



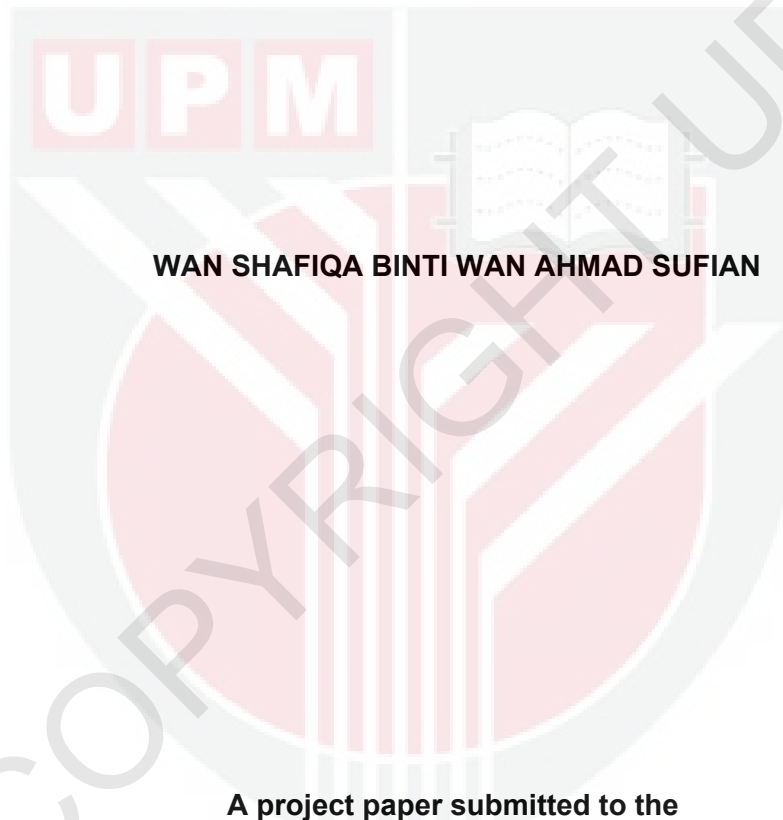
**UNIVERSITI PUTRA MALAYSIA**

**COST AND BENEFIT OF VIBRIOSIS VACCINATION ON MARINE CAGE  
FARM**

**WAN SHAFIQA BINTI WAN AHMAD SUFIAN**

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**COST AND BENEFIT OF VIBRIOSIS VACCINATION ON MARINE CAGE FARM**



**WAN SHAFIQA BINTI WAN AHMAD SUFIAN**

**A project paper submitted to the  
Faculty of Veterinary Medicine, Universiti Putra Malaysia**

**In partial fulfilment of the requirement for the  
DEGREE OF DOCTOR OF VETERINARY MEDICINE**

**Universiti Putra Malaysia  
Serdang, Selangor Darul Ehsan**

**2023/2024**

**CERTIFICATION**

It is hereby certified that we have read this project paper entitled “Cost and Benefit of Vibriosis Vaccination on Marine Cage Farm”, by Wan Shafiqah Binti Wan Ahmad Sufian and in our opinion, it is satisfactory in terms of scope, quality, and presentation as partial fulfilment of the requirement for the course VPD 4999 – Final Year Project.

The logo of Universiti Putra Malaysia (UPM) is a shield-shaped emblem. It features a red and white design with a book in the center, symbolizing knowledge and learning. The letters 'UPM' are prominently displayed in a red box at the top left of the shield.

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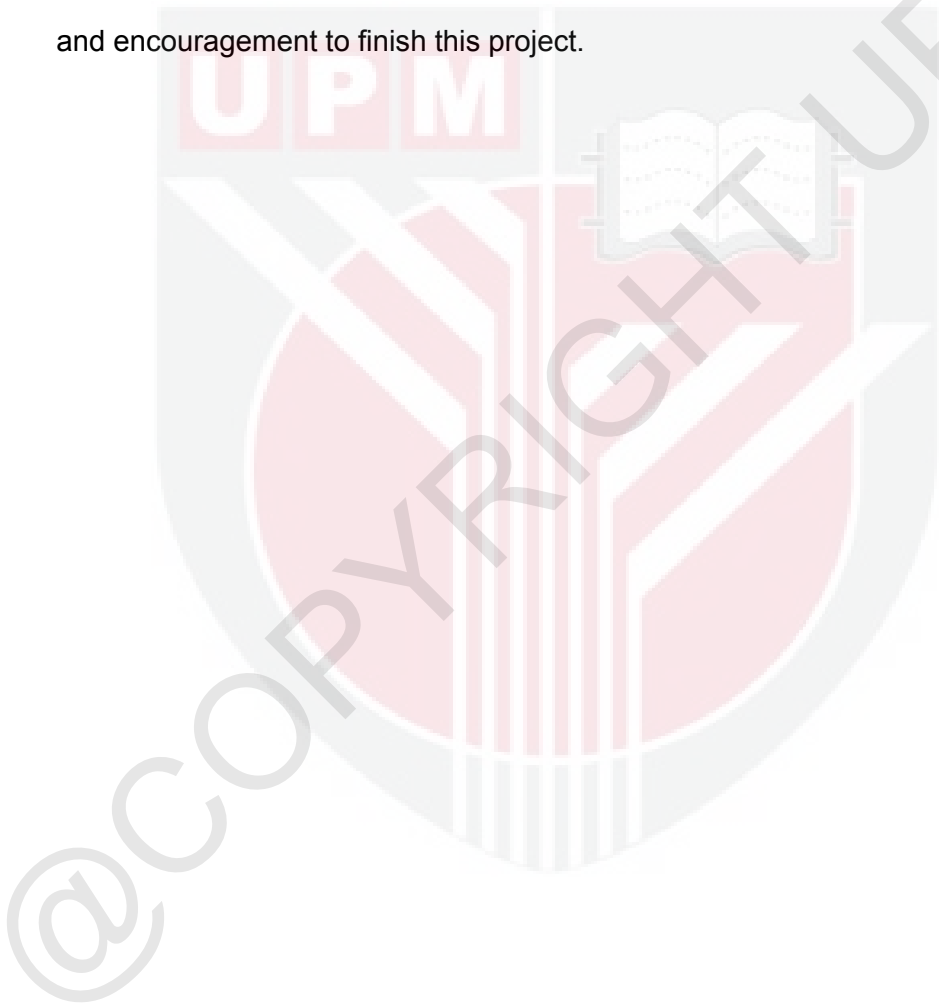
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**DEDICATION**

This study is wholeheartedly dedicated to my parents; Wan Ahmad Sufian Bin Wan Mohd Ali and Zainani Binti Ismail who have been my source of strength and inspiration, who continuously love and support me until I reach this level and for making me who I am today.

To my siblings as well as my friends for their endless love, prayers, advice, and encouragement to finish this project.



