; Smith et al., 2010). Malaysia is a Southeast Asian country divided into two distinct regions, namely Peninsular Malaysia, also known as West Malaysia, and East Malaysia, also known as the Borneo States (Bee et al., 2022). According to the Department of Statistics Malaysia (DoSM), Malaysia covers a total area of 329,847 km² with a population of 32.7 million in 2022. The growth in the human population also means a parallel increase in food intake (DoSM, 2022). The Food and Agricultural Organisation of United Nations (FAO) stated that fish meal is an essential source of animal protein for the Malaysian population and therefore the fisheries sector is crucial for ensuring food security for the world's rising population (FAO, 2019; Ghee-Thean et al., 2016).

According to Jumatli and Ismail (2021) and FAO (2019), marine capture fisheries and aquaculture are generally considered to be the two major components of fisheries in Malaysia. In 2017, the country's overall fisheries production was 1.7 million tonnes, contributed by marine capture (1.5 million tonnes) and aquaculture excluding seaweed (0.2 million tonnes). According to Kurniawan et al. (2021) and the Department of Fisheries, DoF (2020), Malaysian aquaculture includes both food (brackish water fish, freshwater fish, and seaweed) and non-food (ornamental fish and aquatic plant) products and currently comprised more than 49,989 fish farmers and cultivators.

According to Thiang et al. (2021), Malaysia is ranked 15th in the world and sixth in Asia in terms of aquaculture production consisting of freshwater fish, marine fish or prawn, and seaweed products, with an estimated output of 427,022.66 metric tonnes valued at USD 731.81 million. This makes the aquaculture sector as a promising component for bolster the Malaysia's economic growth (Thiang et al., 2021; SEAFDEC, 2017; Lundgren, Staples et al., 2006). Accordingly, the importance of aquaculture output in Malaysia's economic growth has been emphasised in the National Agro-Food Policy (NAFP 2011-2020) as the key priority in strengthening the competitiveness of Malaysia's agriculture sector (Jumatli & Ismail, 2021).

Figure 1.1 depicts the gross value added of the agriculture sector according to economic activity in 2021. It shows that Malaysia's Gross Domestic Product (GDP) increased by 3.1% amounting to RM1,386.7 billion compared to 2020 (RM1,345.1 billion). In particular, the fisheries sector contributes 11.3% to Malaysia's economic position in 2021 compared to 2020 (11.2%), with the percentage change of -0.6%.

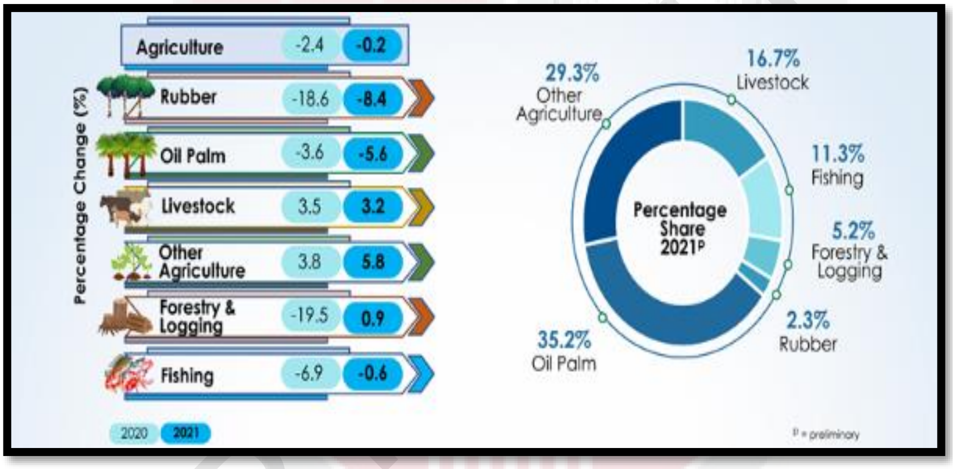

Figure 1.1: Gross Value Added of Agriculture Sector according to Economic Activity (Constant 2015 Prices)
(Source: Department of Statistics Malaysia, 2022)

Figure 1.2 shows the production of selected agriculture and the number of livestock in 2021. The total marine fish landings production in 2021 is 1,328.0 thousand tonnes, a 4.0% decrease from 1,383.3 thousand tonnes in 2020. The decline was attributed to the reduction in the number of deep-sea vessel operations due to the limits of immigrant labour re-entry (DoSM, 2021). Meanwhile, the production of freshwater and brackish water aquaculture increased by 9.0% and 2.8% respectively compared to 2020.

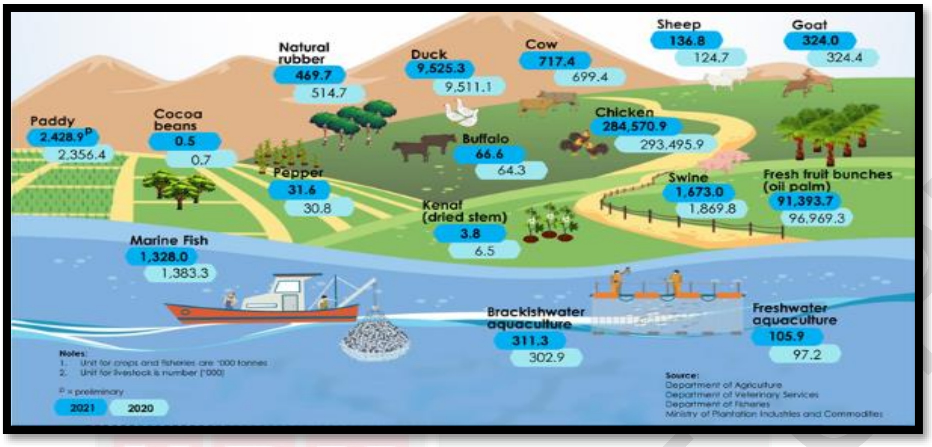

Figure 1.2: Production of Selected Agriculture and Number of Livestock 2021
(Source: Department of Statistics Malaysia, 2022)

Table 1.1 presents the production and value of fisheries in Malaysia from 2017 to 2021. The fisheries sector contributed RM1,386.7 billion compared to RM1,345.1 billion in 2020, which is an increase by 3.1% from the previous year. The edible fish comprises marine capture fisheries, aquaculture, and inland fisheries, and the total food fish from 2019, 2020, and 2021 declined significantly from 1,872,797.24 tonnes to 1,750,790.22 tonnes. The marine capture fisheries is the highest of the production of fisheries in Malaysia (2021), which include in shore and deep-sea (1,328,041 tonnes). Meanwhile, the aquaculture was reported to be the second highest contributor for the production of fisheries in Malaysia, which include freshwater, brackish water, and seaweed, with a total production of 417,187.68 tonnes. Inland fisheries supply 5,561.94 tonnes to the total production of fisheries in Malaysia in 2021.

Non-edible fish, on the other hand, which comprises ornamental fish and aquatic plants, recorded an increasing trend from 2018 to 2020. However, the overall value of non-edible fish was valued at RM5,558.09 million, which is a substantial improvement from the previous years.

