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Seasonal Change or COVID-19 More Impacting Aquafarmers' Economic? Assessing the Role of Technological Facilities in Alleviating These Vulnerabilities

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ABSTRACT

Upon the outbreak of the COVID-19 pandemic, technological facility has become increasingly crucial to the aquafarmers, particularly in dealing with seasonal shifts. The technological facilities have assisted the aquafarmers to monitor and manage their operations during the limited movement. This study aimed to determine whether vulnerability to the COVID-19 pandemic or vulnerability to seasonal changes has more significant impact on aquafarmers' economics, with assistance of technology facility. Additionally, the role of technology in mitigating the vulnerabilities toward aquafarmers economics was identified. The primary data via survey questionnaire and interviews were conducted on 274 aquafarmers in Terengganu, Malaysia, and data were analyzed using the stepwise regression analysis. An impact of vulnerability to COVID-19 pandemic was detected on aquafarmers economic constraint. Meanwhile, no significant vulnerability to seasonal change was recorded on aquafarmers economic constraint in Terengganu. This indicates that COVID-19 epidemic had a greater and more extensive impact compared to seasonal fluctuations. However, seasonal shifts have always been part of aquaculture, and farmers have developed new approaches to adapt and control them. The Movement Control Order (MCO) during the pandemic restricted the demand and supply chain of seafood products, resulting in a decrease in pricing and sales for aquafarmers. Furthermore, a significant impact of technological facility adoption was determined in reducing vulnerability to COVID-19 pandemic toward aquafarmers economics in Terengganu. The findings of this study provide important information on how these technologies can help aquafarmers maintain their economic stability while maintaining their businesses operating.

INTRODUCTION

The COVID-19 pandemic, originating in late 2019, had a profound impact on Malaysia, overwhelming public health systems and leading to high fatalities **(Wan Mohamad *et al.*, 2024)**. The pandemic triggered significant social and lifestyle changes, including strict lockdowns, social distancing measures, and a transition to remote work and learning **(Cheah *et al.*, 2023)**. Economically, Malaysia faced a recession due to

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reduced consumer demand and disrupted supply chains, particularly affecting sectors like tourism, retail, and manufacturing **(Lim *et al.*, 2023)**.

Transportation restrictions and border closures hindered the movement of goods, leading to shortages of essential inputs like feed **(Chodakowska *et al.*, 2024)**. Fluctuating market demand due to closures of restaurants and shifting consumer preferences caused instability in sales and pricing for aquaculture products **(Found *et al.*, 2024)**. Operational challenges arose from implementing safety measures, such as social distancing and sanitization protocols, which reduced productivity and efficiency. Additionally, workforce issues emerged from illness and movement restrictions, resulting in labor shortages and decreased employment in the aquaculture sector **(Aloqab *et al.*, 2024)**. These combined factors underscore the complex and interconnected nature of the challenges faced by the aquaculture industry during the pandemic, highlighting the need for resilience and adaptability in supply chain management **(Ali *et al.*, 2023)**.

The aquaculture industry in Malaysia has responded to challenges like the COVID-19 pandemic by implementing various adaptation and recovery strategies. These strategies include diversifying market channels to incorporate more direct-to-consumer sales, leveraging digital platforms for marketing and sales, and enhancing biosecurity measures to safeguard both workers and products. Furthermore, government support in the form of financial aid and subsidies has played a crucial role in facilitating the sector's recovery. By adopting these measures, the industry aims to stabilize its operations, enhance resilience against future disruptions, and ensure sustained growth and sustainability, aligning with the broader goal of economic recovery and development in Malaysia **(Ahmad *et al.*, 2023)**.

In response, the aquaculture industry has implemented various adaptation and recovery strategies. To mitigate these effects, aquafarmers have adopted various adaptation strategies, such as developing their own feed, diversifying market channels to include direct-to-consumer sales, and increasing the use of digital platforms for marketing. Government support through financial aid and subsidies has also been crucial in aiding the recovery of the aquaculture sector. While the pandemic has caused disruptions, the long-term economic challenges posed by seasonal changes should not be overlooked since they can also significantly impact aquafarmers' economic stability and production levels **(Muntaha *et al.*, 2023)**. Understanding these dual challenges is essential for policymakers and stakeholders to develop effective strategies to enhance the resilience of the aquaculture industry. However, these adaptations have also highlighted the vulnerability of the aquaculture industry to climate change.