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## **ABSTRAK**

Abstrak daripada kertas projek yang dikemukakan kepada Fakulti Perubatan Veterinar untuk memenuhi sebahagian daripada keperluan kursus VPD 4999 –  
Projek akhir tahun

### **KOS DAN FAEDAH VAKSINASI VIBRIOSIS PADA IKAN MARIN**

Oleh

**Wan Shafiqah Binti Wan Ahmad Sufian**

2024

**Penyelia: Dr. Norhariyani Binti Mohd Nor**

**Penolong Penyelia: Dr Mark Bin Buda**

Vaksinasi adalah intervensi yang paling selamat dan berkesan untuk melindungi ikan marin daripada vibriosis dan mencegah kematian yang tinggi dan kerugian ekonomi yang teruk kepada penternak. Objektif kajian adalah untuk mengangkar kos dan faedah vaksinasi vibriosis di ladang sangkar marin bagi meningkatkan kesedaran pihak berkepentingan dalam membuat keputusan penggunaan vaksin. Vaksin berasaskan makanan telah diberikan kepada ikan yang ditenak di ladang sangkar marin di Pulau Ketam selama tiga hari pada minggu 0, minggu 2 dan minggu 6 mengikut keperluan pemakanan. Untuk analisis pertama, model belanjawan separa digunakan di mana kos dan faedah vaksinasi telah dianalisa menggunakan Microsoft Excel®. Perubahan selepas menggunakan vaksin mengambilkira faedah bersih perubahan dikira sebagai perbezaan jumlah faedah (jumlah keuntungan tambahan dan kos dikurangkan) dengan jumlah kerugian perubahan (jumlah kos tambahan dan hasil diketepikan). Jumlah keuntungan tambahan dengan penggunaan vaksinasi adalah peningkatan kadar kelangsungan hidup dan berat badan, manakala jumlah pengurangan kos adalah pengurangan

kitaran pengeluaran, kos penyelenggaraan, kos utiliti, kos petrol dan kos pelupusan, Jumlah kos tambahan ialah kos vaksin, kos buruh dalam pemberian vaksin dan peningkatan penggunaan makanan, dan pendapatan diketepikan. Untuk analisa kedua, harga optimum vaksin dianggarkan dengan menggunakan SOLVER dalam Microsoft Excel. Tiga senario telah dicipta dengan perbandingan di antara penggunaan vaksin dan tidak menggunakan vaksin; senario asas (perubahan dalam survival=6%), senario terbaik (perubahan dalam survival=0%) dan senario terburuk (perubahan dalam survival=21%), di mana model akan mendapatkan harga optimum vaksin apabila faedah bersih ditetapkan bersamaan dengan RM0 atau tiada faedah atau kerugian. Input model adalah berdasarkan model stokastik sebelumnya dan literatur yang berkaitan dengan vaksin vibrio. Keputusan analisis pertama telah menunjukkan faedah bersih adalah RM 1.13 setiap ekor ikan apabila melaksanakan vaksinasi vibriosis berbanding tidak memberi vaksin. Jumlah faedah adalah sebanyak RM1.72 setiap ekor, manakala jumlah kerugian adalah sebanyak RM0.59 setiap ekor. Analisis kedua menunjukkan harga optimum vaksin dalam senario asas adalah sebanyak RM 19.75 setiap dos. Sementara itu, untuk senario terbaik contohnya perbandingan dengan kawasan tanpa risiko masalah vibriosis, harga optimum vaksin adalah sebanyak RM 6.61 setiap dos. Manakala, dalam senario terburuk contohnya di kawasan yang terdapat risiko wabak vibriosis, harga optimum vaksin adalah sebanyak RM 52.54 setiap dos. Kesimpulannya, kajian ini telah mendedahkan bahawa pelaburan dalam vaksinasi akan memberi manfaat ekonomi kepada ladang terutamanya di kawasan berisiko tinggi.

Kata kunci: Vaksinasi vibriosis, Ladang sangkar laut, Analisis kos dan faedah vaksinasi vibriosis, Harga optimum vaksin

**ABSTRACT**

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

**COST AND BENEFIT OF VIBRIOSIS VACCINATION ON MARINE CAGE FARM**

By

**Wan Shafiqah Binti Wan Ahmad Sufian**

**2024**

**Supervisor: Dr Norhariyani Binti Mohd Nor**

**Co-Supervisor: Dr Mark Bin Buda**

Vaccination is the safest and effective intervention to protect marine fish against vibriosis and prevent high mortality and severe economic losses to farmers. The objective of this study is to estimate the cost and benefits of vibriosis vaccination on marine cage farms to improve awareness to the stakeholders to make decisions on using the vaccine. The oral feed-based vaccine was given at a marine cage farm in Pulau Ketam for three days during week 0, week 2 and week 6 of grow-out period where the amount given is according to the feed requirement of fish. In the first analysis, partial budget model was deployed and used cost benefit analysis in Excel®. In the model, the net benefit was calculated as the difference between total benefit (sum of added gain and reduced cost) and total loss (sum of added cost and revenue foregone). The added gain from vaccination are increased survival rate and weight, reduced cost are reduced production cycle, maintenance cost, utility cost, petrol cost and disposal cost, added cost are vaccine cost, labour cost in administering vaccine and increased feed consumption, and revenue foregone are none. The second analysis estimated the threshold price of vaccines by using

add-in SOLVER in Microsoft Excel. Three scenarios were created comparing vaccinated and non-vaccinated scenario; the baseline scenario (change in survival=6%), best-case scenario (change in survival=0%) and worst-case scenario (change in survival=21%), where the model will find the optimal vaccine price when the net benefit is set to be equal to RM0 or there is no benefit or loss. The model inputs were based on previous developed stochastic animal level models and literature related to the *vibrio* vaccine. Results showed net benefits of RM 1.13 per tail of fish when implementing vibriosis vaccination as compared to not vaccinating where, the total benefit was RM1.72 per tail, while total loss was RM0.59 per tail. The threshold price estimated the vaccine optimal price in the baseline scenario is at RM 19.75 per dose. Meanwhile, for the best-case scenario for example in an area without Vibriosis problem, the vaccine's optimal price is RM 6.61 per dose. In the worst-case scenario for example in an area where there is a risk of a vibriosis outbreak, the vaccine 's optimal price is at RM 52.54 per dose. This study revealed that investing in vaccination will give economic benefit to the farm especially in high-risk areas.

Keywords: Vibriosis vaccination, Marine fish, Cost benefit analysis, threshold point of vaccine price

## 1.0 INTRODUCTION

### 1.1 Background

Aquaculture has become a major sector in Malaysia approximately producing 411,781 tons of total aquaculture production with an estimation of USD 700 millions of its economic value in 2019. (Tan, et al, 2023). Not only does it provide consumers with the main protein source, but it also contributes to Malaysia's economy (Yusoff, 2014). However, there are some concerns in the aquaculture sector, particularly disease outbreaks due to bacteria and viruses which result in severe production and economic losses. (Sanches-Fernandes, et al, 2022). Vibriosis caused by genus *Vibrio* spp. is one of the most common bacterial infections threatening the growth of the aquaculture sector worldwide (Sanches-Fernandes, et al, 2022).

Vibriosis affects marine fishes leading to high mortalities, low production, and low farm-gate price (Peterman, & Posadas, 2019). In Malaysia, outbreak of vibriosis in sea-cage farms in 1990 had caused USD 5 million losses and thereafter, annual USD 1.47 - USD 2.5 million losses with only 40% of the survivability rate (Mohamed Din, 1995). Another study recorded economic loss due to vibriosis in the Asian seabass at 7.06% from the total production cost per kilogram and much higher when including the diagnosis and treatment costs (Mohd Yazid et al, 2021). Similarly, total vibriosis costs of grow-out Asian Seabass including mortality, diagnosis and treatment costs were at USD 0.24/tail (Mohd Nor et al, 2019). Interventions such as application of antibiotics, probiotics, vaccination, good biosecurity, and water quality can be applied to prevent and decrease the risk of vibriosis.

Vaccination is proven to be more effective and safer by producing antibodies to stimulate the fish's immune system against vibriosis (Mohamad et. al, 2022). A

study recorded 0.52kg of net savings per kilogram of fish harvested and benefit-cost ratio of 4:1 in vaccinated Asian seabass against vibriosis (Thorarinsson, & Powell, 2006). Additionally, fish vaccination consists of modified live vaccine and inactivated or whole killed organisms given either by oral, injection or immersion. Our study employs inactivated vaccines in Asian seabass via oral route as it has been proven effective to improve growth performance, stimulates innate and adaptive immune response, increases production, increase in weight, have lower feed conversion ratio and higher survival rate at 71.3% (Amir-Danial, et al, 2022).

