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Analysis of the factors influencing the quality of farmed mud crabs in the Mekong Delta, Vietnam

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Abstract. Enhancing the quality of cultivated mud crabs is a crucial element for elevating productivity, quality, and economic effectiveness within the mud crab farming sector. This study investigates factors influencing the quality of farmed crabs in the Mekong Delta, Vietnam. The study employs descriptive statistical methods and synthesis approaches to analyse the current situation of crab farming in the Mekong Delta, Vietnam. Additionally, multivariate regression analysis was employed to identify factors affecting the quality of farmed crabs in the Mekong Delta, Vietnam. The survey results from 304 crab farmers in the Mekong Delta, Vietnam indicate that the total area of the Mekong Delta, Vietnam is 465 thousand hectares, with a production of 68 thousand tons. Among the provinces in the Mekong Delta, Vietnam, Kien Giang, Ca Mau, and Bac Lieu are the top three provinces with the highest area and production. Furthermore, factors influencing the quality of crab products during the farming process were analysed, and three main factors were identified: the decision to catch crabs at the fourth moult stage (Y4), the

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number of crab traps used, and the duration of the farming period. This research represents the first study on the quality of farmed crab in the Mekong Delta, Vietnam. Therefore, these findings provide guidelines for improving the quality of farmed crab and serve as a foundation for further research in this field

Keywords: decision to catch crabs; Mekong Delta; mud crab quality; farming

INTRODUCTION

The total output of farmed mud crabs in the Mekong Delta in 2020 was 67 thousand tons, an increase of 19% compared to 2015 (Directorate of Fisheries, 2020). Converting the specialized shrimp farming model into extensive crab farming initially brings high profits. On average, each farmer earns 30 million VND/hectare/crab crop (Long, 2019). In addition to the rapid growth in output and profits for mud crab farmers, the mud crab industry faces many difficulties in consumption as well as stable development. The rapid and unstable development has caused current difficulties for the mud crab industry such as a lack of specific farming area planning for mud crabs, unquarantined breeds, and lack of cooperation between entities, the undeveloped mud crab brand, lack of a set of standards in the production stage, inconsistent mud crab quality, slow transportation and long waiting time, and lack of product diversity for consumers. These reasons caused unstable development of mud crab products in recent years and the products have not been exported to international markets.

T. Trang and N. Toan (2020) and A. Coronado Mondragon *et al.* (2021) believe that product quality contributes to the expansion of competitive advantage while products are designed and manufactured to achieve customer requirements related to high product performance. D. Love *et al.* (2021) believe that there are many product features used to evaluate the quality of that product. Among them, the most common attributes are technical, practical, aesthetic, economic, ergonomic, ecological, and logistical factors. Fishery quality refers to the objective or subjective value attributed to one or all of the four identified qualitative characteristics. The quality of aquatic products directly influences the revenues of crab farmers and affects the economic chain. Quality can include four characteristics: nutrition, safety, function, and sensory attributes, depending on the type of seafood. Assessing the quality of aquatic products will involve product research, experience, beliefs, and other attributes. Li *et al.* (2018) suggest that, in particular, product research is done before purchasing (price, colour, size), experience is evaluated after the process of purchasing and consuming the product (smell, taste), beliefs are related to food safety (being free from chemical or microbiological contamination) and other attributes cannot be observed both before and after consumption such as production method or place of production (Stadtler, *et al.,* 2015; Booncharoen & Anal, 2021).

N. Mangun *et al.* (2021) define that quality standards include all activities and measures to ensure that products are delivered to consumers with the best quality and that the products have the maximum satisfaction of consumer needs at the lowest cost. Analysis of product quality standards must also be performed throughout the product life cycle from production and distribution to product consumption. However, T. Phong *et al.* (2021) determined that product quality for mud crab products depends largely on the production stage. In addition, analysing mud crab quality is to manage the following quality attributes: (1) nutritional quality; (2) sensory quality (colour, flexibility, size) and eating quality (fatness, sweetness); (3) product quality (tying quality, shipping quality, aesthetic quality); (4) food hygiene and safety quality (soil environment, water, air; aquatic chemicals; storage and sale); (5) preservation quality; and (6) seed quality. Furthermore, mud crab is a commodity whose meat needs to be fresh, and the quality of mud crab is greatly affected by the farming process of farmers. This is also the biggest barrier that makes the mud crab industry develop slowly (Samah & Kamaruddin, 2015).