Seasonal changes, especially caused by climate change, have a significant impact on aquafarmers' economic stability **(Berio & Salugsugan, 2022)**. Additionally, rainfall patterns, temperature changes, and extreme weather events can all affect aquaculture output, which can lead to higher costs and lower yields **(Hamdan *et al.*, 2011)**. Climate fluctuation causes problems for aquafarmers in regions like Bangladesh and Malaysia, such as water scarcity, disease outbreaks, and productivity losses because of variations in water temperature and dissolved oxygen levels **(Puspa *et al.*, 2018)**. Moreover, seasonal changes impact aquafarmers by influencing water parameters, fish performance, fish health, and parasitic infestation **(Renis *et al.*, 2018)**. Monitoring and adjusting conditions, especially in summer, can enhance fish growth and survival rates **(Emmanuel *et al.*, 2018; Mavraganis *et al.*, 2021)**.

Seasonal changes during the COVID-19 pandemic have significantly impacted aquafarmers globally **(Jonathan *et al.*, 2021)**. Fish farmers are already susceptible, but the disruptions to workforces, production, supply and demand, and fish and feed delivery caused by COVID-19 have made them even more vulnerable **(Alam *et al.*, 2023)**. The vulnerability to COVID-19 has significantly impacted the economic stability of aquafarmers **(Amoussou *et al.*, 2022)**. Moreover, it has resulted in a substantial decrease in income and employment for fish farmers, fishers, and traders **(Van Senten *et al.*, 2021)**. High shipping costs, lack of capital and credit, and fish value chain disruptions have hit traders hardest, emphasizing the vulnerability of the sector **(Bashar, 2022)**. The market demand for fish has sharply declined, leading to a reduction in fish consumption and a decline in pricing. The necessity to stock mature fish longer and rising feed costs have raised production expenses **(Khan *et al.*, 2023)**. The prolonged farming cycle was a result of delayed harvesting, which caused fish stocks to be kept in ponds **(Yuan *et al.*, 2022)**. In addition, farmers confront problems and risks associated with their agricultural activities, such as limited control over diseases and pests on their farms **(Moradhaseli *et al.*, 2022)**.

Furthermore, the pandemic and seasonal change has necessitated the adoption of new strategies, such as direct selling through mobile phones and social media platforms. Mobile phone applications offer remote aquatic environment monitoring, enabling farmers to make informed water and fish health decisions without physical presence **(Kjellby *et al.*, 2019)**. The COVID-19 pandemic has significantly impacted marketing strategies, leading to a shift from offline to online platforms **(Mahan *et al.*, 2023)**. Additionally, the rise of digital adoption during the pandemic has highlighted the importance of empowering businesses in digital marketing to increase product sales **(Raluca *et al.*, 2022)**. Aquafarmers had to adapt to market changes, with some exploring new marketing strategies like direct sales through mobile phones and social media platforms. The use of technology in selling fish products has been highlighted as a solution to the existing problems faced by fish cultivators, especially in reaching potential buyers and enhancing sales focus **(Yeremia *et al.*, 2023)**. Therefore, the technology facilities play an important role in decreasing vulnerability and increasing the long-term viability of aquaculture especially during seasonal change and pandemic.

Through the technology's utilization, aquafarming activities have the capacity to enhance sustainability, mitigate environmental contamination, and establish a dependable food supply. Various technologies have been created to improve production and address environmental issues **(Elaswad & Dunham, 2018)**. Technological facilities are essential to the management of aquafarming activities **(Ubina & Cheng, 2022)**. IoT management solutions for aquaculture farms collect and handle operational information from installed facilities, enabling remote operation and informing the farm company when sensor data surpass a certain range **(Chiu *et al.*, 2022)**. Advances in IoT and artificial intelligence (AI) technology allow for the gathering, exchange, and automation of data in aquaculture farms, resulting in better monitoring and decision-making processes **(Lu *et al.*, 2019)**. Intelligent fish farms use IoT and cloud-based monitoring systems to optimize feeding, minimize disease incidence, and improve water quality through automation and data analysis **(Gao *et al.*, 2019)**. Additionally, the utilization of AI technology in the agricultural sector, including machine learning, IoT, expert systems, image processing, and computer vision, has improved the quantity and quality of work in agriculture **(Elbasi *et al.*, 2022)**. These technological facilities help improve the precision and efficiency of aquafarming operations, addressing issues like labor shortages and the need for innovation in aquaculture technologies.