The economic losses due to vibriosis and importance of vaccination are well described, however study available that measures the cost and benefit of vibriosis vaccination is scarce. Therefore, this study aims to estimate the cost of vibriosis vaccination and the benefits of vaccinated fishes against vibriosis to justify the importance of vibriosis vaccination on marine fish farms. This can provide a better understanding to the farmers and to improve policy by showing it is worth investing in vaccines as it brings more benefits, thus, reducing economic losses, improving the aquaculture sector and sustainability of the community.

## **1.2 Overall objectives**

To analyse the costs and benefits of vibriosis vaccination on marine cage farm

- i. To compute the costs and benefits of vibriosis vaccination on marine cage farm using a partial budget model by comparing the total benefits and total losses due to the proposed change.
- ii. To estimate the threshold price of vibrio vaccine in three different comparison scenarios between vaccinated and non-vaccinated fish (baseline scenario, best-case scenario, and worst-case scenario).

### 1.3 Justification

Vibriosis in marine fish leads to low production and high mortality which eventually cause severe economic losses. One of the safest and effective methods to prevent this is by applying a *vibrio* vaccine. However, there are limited studies that measure the costs and benefits of vibriosis vaccination because most of the studies only measure the benefits of the vaccination which is unable to give the farmer a general view whether applying the vaccine will improve the farm's income or not. Other than that, this project will indirectly improve awareness to the farmers and important stakeholders on the importance of the *vibrio* vaccine and help them to make decisions on whether to use the vaccine to control and prevent vibriosis on marine fish farm.

### 1.4 Research question

- i. What are the costs and benefits of vibriosis vaccination on marine cage farm using a partial budget model by comparing the total benefits and total losses due to the proposed change.
- ii. What is the estimation of the threshold price of *vibrio* vaccine in three different scenarios (baseline scenario, best-case scenario and worst-case scenario).

## 2.0 LITERATURE REVIEW

### 2.1 Vibriosis in Marine Animals

Vibriosis is a bacterial disease caused by genus *Vibrio* which is pathogenic, most common, widespread disease-causing agent and can result in severe production and economic losses in the aquaculture sector (Sanches-Fernandes, et al, 2022). *Vibrio spp.* are gram-negative, straight or comma-shaped rod bacteria, non-spore-forming (Mohamad et al, 2019), thermophilic that are highly adaptive in seawater and can survive under adverse condition (Vezzulli, et al, 2015), as well as more prevalent in cultured marine fish and shellfish species as it was naturally found in estuarine environments (Manchanayake, et al, 2023).

In Malaysia, groupers and Asian seabass are highly reported with vibriosis (Kah Sem, et al, 2023). Major vibriosis outbreaks had occurred in Asian seabass farm at Sabah in September and October 2010 which revealed *Vibrio harveyi* as the etiological agent causing the high fish mortality (Albert, and Ransangan, 2013). Infected fish will cause symptoms such as skin ulceration, scale drops on the stomach, caudal fin necrosis (Mohamad, et al, 2019), hemorrhages and septicaemia (Manchanayake, et al, 2023).

Vibriosis outbreak resulted from the rapid expansion and intensiveness of the aquaculture sector (Kah Sem, et al, 2023), which can affect the production by destroying the basic resources, reducing the unit value and efficiency of the production process and directly affect human being that further lead to economic losses in the aquaculture sector (Mohd Yazid et al, 2021). In Malaysia, an outbreak of vibriosis in sea-cage farms in 1990 had caused USD 5 million losses and thereafter, annual USD 1.47-USD 2.5 million losses as the survivability rate was only 40% (Mohamed Din, 1995). A previous study recorded that the average cost of vibriosis in Asian seabass cultured in floating marine cage-culture system was USD

0.24/tail which consist of the mortality cost at USD 0.19/tail, treatment cost at USD 0.05/tail, and diagnosis cost at USD 0.003/tail which was estimated to increase by 7.8% of the total production cost (Mohd Nor et al, 2019). Similarly, a recent study also recorded that the mortality rate due to vibriosis was at 16.23% which led to the total economic loss at USD 0.19 per tail, representing 7.06% of the total production cost of Asian seabass per kilogram (Mohd Yazid et al, 2021).

## **2.2 Benefits of Disease Control and Prevention Using Vibrio Vaccine**

One of the interventions to control or prevent vibriosis in aquaculture is by vaccination. It is a non-polluting biological agent that induces immunological memory resulting in enhanced immune protection (Kah Sem, et al, 2023). Previous study had stated that uncontrolled use of antibiotics for vibriosis has led to formation of multidrug resistant (MDR) bacteria which reduce the effectiveness of the antibiotics (Manyi Loh, et al, 2018). Hence, vaccination is more effective and safer than antimicrobial drugs (Manchanayake, et al, 2023) where vaccine aim is to stimulate the immune system for antibody production against the bacteria (Mohamad, et. al, 2022).

This was proven in a study of a live attenuated vaccine administered to a marine red hybrid tilapia which improved the fish's vibriosis resistance, antibody response and has higher survival rate at 87% than unvaccinated fish at 20% (Abu Nor, et al, 2020). Similarly, vaccinated fish against vibriosis in farm hybrid grouper showed high survival rate at 80% compared to unvaccinated at 65%, better growth performances at 22.56% of weight gain and less feed conversion at 58.05% less feed than the unvaccinated. (Mohamad, et. al, 2022). Additionally, a study by Amir Danial in cultured Asian seabass also recorded that innate and adaptive immune response were higher in vaccinated than the unvaccinated with survival rate at

71.3% and 67.7% respectively. The body weight was also heavier in vaccinated, and the mean isolation of *Vibrio spp.* was lower in vaccinated at  $22.50 \pm 9.39\%$  compared to unvaccinated fish at  $46.67 \pm 7.90\%$ .

The decision on implementing vaccination can also be based on the agricultural economy which according to Penson et al. 2002, it is an applied social science that deals with how scarce resources are used in the production, processing, marketing, and consumption of food and fiber products. This means, when there is an outbreak of vibriosis, there will be an increase in labour and capital resources due to the high mortality and this will result in limited resources. To reduce those resources, this is where the decision to implement vaccination takes place.

### **2.3 Cost and Benefits Analysis of Vibriosis Vaccination through Partial Budget Model**

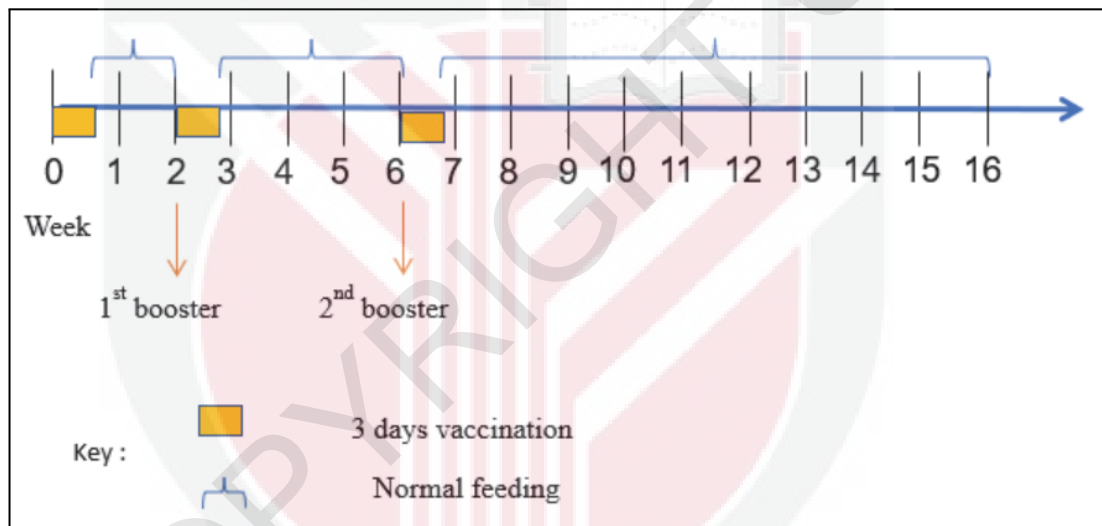
Cost and Benefit Analysis (CBA) is one of the Economic Financial Analysis (EFA) method to estimate whether implementing vaccination having more benefits than the cost which provides the grounds for making decisions on the project sustainability, promotes understanding of strengths and weaknesses during implementation and help assess the most important outcomes of interventions (Swiss Agency for Development and Cooperation SDC, 2015).