Table 1.1: Production and Value of Fisheries in Malaysia (2017-2021)

Year		2017		2018		2019		2020		2021	
Fisheries sector		Quantity (tonnes)	Value (RM mil)	Quantity (tonnes)	Value (RM mil)	Quantity (tonnes)	Value (RM mil)	Quantity (tonnes)	Value (RM mil)	Quantity (tonnes)	Value (RM mil)
Food Fish	In shore	1,170,270	9,220.34	1,192,722	9,838.28	1,192,354	9,785.94	1,169,201	8,908.93	1,168,972	9,778.01
	Deep-sea	294,842	1,598.50	260,140	1,474.55	263,093	1,550.38	214,098	1,189.32	159,070	1,024.81
	Total Marine Capture Fisheries	**1,465,113**	**10,818.85**	**1,452,862**	**11,312.83**	**1,455,446**	**11,336.32**	**1,383,299**	**10,098.25**	**1,328,041**	**10,802.83**
	Freshwater	102,596.83	728.1	101,269.88	711.09	104,601.56	780.50	97,210.32	766.47	105,904.01	8,563.54
	Brackish water	121,453.02	2,268.1	116,112.08	2,293.68	119,069.47	2,458.2	120,746.25	2,289.39	132,395.55	2,516.45
	Seaweed	202,965.58	44.661	174,083.20	52.224	188,111.10	66.850	182,061.00	58.873	178,888.12	57.54
	Total Aquaculture	**427,015.43**	**3,040.9**	**391,465.16**	**3,057.00**	**411,782.14**	**3,304.6**	**400,017.57**	**3,114.74**	**417,187.68**	**3,430.34**
	Total Inland Fisheries	**5,177.19**	**93.31**	**6,089.08**	**124.36**	**5,568.70**	**90.17**	**5,625.14**	**83,178,104**	**5,561.94**	**9,389.16**
	Total Food Fish	**1,897,305.45**	**13,953.1**	**1,850,416.54**	**14,494.2**	**1,872,797.24**	**14,731.12**	**1,788,941.54**	**13,296.16**	**1,750,790.22**	**14,327.06**

Table 2.1: Continued

Year		2017		2018		2019		2020		2021	
Fisheries sector		**Quantity (tonnes)**	**Value (RM mil)**	**Quantity (tonnes)**	**Value (RM mil)**	**Quantity (tonnes)**	**Fisheries sector**	**Quantity (tonnes)**	**Value (RM mil)**	**Quantity (tonnes)**	**Value (RM mil)**
Non-Food Fish	Ornamental Fish*	402,301,230	456.0	324,813,016	327.0	287,531,539	5,06.47	227,944,067	494.41	2,4249.8	5,343.60
	Aquatic Plants**	339,519,589	215.0	112,249,911	13.0	51,705,533	20.64	41,990,762	53.573	2,4413.66	2,14.49
	Total Non-Food Fish	**N.A.**	**671.0**	**N.A.**	**340.0**	**N.A.**	**527.0**	**N.A.**	**548.0**	**N.A.**	**556.8**
	Grand Total	**N.A.**	**14,625.0**	**N.A.**	**14,834.45**	**N.A.**	**15,258.22**	**N.A.**	**13,844.14**	**N.A.**	**14,882.87**

Note: *Quantity in pieces
**Quantity in bundles
N.A.: Not available
(Source: Department of Fisheries, 2017-2021)

1.1.1 Types of Aquaculture Practices in Malaysia

Since its inception in the 1920s, aquaculture in Malaysia has quickly grown to become a significant part of the economy (FAO, 2013). According to Ntsama et al. (2018), the production of aquatic creatures, such as fish, molluscs, crustaceans, and aquatic plants, is known as aquaculture. There are several culture practices in Malaysia, namely freshwater aquaculture, marine aquaculture, and brackish water aquaculture (Chowdhury et al., 2014; Hashim & Kathamuthu, 2005).

Freshwater aquaculture mostly produces fish as well as other species including crab, shrimp, and aquatic plants. This is done by utilising a culture system that is established based on economic factors, such as ponds, flow-through, recirculation aquaculture systems (RAS), or other inland waterways (Ahmad et al., 2021; Li & Liu, 2019). Kurniawan et al. (2021) stated that even though it is one of the oldest and most established, the pond system is still the best one for growing freshwater aquaculture products. According to Mohamad et al. (2021) after the African catfish, *Clarias gariepinus*, tilapia is the second most widely farmed freshwater fish in Malaysia. Red hybrid tilapia is the variety that fish farmers prefer to cultivate, and they are responsible for more than 94% of the nation's tilapia output (DOF, 2020).

Next, mariculture, or known as marine culture, is a practice that depends on the salinity of the water, and this is done in the sea or along the coast (Ahmad et al., 2021). It is a type of aquaculture that involves the cultivation of marine creatures in open or closed seas/oceans, as well as the use of man-made facilities, such as cages or ponds for fish culture, which can be managed traditionally, extensively, semi-intensively, or intensively (Ahmad et al., 2021; Joseph & Augustine, 2020). Seaweeds, molluscs, crabs, and fish are among the most common species cultivated in mariculture.

The brackish water aquaculture is characterized by the extensive culture of bivalve molluscs, occupying the area of 7,659 ha, mostly in the western coastal (FAO, 2013). The most common species cultured in brackish water includes bivalve molluscs, such as blood cockles (*Anadara granosa*), followed by shrimps, tiger prawns (*Penaeus monodon*), and marine fish (FAO, 2013). According to Fisheries Research Institute Malaysia (FRIM), commonly cultured shrimp and prawn in brackish water include white shrimp (*Penaeus vannamei*), banana shrimp (*Fenneropenaeus merguiensis*), tiger prawn (*Penaeus monodon*) and others (FRIM, 2021). The concentration of salinity differentiates the water type, with the salinity values of 0.05 ppt, 0.5-30 ppt, and >30 ppt for freshwater, brackish water, and sea water, respectively (Ahmed & Thompson, 2019).

Malaysia's aquaculture sector is considered relatively minor in comparison to neighbouring countries, such as Thailand, Indonesia, the Philippines, and

Vietnam (Jumatli & Ismail, 2021; Roslina & Amir, 2018). Numerous programs have been established by the Malaysian government to boost the aquaculture performance, such as the Aquaculture Industrial Zone (AIZ) project established by the Ministry of Agriculture and Agro-based Industry (MOA), which is currently known as the Ministry of Agriculture and Food Security (MAFS) through Department of Fisheries Malaysia (DoF), in 2003. The AIZ is generally a designated zone for both lands and bodies of water that are provided by the state government for commercial scale aquaculture ventures. The development of AIZ has converted the aquaculture industry into a more technological activity supported by a large market contribution to boost national food production and overcome the captured fish output gap. Since then, the aquaculture sector has been recognised for its ability to supply both local need for high-value protein source and trade demand for fish products (Jumatli & Ismail, 2021; Thiang et al., 2021).