Indeed, the COVID-19 epidemic along with unpredictable seasonal change affected the aquafarmer management, communication, and financial status. The pandemic introduced substantial challenges, including disruptions in supply chains, fluctuating market demand, and increased operational hurdles due to safety measures. These factors compounded the difficulties posed by seasonal variations, such as shifts in water temperature and weather patterns, which further affect aquaculture productivity and profitability. As a result, aquafarmers have faced heightened uncertainty and financial strain, necessitating robust adaptation and recovery strategies to navigate these compounded challenges effectively.

This study aimed to determine whether vulnerability to the COVID-19 pandemic or seasonal changes has a more significant impact on aquafarmers' economics, with a focus on the role of technology in mitigating these impacts. By comparing the effects of these two factors, the research seeked to identify which of the two factors presents a greater economic challenge to aquafarmers and how technology adoption influences their ability to manage and adapt to these challenges. The findings would offer insights into the relative importance of COVID-19 versus seasonal changes, highlighting the potential of technology to support the economic resilience in the aquaculture sector. In addition, the findings of this study would provide the government and stakeholders with knowledge and understanding, regarding the importance and impact of technology on aquafarmer business. The information obtained would result in improved policies and strategies that encourage the growth and long-term viability of the aquaculture industry. Furthermore, this study provides a valuable insight for the policymakers, researchers, and stakeholders into the issues and challenges encountered by aquafarmers & the potential implications for the aquafarmer economy and aquaculture industry. Examining how COVID-19 and seasonal change affected aquafarmers might shed light on industry weaknesses and guide future risk mitigation efforts. Researchers can learn a lot about how to handle future pandemics and crises by studying how COVID-19 affected aquafarmers. Industry and government may utilize this information to strengthen resilience, improve crisis management, and create better backup plans.

MATERIALS AND METHODS

1. Data collection

In this study, the primary survey design was carried out on 274 respondents of aquafarmers in Terengganu using simple random sampling technique. This study involved 274 randomly chosen respondents from a population of 945 aquafarmers in Terengganu State of Malaysia, determined using the table of **Krejcie and Morgan (1970)**. Data were collected via telephonic, face-to-face, and online questionnaire surveys.

2. Method of analysis

This study utilized the stepwise linear regression analysis to determine the impact of vulnerability to seasonal change and COVID-19 on the aquafarmer’s economic constraints. Moreover, the impact of technological facilities adoption on the aquafarmers’ economic constraints was identified along with degree to which the aquafarmers constraints and vulnerability can be reduced when adopting the technological facilities. However, before carrying out the stepwise regression analysis, the exploratory factor analysis (EFA), normality test, reliability test and common method bias (CMB) were employed to ensure the data accuracy that meet the requirement of stepwise linear regression. Data accuracy and analysis were conducted using the SPSS software.

2.1 Data screening

The 27 generated items were then included in a formal questionnaire following the preceding steps. Each question was rated using a 5-point Likert scale that ranged from 1 (strongly disagree) to 5 (strongly agree). The purpose of employing EFA was to determine whether the items in a questionnaire are assessing a single construct or numerous constructs. **Hair *et al.* (2017)** recommended employing EFA before regression analysis as a best practice in statistical analysis. They argue that EFA can help to identify the underlying factors that are driving the relationships between the predictor variables and the outcome variable, which can improve model fit and reduce dimensionality. This process will produce factor loadings, which represent the degree of correlation between each item and the identified factors (constructs). The factor loadings indicate that the items are assessing both similar and distinct constructs.