The partial budget model is used to assess the costs and benefits of vibriosis vaccination. The model compares benefits with costs in which are higher. This is concurrent with a study that stated that a partial budget examines how a change in the operation will affect the operation's profitability from identifying changes that bring any benefits and reduced gain to the operation, to identifying changes that would result in increased cost of production (Hanson et al, 2007).

### 3.0 MATERIALS AND METHODS

#### 3.1 Vaccine Regime

This project is based on previous study by Amir-Danial that assessed the effectiveness of oral *vibrio* vaccine at a marine cage farm in Pulau Ketam by following the regimen of *Vibrio harveyi* feed-based vaccine, which was given three days each on week 0, week 2 and week 6 during grow-out period (Amir-Danial, et al, 2022) and changes were observed on both vaccinated and non-vaccinated Asian seabass until they reached week 10.



**Figure 1: Vaccine regime of feed-based inactivated vaccine against vibriosis in cage-cultured Asian Seabass (Amir-Danial, et al, 2022)**

#### 3.2 Model Framework and assumption

This study is based on the assumption that the marine cage farm in Pulau Ketam is free from vibriosis outbreak following good aquaculture practice, good biosecurity, and strategic farm's location that is not badly affected by the monsoon season leading to good water quality and management.

Partial budget model framework is applied to assess the costs and benefits of vibriosis vaccination. The model comprises of two categories; the first category is

the total benefits calculated by summing the added gain and reduced cost. Added gain is change in revenue received due to the new practice while reduced cost is change in cost that will be reduced due to the new practice. The second category is the total losses calculated by summing the added cost and reduced revenue. Added cost is additional cost applied with the new practice while reduced revenue is return that is loss or revenue foregone due to the new practice. To obtain the net benefit or loss due to proposed vaccination practices on marine cage farm is by extracting the total losses from the total benefits (Table 1).

**Table 1: Partial budget model to calculate the cost and benefit of vibriosis vaccination.**

<b>Benefits</b>	<b>Losses</b>
<p><b>A. Added gain</b> Return received due to the new practice</p>	<p><b>C. Added cost</b> Additional cost applies with the new practice</p>
<p><b>B. Reduced cost</b> Cost that will be reduced due to the new practice</p>	<p><b>D. Reduced revenue</b> Return that are loss due to the new practice</p>
<p style="text-align: center;"><b>E. Total benefits</b> Added gain (A) + Reduced cost (B)</p>	<p style="text-align: center;"><b>F. Total losses</b> Added cost (C) + Reduced revenue (D)</p>
<p><b>Net benefit change (gain/loss)</b> Total benefits (E) – Total losses (F)</p>	

### 3.3 Model equation and inputs

Based on the data inputs above, formulas are formed to assess the costs and benefits of vibriosis vaccination on marine cage farm in a partial budget model.

**Table 2: Partial budget component of vaccinated Asian seabass against vibriosis**

<b>Benefits</b>	<b>Losses</b>
<p><b>A. Added gain</b></p> <ul style="list-style-type: none"> <li>• Increase survival</li> <li>• increase weight</li> </ul>	<p><b>C. Added cost</b></p> <ul style="list-style-type: none"> <li>• Vaccine cost</li> <li>• Labour cost (vibrio vaccine administration)</li> <li>• Increase feed consumption</li> </ul>
<p><b>B. Reduce cost</b></p> <ul style="list-style-type: none"> <li>• Reduce production cycle</li> <li>• Reduce maintenance, utility, and petrol cost</li> <li>• Reduce disposal cost</li> </ul>	<p><b>D. Reduce revenue</b></p> <ul style="list-style-type: none"> <li>• None</li> </ul>
<p><b>E. Total benefits</b></p> <p>Added gain (A) + Reduce cost (B)</p>	<p><b>F. Total losses</b></p> <p>Added cost (C) + Reduce revenue (D)</p>
<p><b>Net benefit change (gain/loss)</b></p> <p>Total benefits (E) – Total losses (F)</p>	

The formulas of each component are shown as below:

### A. Added gain after vaccination

#### i. Increase survival

$$Surv (RM) = SR (\%) \times Pfish (RM)$$

Where,

Surv (RM) = The value of increase survival

SR (%) = Change in survival rate

Pfish (RM) = Price of fish per kg

#### ii. Increase weight

$$Wgt (RM) = BWT (kg) \times Pfish (RM)$$

Where,

Wgt (RM) = The value of increase weight

BWT (kg) = Change in body weight

Pfish (RM) = Price of fish per kg

### B. Reduce cost after vaccination

#### i. Reduce production cycle

$$Procycle (RM) = (VPC (RM) / PC (days)) - (UPC (RM) / PC (days))$$

Where,

Procycle (RM) = The value of reduce production cycle

VPC (RM) = Average production cost of vaccinated fish

UPC (RM) = Average production cost of unvaccinated fish

PC (days) = Production cycle

**ii. Reduce maintenance, utility, and petrol cost after vaccination**

$$Cmup (RM) = Pmup (RM)$$

Where,

$Cmup (RM)$  = Value of reduce maintenance, utility, and petrol cost after vaccination

$Pmup (RM)$  = Change in cost of maintenance, utility, and petrol

**iii. Reduce disposal cost after vaccination**

$$Cdisposal (RM) = Pdisposal (RM)$$

Where,

$Cdisposal (RM)$  = Value of reduce disposal cost after vaccination

$Pdisposal (RM)$  = Change of disposal price

**C. Added cost**

**i. Vaccine cost**

$$Vacc (RM) = Pvacc (g) \times Cvacc (g)$$

Where,

$Vacc (RM)$  = The vaccine cost

$Pvacc (RM)$  = Price of vaccine per fish

$Cvacc (g)$  = Vaccine consumption per fish

The vaccine cost is the price of the vaccine provided by the manufacturer which is RM 18. However, the vaccine cost will also be based on the vaccine regime which according to this study, the vaccine was given three times in week 0 (Prime vaccine), week 2 (1st booster), and week 6 (2nd booster). With that, the price of the vaccine ( $Pvacc$ ) is considered as RM 6 per fish per 3 days.

The vaccine consumption of the Asian seabass is 4% of its body weight per fish. This was calculated by addition of the amount of vaccine consumption per fish on week 0, week 2 and week 6 of vaccine administration.