Given the current status of mud crab production by farmers in the Mekong Delta and the context of international economic integration, the Mekong Delta region requires practical and effective solutions to enhance quality and satisfy consumer requirements related to competitive prices and help develop the mud crab industry in the Mekong Delta sustainably. The study aims to establish theoretical foundations and demonstrate the logical methodology of determining factors influencing the quality of farmed mud crabs among crab farmers in the Mekong Delta, Vietnam. The hypotheses of this study posit the existence of relationships between factors such as experience, training, number of harvests, decision to catch crabs Y4; the number of crab traps; the farming time of crabs; pond renovation and breeds.

MATERIALS AND METHODS

Following Binh Dien Wholesale Market (2020), the mud crab market in Vietnam is regulated by a set of criteria, such as type, size, and quality of mud crabs. Crab parts are divided into 3 main types per crab: meat crabs (male or female crabs without crab roe over 180g), gravid crabs (female crabs with roe over 200g) and mixed crabs (crabs with missing claws, sticks or soft shells). However, each type of crab is different based on size and gender and thus the market divides mud crabs into 4 types. The 3 types of which meet quality standards (Y1 crab, Y4 crab, gravid crab) and 1 type does not meet standards about quality (mixed crab).

Table 1. *Criteria for classifying mud crabs in the Mekong Delta*

No.	Crab type	Description	Size	Quality
1	Y1 crab (meat crab)	Y crab is a male crab or meaty crab, with big claws and a long Y-shaped apron	>270g/crab	All intact parts intact, no dirt or parasites clinging to the crab, good reflexes, and more than 70% flesh in the body
2	Y4 crab (meat crab)	Y crab is a male crab or meaty crab, with big claws and a long Y-shaped apron	180-265 g/crab	All intact crab parts, no dirt or parasites clinging to the crab, good reflexes, and more than 70% flesh in the body
3	Gravid crab	Female crab carries crab roe	>200g/crab	All intact crab parts, no dirt or parasites clinging to crab, good reflexes, and dark yellow roe
4	mixed crab	The type of meaty crab only has one claw or has a broken stick, the shell is soft, and the meat in the crab body is low		No dirt or parasites clinging to crab, and good reflexes

Source: *compiled by the authors based on the Binh Dien Wholesale Market (2018)*

Sampling. The study selected three provinces with the largest mud crab output using multi-stage probability sampling based on the criteria of mud crab output of provinces in the Mekong Delta in 2020 after the covid 19 pandemic, mainly Kien Giang, Ca Mau and Bac Lieu. From the distribution structure of mud crab production in districts in three provinces, the study selected three districts from each province. Three communes were selected from each district, and three hamlets were selected from each commune according to the criteria of greatest output to be the research areas. In Kien Giang province, there were 03 districts (An Minh, An Bien, Vinh Thuan) with the highest mud crab production (accounting for 90% of the entire province). Ca Mau province has 3 districts (Nam Can, Dam Doi, Ngoc Hien) with the output accounting for 60% of the entire province and Bac Lieu province has 3 districts (Gia Rai, Phuoc Long and Dong Hai) with output accounting for 70% of the entire province. Probability sampling was conducted using a systematic sampling method at hamlets based on the list of mud crab farmers (Fig. 1).