The normality test was implemented to check whether data follow the normal distribution or not and then, reliability test was conducted to identify the extent to which the item of questionnaire can measure their respective factor. Reliability test depends on Cronbach Alpha value (α). A value of α around 0.70 or greater is widely considered acceptable. Additionally, the common method bias (CMB) was also employed using Harman's single-factor test. To mitigate CMB, it is necessary to acknowledge and account for situations where data are collected from a single source, with the same individual responding to both the independent and dependent variables. Common method bias can arise when a single response method is employed to measure both the independent and dependent variables in a single survey conducted simultaneously and in the same location. To ensure the accuracy and reliability of a study, it is important to address the issue of common method bias. This bias has the potential to distort the relationships between variables and introduce measurement errors, which can significantly impact the reliability, validity, and accuracy of parameter estimations, as detailed in the studies of **Podsakoff (2012)** and **Kock *et al*., (2021)**. Harman's single-factor test reveals problematic common method bias (CMB) if the eigenvalues from exploratory factor analysis (EFA) indicate that the first factor explains more than 50% of the variance **(Podsakoff & Organ, 1986)**.

Hair *et al.* (2017) claimed that the assessment of the structural model should consider the β value's direction (band coefficient), a t- value greater than 1.645, and a *P*-value less than 0.05. The conceptual framework of this study, illustrated in Fig. (1), consists of three independent variables: vulnerability to seasonal change, vulnerability to COVID-19, and technology facility. The dependent variable is aquafarmers' economic constraints.

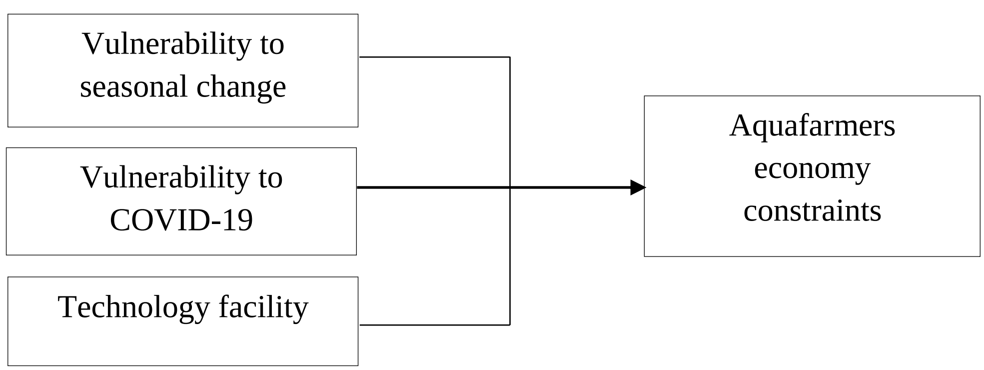

Fig. 1. Conceptual framework of study

2.2 Descriptive analysis

In addition, this study also included a descriptive analysis that provides the demographic profile as well as details on aquafarm.

2.3 Stepwise linear regression analysis

Pearson correlation analysis was carried out to select the two variables that significantly have relationship to each other. This significant variable was used for further analysis; the stepwise regression analysis. It was used to add or remove control variables (independent variables) in succession and testing for statistical significance after each iteration. Stepwise regression equation model of this study was presented as follows using the model of multiple linear regression:

$$Y=\beta_0 + \beta_1X_1 + \beta_2X_2 +\beta_3X_3+e \quad (1)$$

Where,

Y = Response variable (Marine fish landing)
β_0 = Constant variable
β_1 = Coefficient of first control variable, X_1
β_2 = Coefficient of second control variable, X_2
β_3 = Coefficient of third control variable, X_3
X_1 = Controlled variable (Vulnerability to the seasonal change)
X_2 = Controlled variable (Vulnerability to the COVID-19)
X_3 = Controlled variable (Technology facilities)
e = Error

RESULTS

The outcomes of data screening viz. EFA, reliability test, normality test, and CMB as well as descriptive, correlation and stepwise linear regression analysis were addressed. The result of descriptive analysis clarifies the number and percentage of respondents based on demographic profile and aquafarm details. Whereas, the result of VBSEM discusses the impact of vulnerabilities and technological facilities adoption on aquafarmers' economics in Terengganu.

1. Data screening

1.1 EFA result

To assess the dimensionality of the proposed scale, an EFA was performed on the first dataset using the principal component technique and varimax rotation. About two items were deleted due to their low communalities (less than 0.50) since they were not sufficiently connected to the other items in the dataset. Items with low loading (less than 0.50) on any factor were also deleted since they had no substantial association with any factor. However, 25 items with a loading of 0.50 or higher on multiple components were maintained since they may have some relevance to multiple elements of the data. Hence 4 factors were determined (vulnerability to seasonal change, vulnerability to COVID-19, technology facility and aquafarmers' economic constraints). The Kaiser Meyer Olkin (KMO) test result of 0.873 showed that the sample size was adequate. Furthermore, Bartlett's sphericity test yielded a significant result. Eventually, a four-variable structure was formed, which encompassed all 25 remaining components and accounted for 60.598% of total observed variations.