The formula are shown as below:

$$Cvacc (g) = Famount \times BWT (g) \times 4\% \times DVacc (days)$$

Where,

$Cvacc (g)$  = Vaccine consumption per fish

Famount = Amount of fish

BWT (g) = Average body weight per fish

DVacc (days) = Days of vaccine administration on week 0, 2 and 6

Further calculation based on days of vaccine administration on week 0, week 2 and week 6 are shown as below:

### 1. Week 0 of vibriosis vaccination

$$Cvacc (g) = 2400 \text{ fishes} \times 190g \times 0.04 \times 3 \text{ days}$$

$$Cvacc (g) = \frac{54720}{1000g} = \frac{55 \text{ kg} \times 1000}{2400 \text{ fishes}} = 22.9g$$

### 2. Week 2 of vibriosis vaccination

$$Cvacc (g) = 2212 \text{ fishes} \times 210g \times 0.04 \times 3 \text{ days}$$

$$Cvacc (g) = \frac{5574}{1000g} = \frac{56 \text{ kg} \times 1000}{2212 \text{ fishes}} = 25.3g$$

### 3. Week 6 of vibriosis vaccination

$$Cvacc (g) = 1921 \text{ fishes} \times 280g \times 0.04 \times 3 \text{ days}$$

$$C_{vacc}(g) = \frac{6454}{1000g} = \frac{65 \text{ kg} \times 1000}{1921 \text{ fishes}} = 33.84g$$

#### 4. Total vaccine consumption per fish

$$C_{vacc}(g) = 22.9g + 25.3g + 33.84g$$

$$C_{vacc}(g) = 82.04g$$

#### ii. Labour cost (vibrio vaccine administration)

$$Clabour(RM) = 0$$

Where,

Clabour (RM) = Labour cost

#### iii. Increase feed consumption

$$Fcons(RM) = FC(kg) \times Pfeed(RM)$$

Where,

Fcons (RM) = Value of increase feed consumption

FC (kg) = Feed consumption

Pfeed (RM) = Price of feed

#### D. Reduced revenue

##### i. None

$$Reduce \text{ revenue} = RM 0$$

Reduced revenue is considered as none because there is no change in quality of fish that had been vaccinated compared to the unvaccinated fish. Thus it gives the value of RM 0.

Inputs for the model were gathered from simulated stochastic animal level models that produced information on the vaccinated and non-vaccinated Asian seabass (Table 3).

**Table 3: The inputs used in the cost-benefit analysis of vaccinated Asian seabass with oral feed-based *vibrio* vaccination where comparison was made with unvaccinated fish. The inputs were generated from a stochastic bioeconomic model at animal level (not published).**

Variables	VACCINATED			NON-VACCINATED		
	Average	Min	Max	Average	Min	Max
Survival rate (%)	77	-	-	71	-	-
Production cycle (days)	166	154	182	210	210	210
Market weight (kg)	1.15	1.09	1.20	1.14	1.10	1.17
Trash fish (kg)	1.41	1.30	1.53	1.42	1.34	1.50
Pellet (kg)	1.62	1.40	1.91	1.60	1.39	1.86
Feed cost – Trash fish and Pellet (RM)	9.76	8.55	11.26	9.62	8.51	11.03
Mortality rate – Vibriosis (%)	10	-	-	17	-	-
Mortality rate – Other cause (%)	13	-	-	12	-	-

<b>Mortality – Vibriosis (RM)</b>	0.07	-	-	0.65	-	-
<b>Mortality – Other cause (RM)</b>	0.24	-	-	0.35	-	-
<b>Disposal cost (RM)</b>	0.17	0.16	0.19	0.20	0.20	0.20
<b>Variable cost (RM)</b>	11.43	10.21	12.95	11.32	10.21	12.73
<b>Maintenance, motility, Petrol cost (RM)</b>	0.29	0.27	0.32	0.37	-	-
<b>Cost of fry/tail (RM)</b>	1.50	1.00	2.00	1.50	1.00	2.00
<b>Fish price/kg (RM)</b>	17.80	14.56	18.11	17.80	14.56	18.11
<b>Vaccine price (RM)</b>	18.00	-	-	-	-	-
<b>Vaccine consumption (%)</b>	4	-	-	-	-	-
<b>Average production cost (RM) – Exclude cost of vaccination</b>	12.03	10.79	13.58	12.69	11.58	14.10

### 3.4 Model analysis

Then, the data inputs were incorporated into the formulas (Table 4).

**Table 4: Partial budget model with incorporated data input into the formulation to calculate the net benefit of vaccinating against vibriosis.**

Benefits	Losses
<b>A. Added gain</b>	<b>C. Added cost</b>
i) Increase survival $Surv = 6\% \times RM\ 17.80$ $Surv = RM\ 1.07$	i) Vaccine cost $Vacc = \frac{RM\ 6}{1000\ g} \times RM\ 82.04$ $Vacc = RM\ 0.49$
ii) increase weight $Wgt = 0.01\ kg \times RM\ 17.80$ $Wgt = RM\ 0.18$	ii) Labour cost (vibrio vaccine administration) $Clabour = RM\ 0$
Total = $RM\ 1.07 + RM\ 0.18$ $= RM\ 1.25$	iii) Increase feed consumption $Fcons = 0.01\ kg \times RM\ 9.76$ $Fcons = RM\ 0.10$
	Total = $RM\ 0.49 + RM\ 0 + RM\ 0.10$ $= RM\ 0.59$

<p style="text-align: center;"><b>B. Reduce cost</b></p> <p>i) Reduce production cycle</p> $Procycle = (RM\ 12.03/166\ days) - (RM\ 12.69/210\ days)$ $Procycle = RM\ 0.01$ <p>ii) Reduce maintenance, utility, and petrol cost</p> $Cmup = RM\ 0.29$ <p>iii) Reduce disposal cost</p> $Cdisposal = RM\ 0.17$ <p>Total = <math>RM\ 0.01 + RM\ 0.29 + RM\ 0.17</math></p> $= RM\ 0.47$	<p style="text-align: center;"><b>D. Reduce revenue</b></p> <p>i) None</p> $Reduce\ revenue = RM\ 0$ $Total = RM\ 0$
<p style="text-align: center;"><b>E. Total benefits</b></p> $RM\ 1.25 + RM\ 0.47 = RM\ 1.72$	<p style="text-align: center;"><b>F. Total losses</b></p> $RM\ 0.59 + RM\ 0 = RM\ 0.59$
<p style="text-align: center;"><b>Net benefit change (gain/loss)</b></p> $RM\ 1.72 - RM\ 0.59 = RM\ 1.13$	

### 3.5 Scenario Analysis

In this scenario analysis, 3 scenarios were created which are the Baseline scenario (change in survival rate: 6%), Best-case scenario (change in survival rate: 0%), and Worst-case scenario (change in survival rate: 21%) to estimate the threshold price of vaccine when the net benefit change is set to be RM 0.00, as well as taking into account the disposal cost as the variable in each of the scenarios. This is performed in the add-in SOLVER in the Microsoft Excel ®.

In the baseline scenario, the change in survival rate is at 6% which is based on the default model on the previous stochastic animal levels model that is the difference of survival rate between vaccinated and unvaccinated fish. Then, in best-case scenario, the change in survival rate is at 0% which is when the survival rate of vaccinated fish is compared to an area where the survival rate of the non-vaccinated fish is similar because of lower prevalence of the disease, good aquaculture practice, good biosecurity, and good water quality. Meanwhile, in worst-case scenario, the change in survival rate is at 21% which is when the survival rate of vaccinated fish is compared to an area where the non-vaccinated fish have lower survival of fish due to higher prevalence of the disease, poor aquaculture practice, poor biosecurity, and poor water quality, such as the east coast where the survival rate can be as low as 56%. Thus, there will be a 21% difference in survival rate between vaccinated and non-vaccinated fish. Other than that, disposal cost is considered as the variable because when there is a change in the survival rate, it will lead to change in the number of dead fish and eventually in the number of fish to be disposed of.

**i. Baseline scenario**

The baseline scenario is based on the default model with the change in survival rate between the vaccinated and unvaccinated fish at 6%. Using Microsoft Excel with the add-in SOLVER function, it will set the net benefit change to RM 0 to obtain the threshold price of *vibrio* vaccine which is expected to get almost similar as the price by the manufacturer which is RM 18 with no loss or gain to the farm.