The aquaculture industry has helped the country on both local and international levels by achieving the goal of fish production, with deserving recognition to private sector technological and research skills as an asset for economic development (Jumatli & Ismail, 2021). The importance of aquaculture output to Malaysia's economic growth has been emphasised in the National AgroFood Policy 2.0 (NAFP 2021-2030) as the key priority in strengthening Malaysia's agriculture sector's competitiveness (MAFS, 2021). Malaysia's National Agrofood Policy 2021-2030 (NAP 2.0) was developed with the goal of establishing a sustainable, competitive, and technology-based agro-food industry that drives economic expansion, improves people's well-being, and prioritises food security and nutrition.

1.1.2 Shrimp Production

Shrimp and prawns have traditionally been among the most extensively traded aquatic commodities. Most of the supply currently goes to customers in high-income markets in North America, Europe, and Japan, and is produced largely through industrial shrimp farming operations in Latin America and East and Southeast Asia (FAO, 2022). Roslina (2018) stated that Malaysian aquaculture was developed with three (3) main goals: 1) to improve the country's food security, raise revenue and export profits, 2) to improve the country's food security, raise revenue and export profits, and 3) to maximise producer income and reduce poverty. Consumer preferences have led to an increase in both international and domestic demand for shrimp products. For instance, consumers are more likely to consume white meat (seafood products) than red meat (ruminant products), hence the increased preference to seafood (Ghee-Thean et al., 2016).

The Performance Management and Delivery Unit (PEMANDU) has identified shrimp as one of the target species in Malaysian agriculture, as part of the Malaysia Economic Transformation Programme (ETP) (2010-2020), with the goal of improving shrimp output and productivity (PEMANDU, 2010). Several actions were proposed to improve shrimp production, such as to produce a fully certified and traceable seafood in a suitable way through Integrated Aquaculture Model (IZAQs) in response to the increasing global demand for fully certified and traceable seafood from 20,000 metric tonnes to 600,000 metric tonnes (PEMANDU, 2010). The establishment of an research and development (R&D) facility that will focus on developing a breeding programme for shrimp and also other species, create a fully accredited diagnostic centre to solve the issue of food safety and traceability, launch a trial aquaculture insurance policy, as well as attractive financing programmes to encourage private sector participation in IZAQs and establishing the aquaculture export centres near large airports to allow the shipping of fresh and frozen fish to key importing nations, including Hong Kong, Taiwan, and Japan. Therefore, the aquaculture production will need to be increased by 46.4 million metric tonnes by 2030 to meet the demands of the world's growing population to achieve sustainable food production and security (Thiang et al., 2021; World Bank, 2013).

Table 1.2 and Figure 1.3 show the total production of tiger prawn and white shrimp in Malaysia in 2010. The total production of tiger prawn and white shrimp in Malaysia was 87,2020.61 tonnes, which holds the highest total production in consecutive years (DOF, 2020). However, the production of these two species declined in subsequent years from 2011 (67,472.80 tonnes) to 2013 (49,956.92 tonnes) but showed some increased value in 2017 (45,780.96 tonnes) until 2019 (53,400.03 tonnes). On the other hand, the production of tiger and white shrimp surged by 22.88% in 2014 (61,386.35 tonnes) compared to in 2013 (10.1%, 49,956.92 tonnes), which shows the highest total production after 2010. Although the total production increased in 2017 (45,780.96 tonnes), the trend of total yield showed an unbalanced trend, thus the low productivity of Malaysia shrimp aquaculture can be concluded that the industry is facing minimum of total productions. Furthermore, Malaysian white shrimp farmers realised that their production could not compete with other ASEAN countries, such as Thailand, Vietnam, and Philippines (Ghee-Thean et al., 2016). In 2019, the tiger prawn and white shrimp had the highest wholesale (RM' 000) and retail (RM' 000) values in Malaysia, totalling RM 1,256,378.72 and 1,478,639.54, respectively (DOF, 2020).

Table 1.2: Aquaculture Production of Tiger Prawn and White Shrimps in Malaysia (2010-2020)

Year	Production (Tonnes)	Wholesale value (RM' 000)	Retail value (RM'000)
2010	87,202.61	1,178,964.59	1,491,253.25
2011	67,472.80	888,600.33	1,115,406.96
2012	55,569.06	755,549.73	992,600.44
2013	49,956.92	828,027.51	975,347.04
2014	61,386.35	1,252,309.62	1,466,627.70
2015	52,570.49	1,140,956.74	1,327,516.13
2016	43,247.54	918,024.80	1,155,529.53
2017	45,780.96	1,067,124.45	1,284,116.31
2018	45,912.87	1,113,919.68	1,338,236.05
2019	53,400.03	1,256,378.72	1,478,639.54
2020	48,673.41	1,169,079.87	1,405,407.96

(Source: Department of Fisheries Malaysia, 2010-2020)

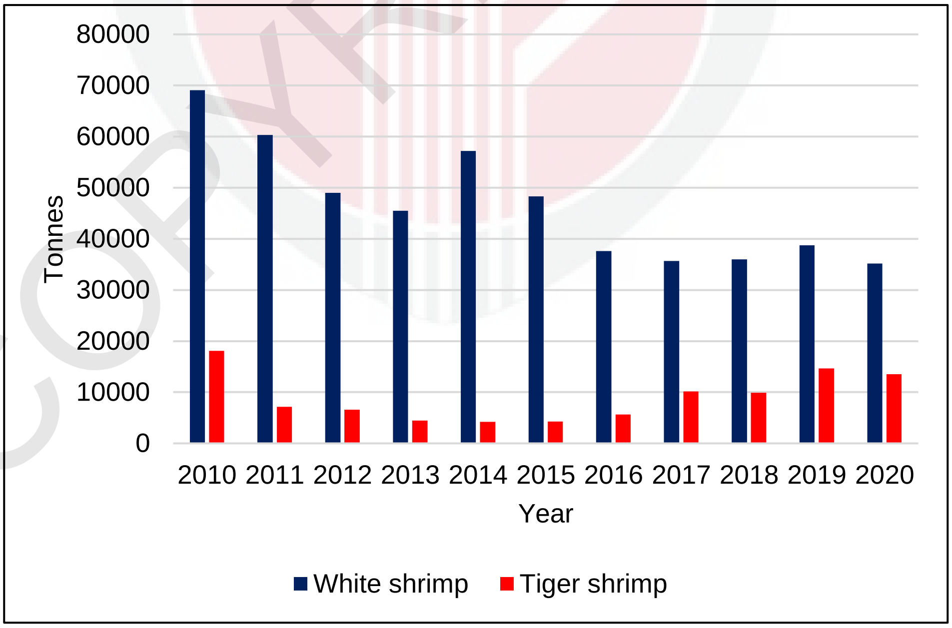

Figure 1.3: Production of Tiger Prawn and White Shrimp in Malaysia
(Source: Department of Fisheries, 2010-2020)