1.2 Reliability test result

Cronbach's alpha (α) values for all four extracted components were greater than 0.80, indicating a sufficient reliability. Additionally, all the constructs met the requirement of reliability being essential for ensuring the reliable operation of constructs. It reveals the degree to which items in a test or scale are connected to one another, giving an approximation of how well the test or scale evaluates a single underlying variable.

1.3 Normality test result

Based on the normality test, the Kolmogorov-Smirnov statistic is 0.054 ($P > 0.05$), indicating that the data follow a normal distribution. Therefore, the data can proceed to the stepwise linear regression analysis. However, 15 outliers (5.5%) were omitted, leaving 259 respondents.

1.4 CMB result

Data of this study were free from problematic CMB since the Harman's one-factor test result showed that the eigenvalue for the first factor accounted for less than 50% of the variance among variables.

2. Descriptive analysis result

Table (1) displays the number and percentage of respondents according to their demographic profile. Most of respondents were from Kuala Terengganu followed by Besut, Hulu Terengganu, Setiu, Dungun, Kemaman, Kuala Nerus and Marang. Meanwhile, mostly respondents were between the age range of 30-39 years, while a minority of respondents were 70 years and older. Furthermore, 88.4% of the respondents were married, 90.7% of respondents were males, and 93.8% of respondents were from Terengganu. Moreover, only 5% of them lacked a formal education, whilst 43.2% of them had an SPM level.

Table 1. Number and percentage of respondents based on demographic profile

Profile demographic	Frequency N=259(%)
District	
Besut	42(16.2)
Dungun	25(9.7)
Hulu Terengganu	46(17.8)
Kemaman	24(8.8)
Kuala Nerus	19(7.3)
Kuala Terengganu	55(21.2)
Marang	17(6.6)
Setiu	31(12.0)
Age	
20 to 29 years old	29(11.2)
30 to 39 years old	68(26.3)
40 to 49 years old	51(19.7)
50 to 59 years old	59(22.8)
60 to 69 years old	39(15.1)
70 years and above	13(5.0)
Gender	
Male	235(90.7)
Female	24(9.3)
Educational level	
No education	13(5.0)
PMR/SRP	68(24.3)
SPM	112(43.2)
STPM/Skills Certificate/Diploma	48(18.5)
Degree and above	23(8.9)
Status of marriage	
Single	24(9.3)
Widowed/divorced	6(2.3)
Married	229(88.4)
Birth of place	
Terengganu	243(93.8)
Others	16(6.2)

Table (2) shows the number and percentage of respondents based on aquafarm details. The majority of respondents were freshwater farmers, followed by freshwater ornamental farmers, and hatchery farmers. Additionally, most respondents utilized the the cage farming approach, which lessened strain on land use and allowed the fish to remain in their natural habitat. Furthermore, most respondents had 5 years and below of experience in aquaculture farming. Approximately, 76.4% of them did not have employees.

Table 2. Number and percentage of respondents based on aquafarm details

Aquafarm details	Frequency N=259 (%)
Aquaculture type	
Freshwater	173(66.8)
Brackish water	59(22.8)
Hatchery	7(2.7)
Freshwater ornamental	20(7.7)
Aquaculture system	
Pond	49(18.9)
Cage	136(52.5)
Tank	29(11.2)
Fish seed	25(9.7)
Aquarium	18(6.9)
Others	2(0.8)
Duration of experience	
5 years and below	105(40.5)
6 to 10 years	73(28.2)
11 to 15 years	31(12.0)
16 to 20 years	32(12.4)
more than 20 years	18(6.9)
Number of workers	
No worker	198 (76.4)
1 to 2 workers	52(20.1)
3 to 4 workers	6(2.3)
5 workers and above	3(1.2)

3. Correlation analysis

Table (3) exhibits the correlation between response variables and control variables based on Pearson correlation analysis. There was a positive moderate correlation between aquafarmers' economic constraints and vulnerability to covid 19 (*P*=0.501). Meanwhile, aquafarmers' economic constraints and technological facility showed a negative low correlation. Moreover, there was a positive low correlation between vulnerability to aquafamers' economic constraints and vulnerability to seasonal change. The three correlations showed that they were not significant since their *P*-values were greater than 0.05.