**Table 5: Scenario analysis for baseline scenario**

<b>Benefits</b>	<b>Losses</b>
<b>A. Added gain</b>	<b>C. Added cost</b>
i) Increase survival $Surv = 6\% \times RM\ 17.80$ $Surv = RM\ 1.07$	i) Vaccine cost $Vacc = \frac{RM\ 19.75}{1000\ g} \times RM\ 82.04$ $Vacc = RM\ 1.62$
ii) increase weight $Wgt = 0.01\ kg \times RM\ 17.80$ $Wgt = RM\ 0.18$	ii) Labour cost (vibrio vaccine administration) $Clabour = RM\ 0$

<p>Total = <math>RM\ 1.07 + RM\ 0.18</math> = <math>RM\ 1.25</math></p>	<p>iii) Increase feed consumption</p> <p><math>F_{cons} = 0.01\ kg \times RM\ 9.76</math></p> <p><math>F_{cons} = RM\ 0.10</math></p> <p>Total = <math>RM\ 1.62 + RM\ 0 + RM\ 0.10</math> = <math>RM\ 1.72</math></p>
<p style="text-align: center;"><b>B. Reduce cost</b></p> <p>i) Reduce production cycle</p> <p><math>Procycle = (RM\ 12.03/166\ days) - (RM\ 12.69/210\ days)</math></p> <p><math>Procycle = RM\ 0.01</math></p> <p>ii) Reduce maintenance, utility, and petrol cost</p> <p><math>C_{mup} = RM\ 0.29</math></p> <p>iii) Reduce disposal cost</p> <p><math>C_{disposal} = RM\ 0.17</math></p> <p>Total = <math>RM\ 0.01 + RM\ 0.29 + RM\ 0.17</math> = <math>RM\ 0.47</math></p>	<p style="text-align: center;"><b>D. Reduce revenue</b></p> <p>i) None</p> <p><math>Reduce\ revenue = RM\ 0</math></p> <p>Total = <math>RM\ 0</math></p>

<b>E. Total benefits</b> $RM\ 1.25 + RM\ 0.47 = RM\ 1.72$	<b>F. Total losses</b> $RM\ 1.72 + RM\ 0 = RM\ 1.72$
<b>Net benefit change (gain/loss)</b> $RM\ 1.72 - RM\ 1.72 = RM\ 0.00$	

**ii. Best-case scenario**

The change in survival rate in the best-case scenario is 0% because it was based on the area where the survival rate of vaccinated fish is similar to the survival rate of the non-vaccinated fish in other areas due to good management and aquaculture practices leading to lower prevalence of the disease. Using Microsoft Excel with the add-in SOLVER function, it will set the net benefit change to RM 0 to obtain the threshold price of *vibrio* vaccine which is expected to get lower than the baseline scenario with no loss or gain to the farm.

Table 6: Scenario analysis for best-case scenario

Benefits	Losses
<p style="text-align: center;"><b>A. Added gain</b></p> <p>i) Increase survival</p> $Surv = 0\% \times RM\ 17.80$ $Surv = RM\ 0.00$ <p>ii) increase weight</p> $Wgt = 0.01\ kg \times RM\ 17.80$ $Wgt = RM\ 0.18$ <p>Total = <math>RM\ 0.00 + RM\ 0.18</math></p> $= RM\ 0.18$	<p style="text-align: center;"><b>C. Added cost</b></p> <p>i) Vaccine cost</p> $Vacc = \frac{RM\ 6.61}{1000\ g} \times RM\ 82.04$ $Vacc = RM\ 0.54$ <p>ii) Labour cost (vibrio vaccine administration)</p> $Clabour = RM\ 0$ <p>iii) Increase feed consumption</p> $Fcons = 0.01\ kg \times RM\ 9.76$ $Fcons = RM\ 0.10$ <p>Total = <math>RM\ 0.54 + RM\ 0 + RM\ 0.10</math></p> $= RM\ 0.64$
<p style="text-align: center;"><b>B. Reduce cost</b></p> <p>i) Reduce production cycle</p>	<p style="text-align: center;"><b>D. Reduce revenue</b></p> <p>i) None</p>

$Procycle = (RM\ 12.03/166\ days) - (RM\ 12.69/210\ days)$ $Procycle = RM\ 0.01$ <p>ii) Reduce maintenance, utility, and petrol cost</p> $C_{mup} = RM\ 0.29$ <p>iii) Reduce disposal cost</p> $C_{disposal} = RM\ 0.16$ $Total = RM\ 0.01 + RM\ 0.29 + RM\ 0.16$ $= RM\ 0.46$	$Reduce\ revenue = RM\ 0$ $Total = RM\ 0$
<p><b>E. Total benefits</b></p> $RM\ 0.18 + RM\ 0.46 = RM\ 0.64$	<p><b>F. Total losses</b></p> $RM\ 0.64 + RM\ 0 = RM\ 0.64$
<p><b>Net benefit change (gain/loss)</b></p> $RM\ 0.64 - RM\ 0.64 = RM\ 0.00$	

### iii. Worst-case scenario

The change in survival rate in the worst-case scenario is 21% because it was based on the area where the survival rate of vaccinated fish is compared to the lower survival rate of the non-vaccinated fish in other areas due to poor management and aquaculture practices leading to higher prevalence of the disease. Using Microsoft Excel with the add-in SOLVER function, it will set the net benefit change to RM 0 to obtain the threshold price of *vibrio* vaccine which is expected to get higher than the baseline scenario and best-case scenario with no loss or gain to the farm.

**Table 7: Scenario analysis for worst-case scenario**

Benefits	Losses
<b>A. Added gain</b>	<b>C. Added cost</b>
i) Increase survival $Surv = 21\% \times RM\ 17.80$ $Surv = RM\ 3.74$	i) Vaccine cost $Vacc = \frac{RM\ 52.54}{1000\ g} \times RM\ 82.04$ $Vacc = RM\ 4.31$
ii) increase weight $Wgt = 0.01\ kg \times RM\ 17.80$	ii) Labour cost (vibrio vaccine administration)

$Wgt = RM\ 0.18$ $\text{Total} = RM\ 3.74 + RM\ 0.18$ $= RM\ 3.92$	$Clabour = RM\ 0$ <p>iii) Increase feed consumption</p> $Fcons = 0.01\ kg \times RM\ 9.76$ $Fcons = RM\ 0.10$ $\text{Total} = RM\ 4.31 + RM\ 0 + RM\ 0.10$ $= RM\ 4.41$
<p style="text-align: center;"><b>B. Reduce cost</b></p> <p>i) Reduce production cycle</p> $Procycle = (RM\ 12.03/166\ days) - (RM\ 12.69/210\ days)$ $Procycle = RM\ 0.01$ <p>ii) Reduce maintenance, utility, and petrol cost</p> $Cmup = RM\ 0.29$ <p>iii) Reduce disposal cost</p> $Cdisposal = RM\ 0.19$ $\text{Total} = RM\ 0.01 + RM\ 0.29 + RM\ 0.19$	<p style="text-align: center;"><b>D. Reduce revenue</b></p> <p>i) None</p> $\text{Reduce revenue} = RM\ 0$ $\text{Total} = RM\ 0$

$= RM\ 0.49$	
<b>E. Total benefits</b> $RM\ 3.92 + RM\ 0.49 = RM\ 4.41$	<b>F. Total losses</b> $RM\ 4.41 + RM\ 0 = RM\ 4.41$
<b>Net benefit change (gain/loss)</b> $RM\ 4.41 - RM\ 4.41 = RM\ 0.00$	

## **4.0 RESULT**

### **4.1 The net benefit change of implementing vibriosis vaccination on marine cage farm via partial budget table**

Vaccination has a net gain of RM 1.13 per kg tail of fish. Our result showed the total benefit of vibriosis vaccination from the addition of added gain (RM 1.25/kg/tail) and reduced cost (RM 0.47/kg/tail) is RM 1.72/kg/tail. Added gain contributes RM 1.25/kg/tail from increase in survival and increase in weight at RM 1.07/kg/tail and RM 0.18/kg/tail respectively. Meanwhile, reduced cost contributes RM 0.47/kg/tail from reduction in production cycle, reduced in maintenance, utility and petrol cost as well as reduced disposal cost at RM 0.01/kg/tail, RM 0.29/kg/tail and RM 0.17/kg/tail respectively. While the total losses from the addition of added cost (RM 0.59/kg/tail) and reduced revenue (RM 0) is much lower at RM 0.59/kg/tail. The added cost contributes RM 0.59/kg/tail from vaccine cost, labour cost in administering vaccination, and increase in feed consumption at RM 0.49/kg/tail, RM 0/kg/tail, and RM 0.10/kg/tail respectively. Lastly, reduced revenue is none, hence, it contributes to RM 0.