Table 1.3 shows the per capita consumption (PCC) and self-sufficiency ratio (SSR) of shrimp in Malaysia. In 2019 and 2020, Malaysians consumed 4.1 kg of shrimp per year. It is reported that shrimp is one of the highest PCC compared to other fisheries after mackerel (5.7 kg/year) and sardine (2.9 kg/year) (DoSM, 2021). According to the Ministry of Agriculture and Food Security (MAFS), Malaysia's self-sufficiency level (SSL) for fish food already achieved a surplus since 2010. Hence, the SSL for the fisheries and aquaculture subsector is expected to increase from 93.7% in 2021 to 98.0% in 2030, with a CAGR 0.50% (MAFS, 2021). Meanwhile, according to the Food and Agriculture Organization (FAO), SSR indicates the degree to which agricultural commodity supply (output) can satisfy domestic demand. The SSR of 100.0% or more implies that agricultural commodity supply or production is adequate to satisfy the country's demands, and vice versa (DoSM, 2021). Since the SSR of the shrimp exceeded 100.0%, thus the production of shrimp is considered sufficient.

Table 1.3: Per Capita Consumption (PCC) and Self-Sufficiency Ratio (SSR) of Shrimp

Year	Per capita consumption (Kg/Year)	Self-sufficiency ratio (%)
2010	N.A.	N.A.
2011	N.A.	N.A.
2012	N.A.	N.A.
2013	4.0	103.8
2014	4.7	102.5
2015	4.6	100.1
2016	4.1	103.2
2017	3.9	103.1
2018	4.4	100.5
2019	4.0	102.9
2020	4.1	101.7
2021	4.6	100.4

Note: N.A.: Not available
(Source: Department of Fisheries, 2010-2021)

1.2 Types of Diseases in Shrimp Farming

Fishing is one of the sub-sectors that has continuously achieved SSL over 90.00% during the last decade. However, there are several problems mostly connected to climate change and the depletion of natural resources that may have an impact on the efficiency of this subsector in the long term if no changes are to be made. Aquaculture products contributed for just around 21.14% of total fish landings in 2018, demonstrating Malaysia's lack of reliance on aquaculture goods. Furthermore, customer preferences for fishing items capture are higher, which indirectly reduces demand for aquaculture products (MAFS, 2021).

The aquaculture industry has been identified as a potential pillar for bolstering economic growth. Disease infection is a common concern in intensive aquaculture, and it has a significant impact on aquaculture productivity and development (Thiang et al., 2022; Hashim & Kathamuthu, 2005). It is also one of the potential challenges to the sustainability and growth of the shrimp business in many nations (Chowdhury et al., 2014). Furthermore, disease transmission is the fundamental issue in aquaculture farming since water is a catalytic medium for disease spreading and this scenario is compounded by tropical environment. The widespread location of aquaculture farms in Malaysia also makes it difficult for extension officers to track and control diseases in each farm (MAFS, 2021).

The bacterial disease, viral disease, fungal disease, protozoa disease, and other common shrimp diseases always strike shrimp farms in Malaysia and other countries, affecting millions of dollars in losses (Chowdhury et al., 2014). In addition, a bacterial infection is one of the most serious dangers to the aquaculture business globally compared to viruses, fungi, or parasites, which is caused by the fact that they can live in aquatic conditions without the help of their hosts (Anirudhan et al., 2021; Thiang et al., 2021). The interaction between pathogens, hosts and the surrounding pond habitats are significant contributors to disease development (El-Saadony et al., 2022; Kautsky et al., 2000).

According to Chiew et al. (2019) and Stentiford et al. (2012), if diseases are not controlled, farms may lose stock, thereby affecting operations and inhibiting development in the aquaculture industry. Table 1.4 shows the most common diseases in shrimp farming that consists of bacterial disease, viral disease, fungus disease, protozoa disease and other common shrimp diseases.

Table 1.4: Most Common Disease in Shrimp Farming

No.	Causative Agent	Types of Diseases
1.	Bacterial disease	Vibriosis, Filamentous bacterial disease, Acute hepatopancreatic necrosis disease (AHPND)
2.	Viral disease	White Spot Disease (WSD), Taura syndrome virus disease (TSVD), Yellow head virus disease (YHV)
3.	Fungus disease	Larval mycosis and *Fusarium sp*.
4.	Protozoa disease	Ciliate disease, Gregarina, Microspridia
5.	Other common shrimp disease	Red disease, Mycobacteriosis and Rickettsial infection

(Source: El-Saadony et al., 2022; Kua et al., 2018; Chowdhury et al., 2014)

1.2.1 Vibriosis Disease

Repeated bacterial and viral disease outbreaks create significant economic losses for aquaculture farmers (El-Saadony et al., 2022). Vibriosis is the most prevalent bacterial disease affecting shrimp farming. Gram-negative bacteria from the Vibrionaceae family, such as *Vibrio. harveyi*, *Vibrio alginolyticus*, *Vibrio parahaemolyticus*, *Vibrio vulnifcus*, *Vibrio cholera*, and *Vibrio splendidus*, cause vibriosis (El-Saadony et al., 2022; Jayasree et al., 2006). According to Figure 1.4, *Vibrio parahaemolyticus* is a Gram-negative, halophilic, curved rod-shaped bacteria that thrives commonly in brackish and marine habitats worldwide (Anirudhan et al., 2021; Letchumanan et al., 2015; Wu et al., 2014; Zhang & Orth, 2013).

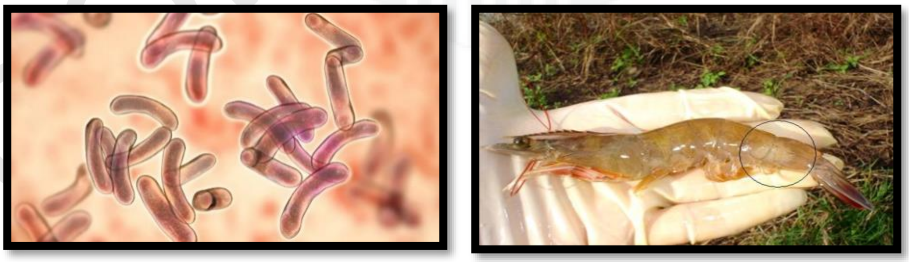

Figure 1.4: *Vibrio Parahaemolyticus* and Vibriosis Disease That Affect Shrimp
(Source: Newman, 2022)

V. parahaemolyticus is naturally found in Malaysia's sea coastal zone due to its prevalence in saltwater; the bacterium can employ seafood as a vehicle of transmission and cause seafood-borne gastroenteritis (Letchumanan et al., 2015). When shrimps are stressed by conditions, such as poor water quality, overcrowding, high water temperature, and inadequate water exchange, vibriosis can cause mass mortality (Rakesh et al., 2018; Adams, 1991). Vibriosis disease appears in hatcheries as luminescence in pond water or inside the shrimp body. Increased levels of *Vibrio spp.* in grow-out ponds are linked to both internal and external necrosis; infection in the ponds resulted in lower feeding rates, gastrointestinal disturbance, red staining of shrimp (especially the tail), high mortality, and reduced immunity, making shrimp more susceptible to secondary infection (El-Saadony et al., 2022; Bianchi et al., 2014). A high incidence of fatalities and injuries is normal in post-larvae and early juvenile shrimps. Mature shrimp suffering from vibromyosis may seem hypoxic, with reddening of the body and legs (El-Saadony et al., 2022; Chen, 1992). A research conducted in the early 1980s demonstrated the prevalence of *V. parahaemolyticus* in the Malaysian shrimp processing sector (Letchumanan et al., 2019). Therefore, this bacterium has recently gained public notice due to the frequent rejection of frozen black tiger shrimp from Malaysia sent to the EU countries (Letchumanan et al., 2019, 2015; Al-Othrubi et al., 2014; Abdullah Sani et al., 2013).