Table 3. Correlation between response variables and control variables

Response variable	Control variable	Pearson correlation, *P*	Sig. (2-tailed)
Aquafarmers' economic constraints	Vulnerability to seasonal change	0.107	0.086
	Vulnerability to covid	.501**	0.000
	Technology facility	-.264**	0.000
Technology facility	Vulnerability to seasonal change	0.047	0.448
	Vulnerability to covid	-0.065	0.300
Vulnerability to seasonal change	Vulnerability to seasonal change	.371**	0.000

Notes: ** and *significant level at 0.01 and 0.05, respectively.

4. Stepwise regression analysis

Table (4) presents the result of stepwise result regression analysis of models 1 and 2. Model 1 comprises vulnerability to covid as an independent variable and aquafarmers' economic constraints as a dependent variable. Meanwhile, there were two independent variables in model 2 which were vulnerable to covid and technological facility with aquafarmers' economic constraints as a dependent variable. The vulnerability of seasonal change was excluded in both models since there was no significant impact on aquafarmers' economic constraints. The *F*-statistics was significant for both models implying that their linear regression lines were meaningful. It described the relation between vulnerability to covid and aquafarmers' economic constraints in Terengganu as well as the relation between vulnerability to covid and technology facility toward aquafarmers' economic constraints in Terengganu. The VIF value was less than 5, indicating that all models were free of multicollinearity issues. Additionally, the Durbin-Watson value was smaller than 4, with DW=0.13 (Model 2).

Models 1 and 2 have R- squares of 0.251 and 0.305, respectively. Model 1 indicated that 25.1% change in aquafarmers' economic constraints was caused by the change vulnerability to COVID-19, while the remaining percent was due to the change of other factors. Moreover, in model 2, around 30.5% changes in aquafarmers' economic constraints were due to the changes in combination with the vulnerability to COVID-19 and technological facility, while the remaining percent was due to the change of other factors. Since the R- square of model 2 was higher, model 2 is a better fit to the data than model 1. Based on Table (4), model 1 and model 2 were expressed in an equation as follows:

$$Y= 1.961+ 0.380CV_1 + e \quad (2)$$

$$Y= 2.620 + 0.368\, CV_1- 0.195TF + e \quad (3)$$

Based on model 1 result (Table 4), there was a positive significant impact of vulnerability to COVID-19 on aquafarmers' economic constraints (β_1=0.380, t=14.227, *P*-value<0.01). It indicated that the increase in 1 unit of vulnerability to covid could increase 0.380 unit of aquafarmers' economic constraints. Furthermore, for model 2, there is a positive significant impact of vulnerability to COVID-19 on aquafarmers' economic constraints (β_1=0.368, t=9.302, *P*-value<0.01). It can be explained that the increase in 1 unit of vulnerability to covid could increase 0.368 unit of aquafarmers' economic constraints. Meanwhile, in model 2, there was a negative significant impact of technology facility on aquafarmers' economic constraints (β_2=-0.195, t=-4.447, *P*-value<0.01). It indicates that the increase in 1 unit of technology facility could decrease 0.195 unit of aquafarmers' economic constraints.

Table 4. Stepwise result regression analysis

Model	Independent variable	Unstandardized coefficients, β	Std. error	t	*P*-value	VIF
1	(Constant)	1.961	0.138	14.227**	0.000	
	Vulnerability to covid (CV)	0.380	0.041	9.277**	0.000	1.000
	R Square	0.251				
	F statistics	86.067**				
2	(Constant)	2.620	0.199	13.152**	0.000	
	Vulnerability to covid (CV)	0.368	0.040	9.302**	0.000	1.004
	Technology facility (TF)	-0.195	0.044	-4.447**	0.000	1.004
	Durbin Watson (DW)	0.130				
	R Square	0.305				
	F statistics	56.067**				

Notes: Dependent variable is aquafarmers' economic constraints.VIF represents variance inflation factor. ** and *significant level at 0.01 and 0.05, respectively.