### **4.2 Threshold price of vaccine in baseline scenario, best-case scenario, and worst-case scenario**

The optimal price of the vaccine in the baseline scenario is at RM 19.75 when the change in survival rate is 6% and considering the disposal cost as the variable at RM 0.17/kg/tail. Meanwhile, the optimal price of the vaccine in the best-case scenario is at RM 6.61 when the change in survival rate is 0% and the disposal cost at RM 0.16/kg/tail. Lastly, the optimal price of the vaccine in the worst-case scenario is at RM 52.54 when the change in survival rate and disposal cost at 21% and RM 0.19/kg/tail respectively.

## 5.0 DISCUSSION

### 5.1 The net benefit of Vibriosis Vaccination

The total benefits (RM 1.72/kg/tail) minus total losses (RM 0.59/kg/tail) of implementing vibriosis vaccination on the Asian seabass has resulted in net benefit of RM 1.13/kg/tail which is the gain received from vaccinating the fish. This shows that the benefits outweigh the costs and will improve the net income of the farm by gaining RM 1.13/kg/tail more when implementing vibriosis vaccination in the farm. For instance, the farm will gain net benefit of RM 2825 per cycle when producing 2500 fishes per cycle in the farm. A previous study recorded 0.52kg of nets saving per kilogram of fish harvested and a benefit-cost ratio of 4:1 in vaccinated Asian Seabass against vibriosis (Thorarinsson and Powell, 2006). This is also supported by a study conducted in channel catfish production in the USA, that shows with vaccination resulted in greater total benefits compared to total cost, producing a net benefit of \$1,443 (RM 6036.79/ha) to the producer. This proves that vaccination lowered the production costs leading to more profitable operations on the farm.

In our model, we calculated the added gain where there was reduced in the mortality and increased the survival by 6% from the unvaccinated fish, as well as increased the weight which is considered the added gain because it gives more benefits to the fish once it is vaccinated. Increase in immunity and better growth has been proven with oral vaccination against vibriosis to limit and control the infection which lead to the high survivability (Amir-Danial, et al, 2022). This is also concurrent with a study in Marine red hybrid Tilapia against vibriosis that stated vaccination resulted in a significantly higher rate of survival at 87% compared to the unvaccinated at 20% (Nadirah, et al, 2020). Similarly, another study conducted in shrimp stated that the mortality among vaccinated shrimp was significantly lower at 31.3 % compared to the unvaccinated group at 78.9 % (Amatul-Samahah, et al,

2020). Furthermore, vaccination altered the gut microbiota which lead to increased nutrient absorption in the intestine and positively affect metabolism leading to better feed conversion and weight gain (Amir-Danial, et al, 2022).

Meanwhile, reduced cost is the cost that will be reduced in the new practice. Reduced production cycle, reduced maintenance, utility, and petrol cost, as well as reduced disposal cost is considered as reduced cost when the fish is vaccinated. This is because of the high immunity against *vibrio spp.* and shorter growth period to reach the market weight at 1kg, leading to the reduced cost of the mentioned above. This is concurrent with a study by Jillian, et al, 2001, that shows vaccinated fish has higher feed conversion ratio (FCR) compared to unvaccinated fish leading to more heavier at harvest at  $357.5 \pm 30g$ , resulting in reduced production cycle than the unvaccinated fish at  $289.5 \pm 20g$  due to reach market weight more faster. This eventually reduced the management cost of the vaccinated fish and indirectly increased the production in the farm.

Other than that, added cost is the additional cost applied with the new practice, which is the vaccine cost, labour cost in administering the vaccine, and increased feed consumption. Here, labour cost in administering the vaccine is RM 0 because the oral vaccination came in the form of feed that had already been repelleted by the manufacturer. With that, there is no additional labour by the workers such as injecting the fish and others as they only need to administer the vaccine like they feed the fish on a daily basis. Moreover, in calculating the cost of vaccination, there are some difficulties encountered such as the exact number of fish in one cage and amount of vaccine consumption per fish. This is because there might be some miscalculation of the number of fish that are not aware of due to different people handling the marine fish or overlooked the dead fish. Other than that, for the vaccine, supposedly, each fish consumed 4% of its body weight.

However, since the vaccine was given orally like giving feed on a daily basis, there might be a chance the fish under-eating or over-eating the vaccine which might affect the effectiveness of the vaccine. There a study conducted in a Red Hybrid Tilapia against Streptococcosis and Motile Aeromonas Septicaemia that shows consumption of 5% vaccine of the fish's body weight brings significant results with higher lysozyme activity, higher IgM antibodies level, fewer clinical and gross lesion and less severe pathological changes observed in selected organs upon histopathology in vaccinated fish than the unvaccinated fish (Mohd Ali,, 2023). This shows that even 5% of vaccine consumption per body weight can still improve immunological response and give protection to the fish. Despite that, further studies need to be done as the type of infection may also influence the amount of vaccine needed for the effectiveness to take place.

Lastly, reduced revenue is returned that is lost due to the new practice. There is no change in quality of fish that had been vaccinated compared to the unvaccinated fish as no study has been found. Thus, the reduced revenue is RM 0 because there is no loss of return.

The data limitation is the one of the limitations encountered for this study. This is because the data input was limited on one marine cage farm in Pulau Ketam that underwent a vaccine trial. There is also limited information on cost and benefits of vaccination in the aquaculture industry to be referred, as not much study has yet been conducted. For future research, it is highly recommended to find more papers that are strongly related to the benefits of vibriosis vaccination and partial budget vaccination of fishes.

## **5.2 The threshold price of vaccine**

The scenario analysis is done to estimate the threshold price of the vaccine

when the net benefit change is set to RM 0. This means that there is no loss or gain to the farm and also shows the optimal price of vaccine that the farmers are capable of investing without having any loss. Our results showed that for the worst-case scenario for example when there is an outbreak of vibriosis in the farm (21% survival difference), the price of the vaccine can be as high as RM 52.54. This means investment in the vaccine would therefore prevent more losses to the farm. Even though the threshold price of the vaccine is higher during an outbreak as compared to baseline scenario, the farmers can control the disease and prevent more deaths, rather than choosing not to vaccinate the fish which will result in more damage and losses to the farm. Based on these results, it can also be used by the policy maker on how much incentive they can provide to the farmers by comparing the price of vaccine with the baseline scenario. We showed that by subsidizing farmers with vaccine costs in high-risk areas and for smallholder farms would reduce loss of resources, prevent further transmission of disease to other farms, lowering use of antibiotics, increases the productivity and sustainability of aquaculture industry. The approach could be seen better than giving incentives based on the production of fish per cycle. According to a study by Huong, et al, 2021, the medicine cost to produce 1 kg of fish per cycle is 0.5 - 0.7 USD which includes the antibiotic cost, accounted for 60% (0.12 - 0.24 USD), the tonic and vitamins cost, accounted for 24.5% and the cost of disinfectant at 15.4% of the total medicine cost. Other studies also reported the treatment with probiotics cost the farmers \$60 per kilogram of fish (Dias, et al, 2020), much higher than the price of the vaccine. Based on these, the cost of antibiotics treatment is seen to be lower than the price of the vaccine, but there are some concerns such as the issue of AMR due to the improper use of the antibiotics, leading to further treatment and increasing the cost resulting in reduced efficiency in the farm than using vaccines.