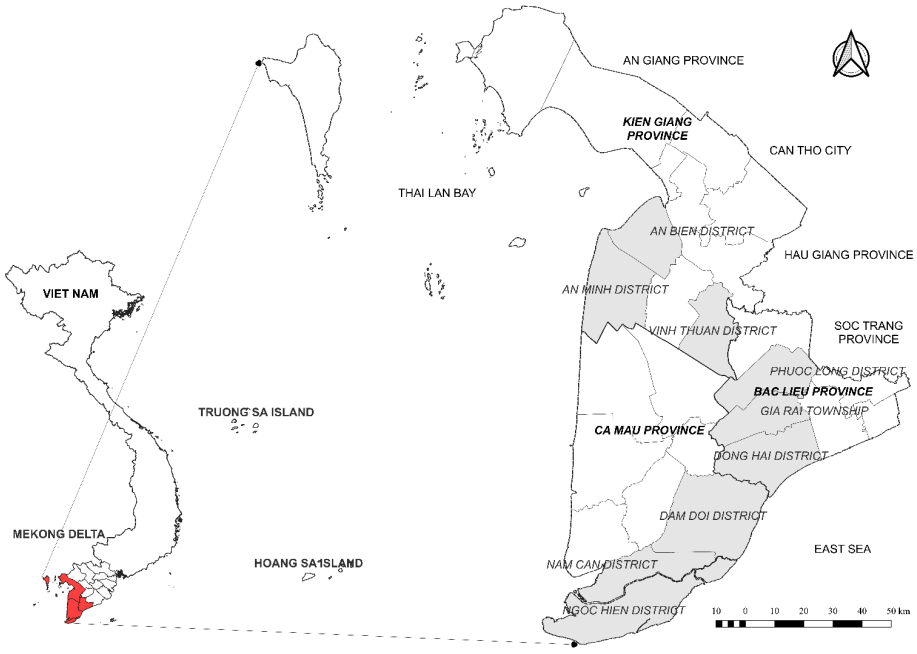

Figure 1. *Map of survey locations*
Note: *red is the survey area of mud crab farmers (Kien Giang, Ca Mau and Bac Lieu)*
Source: *compiled by the authors*

Therefore, based on consultation with experts and previous studies by T. Trang and N. Toan (2020) the dependent variable is calculated via a scale (%) that is equal to the total output of bucket crabs (poor quality crabs)/(total output of all types of crabs). In detail, "unqualified bucket crabs" are defined as crabs with defective appendages, soft shells, and not meeting the meat and size ratio. The independent variables are interpreted for meanings and the scale is explained in Table 2.

Table 2. *Factors in the production stage influencing the mud crab quality*

Independent variable	Symbol	Explanation	Expectation
Quality	Y	The output of bucket crabs/ Total output of crabs (%)	
Experience	X_1	The number of crab farming years of head of household	+
Training	X_2	Participation in training classes in mud crab farming. A dummy variable (receiving the value 1 in the case of participating in training and otherwise, receiving the value 0)	
Number of harvests	X_3	Total times of harvests in a crop (time/crop)	-
The decision to catch crabs Y4	X_4	Catching Y4 crabs (receiving the value 1 in the case of catching the Y4 crabs and otherwise, receiving the value 0)	-
The number of crab traps	X_5	The number of crab traps (trap/1000m2).	-
The farming time of crabs.	X_6	The number of months in a crab farming crop (month/crop).	+
Pond renovation	X_7	Pond renovation (receiving the value 1 in the case of having pond renovation and otherwise, receiving the value 0.	+
Breeds	X_8	Breed quarantine (receiving the value 1 in the case of having breed quarantine and otherwise, receiving the value 0)	+

Note: *expectation + affects in the same direction as variable Y; - opposite effect on variable Y*
Source: *compiled by the authors*

The sample size of the production stage of mud crab farmers is determined to satisfy the minimum sample size in the sample size calculation formula based on (Yamane, 1967) as follows:

$$n = \frac{N}{(1+N*\varepsilon^2)}, \quad (1)$$

where n is the minimum number of households that need to be surveyed and N is the number of households raising crabs in the research areas. Following the Directorate of Fisheries (2020) of the three provinces of Kien Giang, Bac Lieu and Ca Mau, the total number of households farming mud crabs (N) is 225,167 households. ε is the sampling error, and according to (Subong & Beldia, 2005), ε is 6% (Nam, 2008)

Therefore, according to the formula, the minimum sample number is:

$$n = \frac{225.167}{(1+225.167*0.06^2)} = 277 \text{ household.} \quad (2)$$

However, to ensure high representativeness, 304 mud crab farmers in the three provinces of Kien Giang, Bac Lieu and Ca Mau were interviewed using face-to-face methods and structured questionnaires. All sea farmers provided participation agreements. Research model. A multivariate linear regression model is employed to study the linear relationship between independent factors (independent variables) Xi and a certain factor Y (dependent variable). In particular, Xi affects Y and Y is considered a factor that is dependent on Xi. "The goal of regression analysis is to identify a relationship via a mathematical model that best represents the relationship between X and Y". The linear regression model is as follows:

$$Y = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n, \quad (3)$$

where Y is a dependent variable that describes the quality of mud crabs in the production stage. Meanwhile, mud crab quality is applied based on the general standards of the seafood industry, which is fresh seafood. When circulating in the market, it must ensure compliance with national standards per food hygiene and safety, chemical residues, and antibiotics (Ministry of Science and Technology, 2016). It is based on a set of criteria including type, size, and quality of mud crabs, as well as gender, the market divides mud crabs into 4 types. The 3 types of which meet quality standards (Y1, Y4, fat crab) and 1 type does not meet quality standards (bucket crab).

RESULTS AND DISCUSSION

Mud crab farming area in the Mekong Delta. In 2016, the mud crab farming area of the Mekong Delta increased by 50% compared to 2012 and the mud crab farming area in this region has been stabilizing from 2016 to 2020 (Table 3). In 2020, the mud crab farming area of the whole Mekong Delta region was nearly 465 thousand hectares. Three provinces of Kien Giang, Ca Mau and Bac Lieu had the highest mud crab farming area in the region, the leading province was Ca Mau province with a total area of nearly 277 thousand hectares, followed by Kien Giang and Bac Lieu with an area of 73 thousand hectares. In recent years, due to high profits from the combined crab farming models, substantial investments in the expansion of their crab farming area and switching to mud crabs were made (Table 3).

Table 3. *Mud crab farming area in some provinces in the Mekong Delta in the period of 2016-2020*

No.	Province	2016	2017	2018	2019	2020
11	Ca Mau	273,237	271,185	273,463	276,377	276,935
22	Kien Giang	58,755	64,284	64,357	65,544	73,245
33	Bac Lieu	111,929	111,213	98,320	87,213	72,962
44	Ben Tre	26,800	26,976	27,212	27,762	28,654
55	Tra Vinh	10,554	10,987	11,324	12,764	13,000
66	Soc Trang	372	350	142	135	160
Total		**481,647**	**484,995**	**474,818**	**469,795**	**464,956**

Note: *metric unit: Hectare*
Source: *Agricultural Extension Center (2019)*

Mud crab output in the Mekong Delta. From 2016 to 2020, farms of mud crabs in the Mekong Delta were regarded as important crab farms in Vietnam (Table 4). Mud crab production accounted for 73% of the country's total crab production. In 2020, the whole region reached 68 thousand tons, an increase of nearly 8.2% of the total output within 5 years. Besides, the average output of mud crabs in 2016 was 143 kg/hectare and in 2020 was 146 kg/hectare. This determines that the average output of mud crabs was very low. The reason for this was the household's lack of mud crab farming knowledge, which was the object that was raised with forms such as extensive form, improved extensive form, polyculture with shrimp and raised in mangroves. Provinces such as Kien Giang, Ca Mau and Bac Lieu have the highest production, accounting for 80% of the total production in the Mekong Delta.

Table 4. *Total production of mud crabs in some provinces in the Mekong Delta in the period of 2016-2020*

No.	Province	2016	2017	2018	2019	2020
1	Kien Giang	17,675	16,790	17,347	18,759	20,305
2	Ca Mau	17,414	20,086	21,993	22,177	24,027
3	Bac Lieu	14,675	15,792	14,748	12,733	10,214
4	Tra Vinh	8,000	8,130	7,360	7,913	8,100
5	Ben Tre	4,820	4,801	4,898	4,664	5,157
6	Soc Trang	203	190	150	150	165
	Total	**62,787**	**65,789**	**66,496**	**66,396**	**67,968**

Note: *metric unit: tons*
Source: *Agricultural Extension Center (2019)*

The opinion of H. Dat (2007) on mud crab farming season in the Mekong Delta. The time of raising mud crabs from stocking to harvesting is approximately 3.5-5 months. When crabs reach a weight of over 250 grams/crab, they can be harvested gradually.

Therefore, mud crabs can be raised three times a year. In Kien Giang province, crab farming lasts an average of 8 months, mud crab farmers stock from mid-November and harvest from March to July next year (Fig. 2).