1.2.2 Acute Hepatopancreatic Necrosis

Acute hepatopancreatic necrosis disease (AHPND) is a shrimp illness that emerged in 2010 and was originally known as 'early mortality syndrome' (EMS) owing to mass death happening within 10 days after post-stocking in a newly constructed pond (Chiew et al., 2019; Tran et al., 2013). This disease affects both of the black tiger shrimp, *Penaeus monodon* and the whiteleg shrimp, *Penaeus vannamei* (Muthukrishnan et al., 2019). In 2009, AHPND was first detected in Southern China (Zhang et al., 2012). Shortly later, in 2010, the disease was detected in Vietnam (Amatul-Samahahet al., 2020; Lightner et al., 2012). In Malaysia, the disease was reported in 2011 (Kua et al., 2018; Lightner et al., 2012), followed by Thailand in 2012 (Lightner et al., 2012), Mexico in 2013 (Soto-Rodriguez et al., 2015; Nunan et al., 2014), the Philippines in 2015 (Dabu et al., 2017; de la Peña et al., 2015), and the United States of America in 2017 (Dhar et al., 2019; Restrepo et al., 2016). This illness has been detected in shrimp farms all over the world, including Malaysia, where the total economic damage from AHPND was projected to be US$ 0.49 billion between 2011 and 2014 (Amatul-Samahah et al., 2020; Chiew et al., 2019; Kua et al., 2018).

AHPND was originally reported in Malaysia in late 2010 and early 2011, with many infectious diseases emerging during the early stages of whiteleg shrimp cultivation owing to *V. parahaemolyticus* infection (Chiew et al., 2019; Beng Chu Kua et al., 2016). Between 2011 and 2013, the disease caused pond mortalities ranging from 40 to 100% in farmed *P. vannamei* populations, resulting in direct economic losses to the shrimp farmers (Tang & Bondad-Reantaso, 2019).

Vibrio parahaemolyticus has now been identified as the causal agent of AHPND in shrimp; however, not all strains of *Vibrio parahaemolyticus* are capable of triggering AHPND; only those that have acquired the pVA1 plasmid, which contains toxins, are capable of causing AHPND (Amatul-Samahah et al., 2020; Lee et al., 2015; Joshi et al., 2014; Tran et al., 2013). During the first 20 to 30 days of stocking in a grow-out pond, this virus attacks post larvae and juvenile shrimp (Amatul-Samahah et al., 2020; Muthukrishnan et al., 2019). As a result, the infected shrimps have a pale and atrophied hepatopancreas (HP) and an empty stomach, as shown in Figure 1.5 (Amatul-Samahah et al., 2020; Muthukrishnan et al., 2019; Hong et al., 2015; Tran et al., 2013). Pathological characteristics of AHPND include enlarged hepatopancreatic nuclei, sloughed HP cells-blister-like (B) fibrilla (F), resorptive (R) cells, soft shells, lethargy, muscle opacity, slow growth, and secondary infections (Chiew et al., 2019; Muthukrishnan et al., 2019; Tran et al., 2013). According to Kua et al., (2018) and Hong et al. (2015), these infections are usually caused by environmental stress i.e., weather, water quality, improper management, such as overfeeding or overstocking, and poor diet.

Figure 1.5: A Pale and Shrunken Hepatopancreas Due to AHPND
(Source: Hong et al., 2015; Tran et al., 2013)

1.2.3 White Spot Disease

The white spot syndrome virus (WSSV) is the main cause of the serious illness known as “White spot syndrome” (WSS) that causes severe damage to farmed prawns and shrimp (Chiew et al., 2019; Walker & Mohan, 2009). WSSV is a non-occluded enveloped, double-stranded DNA virus with a rod form and a tail-like appendage that belongs to the genus *Whispovirus* in the family Nimaviridae (Chiew et al., 2019; Hossain et al., 2014; Sánchez-Paz, 2010; Escobedo-Bonilla et al., 2008). Since this host group’s viral infections were first identified in the 1960s, both wild and domesticated crustaceans have been affected (Stentiford et al., 2012).

According to Hashim and Kathamuthu (2005), in 1996, the White Spot disease (WSD) devastated shrimp farms in Peninsular Malaysia. WSD kills large numbers of shrimp, especially young shrimp of all ages and sizes, which can completely deplete stocks within 3–10 days of the infection, resulting in substantial economic losses when it happens and farming operations are frequently forced to close (Dacho & Mustafa, 2007; Hashim & Kathamuthu, 2005). Acute and highly pathogenic infections can result in up to 90%-100% mortality in farmed shrimp, particularly black tiger shrimp, within 3–10 days of infection in which the shrimps see a quick decrease in food intake, with visual symptoms characterised by 0.5–2.0 mm diameter white spots and loose cuticle (El-Saadony et al., 2022; Flegel, 2006). Figure 1.6 shows the visual symptoms of WSD on shrimp. According to Oseko (2006), there were several WSS outbreaks that were studied in Malaysia, notably farms in Penang, Kedah, and Sarawak. A study conducted by Dacho and Mustafa (2007) stated that the infection in Sabah was first detected in 1998, and it is suspected to have been brought in illegally by post larvae from a neighbouring country. Changes in salinity and temperature have been identified as the primary risk factors for WSD outbreaks, and they have been found to influence how susceptible shrimp are to WSSV infection (Niu et al., 2022; Millard et al., 2021; Tendencia & Verreth, 2011). Despite several research, there are currently no reliable ways to stop or lower WSSV infections (Niu et al., 2022; Yudiati et al., 2019; Wang et al., 2014).