## 6.0 CONCLUSION

In conclusion, the benefits of vibriosis vaccination on the fish exceeds the costs as shown in the partial budget model where vaccination provides a net benefit to the farmers at RM 1.13/kg/tail if vaccination is implemented. Investing in vaccination will also give economic benefit to the farm especially in high-risk areas as it is able to control the disease, prevent disease transmission and prevent more mortality and economic losses to the farms. Thus, farmers are encouraged to implement vaccines as it can control vibriosis especially in high-risk areas leading to reduction in the economic loss and improve the net income of the farm.

Other than that, based on the results of the threshold price of vaccine in the scenario analysis, policy makers may give farmers incentive for investing in vaccines especially during an outbreak by comparing the price with the baseline scenario. This will encourage and help the small-holder farmers with financial problems to invest in vaccines and gain more profit and become more sustainable.

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## 8.0 APPENDICES

Appendix 1: Data input of vaccinated and non-vaccinated Asian seabass in Microsoft Excel (Spreadsheet 1)

Partial Budget Table of Yibriosis Vaccination						
	VACCINATED			NON-VACCINATED		
	Average Cost	Minimum	Maximum	Average Cost	Minimum	Maximum
Survival rate (%)	77	-	-	71	-	-
Production cycle (days)	166	154	182	210	210	210
Market weight (kg)	1.15	1.09	1.2	1.14	1.1	1.17
Trash fish (kg)	1.41	1.3	1.53	1.42	1.34	1.5
Pellet (kg)	1.62	1.4	1.91	1.6	1.39	1.86
Feed cost - Trash fish and Pellet (RM)	9.76	8.55	11.26	9.62	8.51	11.03
Mortality rate - Yibriosis (%)	10	-	-	17	-	-
Mortality rate - Other cause (%)	13	-	-	12	-	-
Mortality - Yibriosis (RM)	0.07	-	-	0.65	-	-
Mortality - Other cause (RM)	0.24	-	-	0.35	-	-
Disposal cost (RM)	0.17	0.16	0.19	0.2	0.2	0.2
Variable cost (RM)	11.43	10.21	12.95	11.32	10.21	12.73
Maintenance, Utility, Petrol cost (RM)	0.29	0.27	0.32	0.37		
Cost of fry/tail (RM)	1.5	1	2	1.5	1	2
Fish price/kg (RM)	17.8	14.56	18.11	17.8	14.56	18.11
Vaccine price (RM)	18	-	-	-	-	-
Vaccine consumption (%)	4	-	-	-	-	-
Average production cost (RM)	12.03	10.79	13.58	12.69	11.58	14.1
	(Exclude cost of vaccination)					

## Appendix 2: Formulation of cost and benefits of vibriosis vaccination on Microsoft Excel (Spreadsheet 2)

Benefits		Losses	
<b>A. Added gain</b>		<b>C. Added cost</b>	
<b>i) Increase survival</b> Difference in survival rate between vaccinated and unvaccinated fish (%) x Price of fish per kg (RM) Surv (RM) = SR (%) x Pfish (RM) Surv (RM) = 6 x 17.8 Surv (RM) = 1.07  Where, Surv (RM) = Increase survival SR (%) = Survival rate Pfish (RM) = Price of fish		<b>i) Vaccine cost</b> Price of vaccine per kg (RM) x Vaccine consumption (g) Vacc (RM) = Pvacc (g) x Cvacc (g) Vacc (RM) = 6 / 1000 x 82.04 Vacc (RM) = 0.49  Where, Vacc (RM) = Vaccine cost Cvacc (g) = Vaccine consumption Pvacc (RM) = Price of vaccine	
<b>ii) Increase weight</b> Difference in body weight between vaccinated and unvaccinated fish (kg) x Price of fish per kg (RM) Wgt (RM) = BWT (kg) x Pfish (RM) Wgt (RM) = 0.01 x 17.8 Wgt (RM) = 0.18  Where, Wgt (RM) = Increase weight BWT (kg) = Body weight Pfish (RM) = Price of fish		<b>ii) Labour cost (vibrio vaccine administration)</b> Vibrio vaccine is given orally with the feed Clabour (RM) = 0  Where, Clabour (RM) = Labour cost	
<b>iii) Reduce production cycle</b> Vaccinated average production cost (RM) divide with production cycle (days) - Unvaccinated average production cost (RM) divide with production cycle (days) Procycle (RM) = (VPC (RM) / PC (days)) - (UPC (RM) / PC (days)) Procycle (RM) = (RM 12.03 / 166 days) - (RM 12.69 / 210 days) Procycle (RM) = 0.07 - 0.06 Procycle (RM) = 0.01  Where, Procycle (RM) = Reduce production cycle VPC (RM) = Vaccinated average production cost UPC (RM) = Unvaccinated average production cost PC (days) = Production cycle		<b>iii) Increase feed consumption</b> Difference in feed consumption between vaccinated and unvaccinated fish (kg) x Price of feed/kg/tail (RM) Fcons (RM) = FC (kg) x Pfeed (RM) Fcons (RM) = 0.01 x 9.76 Fcons (RM) = 0.10  Where, Fcons (RM) = Increase feed consumption FC (kg) = Feed consumption Pfeed (RM) = Price of feed	
<b>iv) Reduce maintenance, utility, and petrol cost</b> Price of maintenance, utility, and petrol cost per kg (RM) Cmp (RM) = 0.29  Where, Cmp (RM) = Reduce maintenance, utility, and petrol cost		<b>iv) Reduce disposal cost</b> Price of disposal cost per kg (RM) Pdisposal (RM) = 0.17  Where, Pdisposal (RM) = Reduce disposal cost	
<b>E. Total benefit</b>		<b>F. Total loss</b>	
Added gain (A) + Reduce cost (B)		Added cost (C) + Reduce revenue (D)	
<b>Net benefit change (gain/loss)</b>			
Total benefit (E) - Total loss (F)			

Appendix 3: Partial budget table of the cost and benefits of vibriosis vaccination on  
Microsoft Excel (Spreadsheet 3)

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	<b>Partial Budget Table of Vibriosis Vaccination - Baseline scenario</b>													
2														
3	<b>Benefits</b>							<b>Losses</b>						
4	<b>A. Added gain</b>							<b>C. Added cost</b>						
5	i) Increase survival (RM)	=	1.07				i) Vaccine cost (RM)	=	0.49					
6	ii) Increase weight (RM)	=	0.18				ii) Labour cost - Vibrio vaccine administration (RM)	=	0					
7							iii) Increase feed consumption (RM)	=	0.10					
8														
9	Total added gain (RM)	=	<b>1.25</b>				Total added cost (RM)	=	<b>0.59</b>					
10														
11	<b>B. Reduce cost</b>							<b>D. Reduce revenue</b>						
12	i) Reduce production cycle (RM)	=	0.01				i) Reduce revenue (RM)	=	0					
13	ii) Reduce maintenance, utility, and petrol cost (RM)	=	0.29											
14	iii) Reduce disposal cost (RM)	=	0.17											
15														
16														
17	Total reduce cost (RM)	=	<b>0.47</b>				Total reduce revenue (RM)	=	<b>0</b>					
18	<b>E. Total benefit</b>							<b>F. Total loss</b>						
19	Total benefit (RM)	=	1.72				Total loss (RM)	=	0.59					
20	<b>Net benefit change (gain/loss)</b>													
21	Net gain (RM) = 1.13													
22														
23														
24														
25														