DISCUSSION

The higher value of the R-square in model 2 shows that this model is better than model 1. Furthermore, it indicates that 30.5% of aquafarmers' economic constraints can be measured and explained by the vulnerability to covid and technology facility. The higher percentage of R-square the better the model could predict the outcome. Based on model 1, the vulnerability to COVID-19 is a factor affecting the aquafarmer's economics constraint. Whereas model 2 explained that vulnerability to COVID-19 and technological facility are the factors impacting the aquafarmer's economics constraint in Terengganu. When the technological facility factor is considered, the smaller coefficient ($\beta 1=0.368$) for vulnerability to COVID in model 2 ($\beta 1=0.380$), compared to model 1, means that vulnerability to COVID had less effect on aquafarmers' economics in Terengganu. It indicates the importance of technological facility adoption in mitigating the aquafarmers' economic constraints in Terengganu. This might be attributed to the effective utilization of technology, enabling them to successfully adapt and continue their operations among the difficulties posed by the pandemic. Technological facility has a significant impact on the aquafarmer's economics constraint. It shows that the adoption of technological facility could reduce aquafarmers' economic constraints in Terengganu. Adopting technology can enhance the social well-being of aquafarmers by improving working circumstances, elevating quality of life, and generating employment chances **(Dey *et al.*, 2021, Fernandes *et al.*, 2020; Amoussou *et al.*, 2022; Jaikumar *et al.*, 2023)**.

However, there is no significant impact of vulnerability to seasonal change on aquafarmers' economic constraints in Terengganu. This indicates that most of aquafarmers in Terengganu were more impacted by COVID-19 outbreak than seasonal change. Notably, aquafarmers are frequented with the seasonal alterations and can easily manage their farms under any new environmental changes. Meanwhile, the epidemic occurred for the first time, and they had to go through numerous abrupt changes to which they were unable to cope. The implementation of restrictions and MCO challenges pose their ability to move and reduced employment activities. Working remotely is not sufficient for managing their business operations as their enterprise requires constant monitoring due to the involvement of livestock that necessitates meticulous attention to food, water quality, temperature, and salinity **(Amoussou *et al.*, 2022; Jaikumar *et al.*, 2023)**. As a result, a significant portion of their livestock perished, adversely affecting their business. Additionally, businesses worldwide have been affected by the vulnerability to COVID-19, which has also hindered their production processes. Several organizations have encountered difficulties in sustaining their typical production levels due to constraints as labor downsizing, supply chain interruptions, and safety precautions. Large farms were more likely to respond by reducing labor costs, seeking new markets, and borrowing money **(Lebel *et al.*, 2021)**. Moreover, limited availability of skilled labor is an ongoing challenge for aquaculture firms **(Ragasa, 2022)**.

Documenting the effects of COVID-19 on aquafarmers could promote knowledge sharing among researchers, policymakers, and stakeholders from various areas and sectors. As a result, the aquaculture industry stakeholders may be able to work together to find solutions for their problems and establish best practices. However, there are limitations to this study in terms of the area covered, as it only focuses on the Terengganu area and does not consider other factors affecting the aquafarmer economy. It is suggested that future studies expand the scope to wider regions, such as throughout Malaysia, and consider other factors affecting the aquafarmer economy to provide a more thorough understanding.

CONCLUSION

The study analyzed the impact of vulnerability to COVID-19 and technology facility on aquafarmers' economic constraints in Terengganu. The results showed that the inclusion of technology facility in the model improved the explanatory power of the model, indicating that 30.5% of aquafarmers' economic constraints can be explained by vulnerability to COVID-19 and technological facility. The study found that vulnerability to the covid had a significant impact on aquafarmers' economic constraints, but the adoption of technological facility mitigated this impact. In contrast, seasonal change did not have a significant impact on aquafarmers' economic constraints.

In conclusion, this study highlights the importance of considering the impact of COVID-19 on aquafarmers' economic constraints, particularly in areas like Terengganu where the pandemic had a significant effect. The study also underscores the importance of technological adoption in mitigating the impact of COVID-19 on aquafarmers' economic constraints. The findings suggest that policymakers, researchers, and stakeholders should prioritize the development of technological facilities to support aquafarmers in adapting to crises like pandemics. Furthermore, the study emphasizes the need for future research to expand the scope to wider regions and consider other factors affecting aquafarmers' economic constraints to provide a more comprehensive understanding of the issue.

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