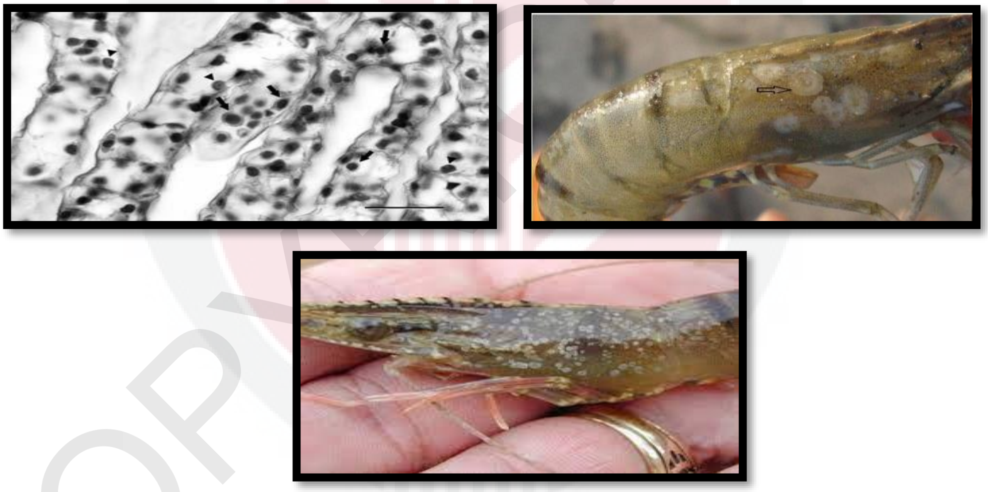

Figure 1.6: White Spot Virus (WSV) and White Spot Disease (WSD) on Shrimp
(Source: El-Saadony et al., 2022; Chiew et al., 2019; Hossain et al., 2014; Flegel, 2006)

1.3 Issues in Shrimp Farming

The aquaculture industry has been suggested as a promising component for bolstering the Malaysia's economic growth (Thiang et al., 2021; SEAFDEC, 2017; Lundgren et al., 2006). The increasing demand for shrimp products on a worldwide and domestic level now derives from the changes in customer taste and preferences, and it is reported that white meat is more likely preferred than red meat (Ghee-Thean et al., 2016). The changeover is said to be caused by outbreaks of mad cow disease and hand, foot, and mouth disease (HFMD) (Ghee-Thean et al., 2016; Ismail & Abdullah, 2013).

In 2010, the total production of tiger and white shrimp in Malaysia was 87,2020.61 tonnes, the highest of total production among the consecutive years; however, Malaysia has felt the impacts as AHPND outbreaks in whiteleg shrimp farms in 2011, 2012, and 2013 resulted in large reductions in shrimp output to 67,000, 55,000, and 50,000 metric tonnes, respectively (Amatul-Samahah et al., 2020; Department of Fisheries Malaysia, 2020; Ghee-Thean et al., 2016). This is because various issues arise from aquaculture operations, including as disease outbreaks in farms and environmental concerns (Chiew et al., 2019; Ashley, 2007; Cao et al., 2007).

1.3.1 Disease Outbreak and Overuse of Antibiotic in Shrimp Farming

Hashim and Kathamuthu (2005) stated that disease can harm culture stocks at any stage of development. Bacterial, viral, fungus, and protozoa diseases are the most common disease that attacks the shrimp in shrimp farming (Anirudhan et al., 2021; Thornber et al., 2020). As a result, many infections, such as Vibriosis, Acute hepatopancreatic necrosis disease, and White spot disease have been reported to have affected shrimp farms throughout Peninsular Malaysia, causing mass mortality in a short period of time (Letchumanan et al., 2019; Kua et al., 2018; Lightner et al., 2012; Hashim & Kathamuthu, 2005). Disease outbreaks should demand an immediate attention and a corresponding swift action owing to the ability to wipe out aquaculture supplies on the farm, which is aided by the ease of disease transmission through the water (Chiew et al., 2019; Leung & Bates, 2013). Furthermore, the combination of stressful situations caused by excessive stocking density in farms and worsening environmental conditions exacerbate disease occurrence and severity (Chiew et al., 2019; Bowden, 2008). According to Chiew et al. (2019) and Stentiford et al., (2012), if diseases are not treated, farms are predicted to lose stock, thereby affecting operation of the system, and restricting the expansion in the aquaculture sector. Precise diagnosis of diseases is even more difficult because many shrimp farmers lack access to professionals or facilities, forcing them to seek treatment guidance from farm supply stores, neighbours, government representatives, non-governmental organizations, or pharmaceutical manufacturers, who are known to offer monetary support (Thornber et al., 2020; Tran et al., 2013).

Hence, antibiotics used in aquaculture to cure, control, and prevent infections are acknowledged as one of the disease prevention approaches in aquaculture management (Thiang et al., 2021; Wan Ibrahim et al., 2021). As stated by Chen et al. (2019), since their development in 1930s, antibiotics have been used primarily to treat and prevent human and animal disease. According to El-Saadony et al. (2022) and Liu et al. (2017), the most prevalent strategy for disease prevention is the use of antimicrobials drugs and antibiotics. Antibiotics and other antimicrobial drugs are frequently used in aquaculture farms as food components or immersion baths to manage bacterial infections (Letchumanan et al., 2019; Manjusha & Sarita, 2011; Devi et al., 2009). The Association of Southeast Asian Nations (ASEAN) identified oxalinic acid, erythromycin, sulfonamides, oxytetracyclines, and sulfamerazine as the most regularly used antibiotics in aquaculture (Thiang et al., 2021; Wan Ibrahim et al., 2021; ASEAN, 2013). These drugs are allowed in food-producing animals based on the recommended Maximum Residue Level (MRL) established by the Food and Agriculture Organization of the United Nations and the World Health Organization (FAO/WHO), the Codex Alimentarius Commission, and European Union legislation (Thiang et al., 2021; FAO & WHO, 2020).

According to Thiang et al. (2021), the Maximum Residue Levels (MRL) vary by geographic location, based on antibiotic usage trends and local food safety regulatory authorities. Rakesh et al. (2018) identified that many farmers employ antimicrobial drugs randomly and did not use them according to the standard approved. The commonly used chemicals antibiotics in aquaculture, recommended concentration and maximum residue level proposed by National Pharmaceutical Regulatory Agency (NPRA) and ASEAN are listed in Table 1.5.

Table 1.5: Antibiotics that Commonly used in Aquaculture, Recommended Concentration Level and Maximum Residue Level (MRL)

Antibiotic	Recommended concentration (ppm)	Maximum Residue Level, MRL (ppm)
Oxolinic acid	0.01	0.1
Erythromycin	0.1	0.2
Sulfonamides	0.01	0.1
Oxytetracyclines	2	0.2

(Source: National Pharmaceutical Regulatory Agency (NPRA), 2017; ASEAN, 2013)

1.3.2 Overuse of Antibiotic Implicating Human Health

Antibiotics are beneficial in combating bacterial infections; however, overuse of this drug has led in the rise of antimicrobial resistance (AMR), particularly among *Vibrio sp.* in the surroundings (Loo et al., 2020; Letchumanan et al., 2019; Sudha et al., 2014). Due to selection pressure brought on by improper and excessive use of antibiotics, the evolution of bacteria towards AMR has been noticeably sped up (Kathleen et al., 2016; Akond et al., 2009), albeit their use is based on modern medicine (Nik Mohd Fauzi et al., 2021). The rapid increase of resistant diseases observed throughout the world is assumed to be caused by the AMR genes' capacity to spread between bacteria, a process known as horizontal gene transfer, or HGT (Thornber et al., 2020; Martínez et al., 2015). As a result of the long-term exposure, bacteria adapt to sublethal antibiotic concentrations, resulting in the selection of resistant mutants at sublethal antibiotic concentrations (Chuah et al., 2016; Torres-Barceló et al., 2015; Andersson & Hughes, 2014). Some bacteria may develop resistance to one or more antibiotics, posing serious health concerns to humans (Kurniawan et al., 2021; Imron et al., 2021; Al-Riyami et al., 2019).

According to Loo et al. (2020), the antibiotic-resistant genes (ARGs) in bacteria can be transmitted through direct contact or the food chain to people via seafood consumption (Loo et al., 2020). Antibiotic residues in food can harm people either directly through toxicity to consumers or indirectly through harmful effects on body systems, resulting in morbidity and even death, or indirectly through antibiotic-resistant bacteria (ARB) and antibiotic-resistant genes (ARGs) (Chen et al., 2019; Kirchhelle, 2018; Rhoads, 2015). It may also be spread through environmental pollution, such as antibiotic-resistant bacteria, resistance genes, and antibiotic residues in faeces, as well as aquatic recreational activities, such as swimming and fishing (Chuah et al., 2016; Huijbers et al., 2015; Marshall & Levy, 2011).

Unfortunately, most Southeast Asian nations lack antimicrobial-use legislation, governmental regulation, and monitoring infrastructure (Thiang et al., 2021; Chuah et al., 2016). As a result, the usage of uncontrolled antibiotics, especially the prohibited ones, will contribute to the emergence of antibiotic resistance (Vian et al., 2020; Chen et al., 2019) that caused antimicrobial drugs contamination in the ecosystem and aquaculture products (Xiong et al., 2015; Lai et al., 2018; Thiang et al., 2021), as well as causing a significant threat to human health (Letchumanan et al., 2019; Chen et al., 2019). Furthermore, it has been documented that these antibiotic residues have a significant and detrimental influence on public health and food safety in terms of drug toxicity, immunopathological disorders, carcinogenic effects, allergic responses, and drug sensitivity, among other things (Chen et al., 2019; Manyi-Loh et al., 2018; Guetiya Wadoum et al., 2016; Baynes et al., 2016; Sarmah et al., 2006; Bedford, 2000).

1.3.3 Overuse of Antibiotic Caused Effect on Environment

One of the primary sources of antibiotic contamination in the environment is aquaculture wastewater (Thiang et al., 2022, 2021; De Jesus Gaffney et al., 2016; Cabello et al., 2013). This is because in aquaculture, antibiotics are usually added directly in the aquaculture feed or water (Chuah et al., 2016; Serrano, 2005). Antibiotics can reach the ecosystem through faeces and uneaten feed (Hua & Apun, 2013). Hua and Apun (2013) also reported that 75% of most antibiotics in aquaculture feed is expected to be transferred to the surrounding environment and deposited in the sediment.

The majority of aquaculture in Malaysia presently lacks a wastewater treatment facility, hence the most typical approach is to discharge effluent straight into surface waters (Ahmad et al., 2021; Kurniawan et al., 2021a; Kurniawan et al., 2021b). Thus, the environment and aquaculture products are often contaminated by antibiotic (Thiang et al., 2021; Lai et al., 2018; Xiong et al., 2015; Rico et al., 2014; Lin et al., 2008; Le & Munekage, 2004). Human communities residing the downstream of these operations may now be exposed to the large volumes of untreated effluent containing antibiotic residues and resistant bacteria released into the surrounding environment by shrimp aquaculture (Kurniawan et al., 2021; Thornber et al., 2020; Chowdhur et al., 2018). There is a possibility that groundwater and eventually drinking water might be contaminated by aquaculture farm wastewater that is discharged into public rivers, sewage systems, or paddy fields (Chuah et al., 2016; Nguyen Dang Giang et al., 2015; Rico et al., 2014; Gao et al, 2012; Seyfried et al., 2010). Antibiotics can also induce allergic responses, diminish therapeutic potential against human and animal diseases, disrupt microbial stability in live species' gastrointestinal tracts, and alter the bacterial ecology in aquatic habitats (Kurniawan et al., 2021; Huang et al., 2019; Al-Riyami et al., 2018). Unfortunately, quantitative approach to document the levels of antibiotic and antimicrobial resistance in aquaculture samples collected are limited (Thiang et al., 2022; Yan et al., 2018; Shimizu et al., 2013; Suzuki et al., 2012; Managaki et al., 2007).

1.4 Improved Technologies to Solve Disease and Antimicrobial Resistance

With regard to both human and non-human antimicrobial usage, antimicrobial resistance (AMR) is one of the global health concerns, and the effort to address the possible harm to human life seems to be sluggish (Citarasu et al., 2022; Chambers et al., 2020). Despite the biological nature of the AMR causing mechanism, current levels, and practises of antibiotic use in both people and food animals are driven by a variety of personal, psychological, social, cultural, political, and economic pressures (Chambers et al., 2020). By evaluating a wide range of possible sources, such as medicinal plants and microorganisms, scientists have sped their quest for new antimicrobial compounds in an effort to deal with this issue (Kathleen et al., 2016; Wong et al., 2016; Lihan et al., 2014; Rahman et al., 2009; Rios & Recio, 2005).

According to Mustafa et al. (2021), numerous technological innovations are available in the aquaculture system, and their use has increased since hatcheries were developed and additional technologies that aided in aquaculture operations became available. Six major factors have been identified to influence aquaculture diversification over time: demand, profit, competitive advantage, system resilience, environmental compatibility, and climate. Some of the technologies established in the industry include Biofloc Technology (BFT) (Ekasari et al., 2014; Xu & Pan, 2013), microalgae (Citarasu et al., 2022; Suleman et al., 2018) and vaccination (Gui & Zhang, 2018; Yogeeswaran et al., 2012; Wu et al., 2002). However, the Department of Fisheries Malaysia (DoF) cited the rather expensive technologies that offer to reduce the issues plaguing the fish farming industry. Other reasons hindering the technological adoption among farmers include knowledge, skilled workers, and the cost of inputs (Mustafa et al., 2021).

Therefore, an affordable improved technology that can enhance the potential for adoption by the shrimp farmers should be invented and made available in the market for improving shrimp production. Accordingly, the improved technology is Quorum Quenching that will be ingested in probiotics, antibodies, and green water system. Rehman and Leiknes (2018) and Natrah et al. (2014), stated that quorum quenching is the process of inhibiting or destroying the signalling molecules involved in bacterial quorum sensing, which interferes with intercellular communication and coordination. Since that bacterial infections may be a major problem in aquaculture settings, with negative effects on the environment and economic growth. A possible remedy to reduce the virulence and spread of bacterial infections in aquaculture settings is quorum quenching. Therefore, there are two (2) approaches to administering the probiotics and antibodies, namely prevention and therapeutic methods. The prevention method involves administering the probiotics and antibodies starting from the post larval age of 14 days until harvest, whereas the therapeutic method will be given when the shrimp are diagnosed with the disease.

It is unclear if shrimp farmers in Malaysia are familiar with employing probiotics, antibodies, and green water systems in the shrimp farming. On the other hand, there is evidence that the use of probiotics in prawn farming is prevalent in Malaysia. As stated by Ringø (2020) and Loh (2017), probiotics such as photosynthetic bacteria and *Bacillus* sp. can increase water quality, livelihoods, and growth rates of shrimp juveniles at farming operations. The findings implied that shrimp farmers in Malaysia are aware of probiotics and their advantages in shrimp farming. Nevertheless, it is unknown if farmers have knowledge of other alternatives comprising of antibodies and green water systems. Thus, more study is needed to establish the degree of farmers' understanding of these approaches.

1.5 Problem Statement

Aquaculture has contributed a significant increase in the supply of seafood available for human consumption. Additionally, the consumer tastes have increased both worldwide and domestic demands for shrimp products due to the change in consumers' preferences from red meat to white meat (Ghee-Thean et al., 2016). The Performance Management and Delivery Unit (PEMANDU) has identified shrimp as one of the target species in the Malaysian agriculture, in line with the Malaysia Economic Transformation Programme (ETP) (2010-2020), with the aim of increasing shrimp production and productivity (PEMANDU, 2010). Following the efforts, the brackish water aquaculture has shown an increased production year after year, followed by marine fish aquaculture and freshwater aquaculture. Several types of shrimps cultured in brackish water aquaculture include white shrimp (*Penaeus vannamei*), tiger prawn (*Penaeus monodon*), banana shrimp (*Fenneropenaeus merguiensis*), and kuruma tiger shrimp (*Penaeus japonicus*).

However, the challenges faced by the shrimp industry are mostly disease related problems, such as bacterial diseases, viral diseases, fungus diseases, and protozoa diseases. In 1996, the first disease epidemic was observed in Peninsular Malaysia, with the White Spot disease (WSD) killing innumerable shrimps within 3-10 days of the emergence of symptoms, particularly in young shrimps of various ages and sizes (Hashim & Kathamuthu, 2005). In 2011, shrimp farming in Peninsular Malaysia was attacked with Acute Hepatopancreatic Necrosis Disease (AHPND) as a result of bacterial infections, specifically *Vibrio parahaemolyticus* (Amatul-Samahah et al., 2020; Kua et al., 2016). Accordingly, Malaysia has suffered the consequences, as AHPND outbreaks in whiteleg shrimp farms in 2011, 2012, and 2013 resulted in large reductions in shrimp output to 67,000, 55,000, and 50,000 metric tonnes, respectively. These diseases can cause a scaling down of shrimp production at the farms.

It compels the shrimp farmers to use antibiotics and antimicrobials drugs to treat disease, which is a common practice since the 1930s. Tetracyclines, sulphomides, oxolinic acids, and erythromycin are commonly used antibiotics to treat disease in aquaculture farming approved by the authority. Unfortunately, the overuse of antibiotics and antimicrobials drugs had triggered antimicrobial resistance (AMR) problems in shrimp farming. The varied Maximum Residue Level (MRL) with geographical regions depending on the antibiotic usage profiles and local food safety regulatory agencies further exacerbate the AMR issues. The overuse of antibiotic has created AMR and implicated human health, such as immunopathological disorders, carcinogenic effects, allergic responses, as well as long-term environmental hazards, such as contamination in wastewater.

According to the Department of Fisheries (DoF), the previous technologies offered to solve the disease and AMR problems, such as Biofloc Technologies (BF), are quite expensive. Hence, the adoption of the technologies among farmers is reported to be low due to high prices and farmers' reluctance to adopt the technologies. Besides, the farmers' knowledge related to the technologies to solve the AMR problem is also not clearly reported. Thus, it calls for improved technologies to solve the AMR problems by eliminating the heavy usage of antibiotics in shrimp farming. The improved technologies should offer various benefits and be affordable for shrimp farmers to adopt in their farms.

1.6 Research Questions

In this study, five (5) research questions were established as follows:

1. Do shrimp farmers have knowledge and attitude about the improved technologies for disease prevention in shrimp farming?

2. What is the level of shrimp farmers' intention to adopt improved technologies for disease prevention in shrimp farming?

3. What is the relationship between farmers' knowledge and their attitudes to adopt improved technologies for disease prevention in shrimp farming?

4. What are the associations between the socio-demographic profiles, farm profiles of shrimp farmers and their intention to adopt improved technologies for disease prevention in shrimp farming?

5. What are the factors that mostly influence shrimp farmers' intentions to adopt improved technologies for disease prevention in shrimp farming?

1.7 Objectives of the Study

The general objective of the study was to determine shrimp farmers' intention to adopt improved technologies for disease prevention in shrimp farming in Peninsular Malaysia.

The specific objectives of this study were as follows:

1. To determine the level of knowledge and attitude of shrimp farmers on improved technologies for disease prevention in shrimp farming.

2. To determine the level of shrimp farmers' intentions to adopt improved technologies for disease prevention in shrimp farming.

3. To examine the relationship between shrimp farmers' knowledge and their attitudes to adopt improved technologies for disease prevention in shrimp farming.

4. To determine the associations between socio-demographic profiles of shrimp farmers, farm profiles, and their intentions to adopt improved technologies for disease prevention in shrimp farming.

5. To investigate the factors that mostly influence shrimp farmers' intentions to adopt improved technologies for disease prevention in shrimp farming.

1.8 Significance of the Study

This study helps to understand the intention of shrimp farmers on the adoption of improved technologies in shrimp farming. With the adoption of improved technologies, it should be able to convince shrimp farmers the technologies could improve their farming activities with the most cost-effective operations. The findings of this study should also benefit technology provider as they should be able to gauge the shrimp farmers' intention to adopt the improved technologies in their shrimp farming. This should facilitate their efforts to develop improved technologies that are easily available on the market at a reasonable price. Government agencies, namely the Department of Fisheries (DoF) and Fisheries Research Institute Malaysia (FRI), could also use this information to improve shrimp quality at the market level, providing early information on the benefits of improved technologies to be adopted by shrimp farmers and enhancing the participation of aquaculture industry players.

1.9 Organisation of the Thesis

This thesis is organised into five (5) chapters. The first (1) chapter begin with the overview of fisheries sector in Malaysia, followed by diseases in shrimp farming, issues in shrimp farming, improved technologies, problem statements, research questions, objectives of the study and lastly, significance of the study. The second (2) chapter consists of the reviews of the literatures on previous studies and other information that are relevant to the study. The third (3) chapter comprises the methodology of the study, including conceptual framework, sources of data, data collection, pilot study and data analysis used in this study. Chapter four (4) reports the findings of the study. The last chapter, which is chapter five (5), consists of summary of the study, recommendation, limitations of the study, suggestions for further study and the overall conclusions of the study.

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