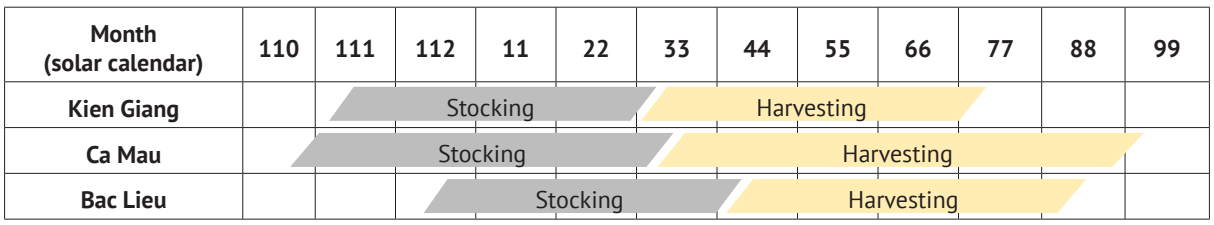

Figure 2. *Crab farming season in the Mekong Delta*
Source: *compiled by the authors*

Crab farming season in Ca Mau province lasts 11 months and mud crab farmers stock from mid-October and start harvesting from March to September next year. Ca Mau is a province with a year-round crab-shrimp farming model. In Bac Lieu province, the farming season lasts an average of 8 months, mud crab farmers start stocking from early December to April next year, and harvest from April to August. In Ca Mau province,

the average crab farming time is 10 months, which is much higher than in Kien Giang and Bac Lieu provinces. Most mud crabs are harvested from March to July, with gradual crab price decrease due to the quantity being higher than the demand. However, in the remaining months of the year, crab harvest levels are very low and thus the price of crabs is often high, peaking in October to December (Fig. 2).

Technical information on crab farming model in the Mekong Delta. The average crab farming area of a household is 2.5 hectares/household. There is a high difference between the lowest household having an area of 0.2 hectares/household and the highest household having an area of 11 hectares/household. Farming areas and farming ponds are also important factors influencing household costs and, thus, the study will focus on analysing these two aspects. The average width of the crab farming ditch is 3.5 meters, the lowest width is only 1 meter, and the highest width is 12 meters. The average depth of the crab farming ditch of extensive farming households in the Mekong Delta is 1.1 meters. The average farming time per crop is from 8 months to 9 months. Because the crab farming model combines shrimp farming and has intercropping with rice farming, there are areas where the farming time is only 6 months, but there are also areas where the farming time lasts 12 months. For the origin of seed crabs, about 90.9% of seed crabs are not quarantined and only 9.1% of seed crabs are quarantined when farming. Mud crab seed sources purchased by households are mainly produced in the Mekong Delta provinces. Kien Giang and Ca Mau provinces have the largest number of crab seed farms.

For seed size, this is an extensive farming model and thus crab seeds are released many times during the farming season, on average 4 to 5 times/crop. The breed size that farmers choose to release most is pepper crabs, accounting for 78.9% and only 21.1% of watermelon crabs. The average density of mud crab farming via survey results is 0.3 crabs/square meter (m^2). However, there is a high difference between households with the lowest density of 0.03 crabs/m^2 and the highest density of 25 crabs/m^2 while the most suitable farming density for mud crabs, according to the recommendations of the Department of Agriculture and Rural Development is 0.05 crabs/m^2. Depending on the pond depth and conditions of farmers in terms of production capital, fuel for production, water supply and change systems, shrimp can be raised at a higher density than the recommended density. Meanwhile, the average density of shrimp in polyculture with crabs is 2 shrimps/m^2, while the density of extensive shrimp farming in polyculture with crabs is 1 shrimp/m^2, according to recommendations of the Department of Agriculture and Rural Development (Table 5)

Table 5. *Technical information on the crab and shrimp model in the Mekong Delta*

No.	Criteria	Metric unit	Mean	Min	Max	Standard deviation
1	Pond area	1,000m^2	25.7	2.0	110.0	16.5
2	Width of farming ditch	meter	3.5	1.0	12.0	1.4
3	Depth of farming ditch	meter	1.1	0.5	2.0	0.2
4	Farming time/crop	month	8.8	6.0	12	2.3
5	Seed source	%				
	Traders	%				93.0
	Hatchery	%				6.0
	Catching	%				1.0
	Having quarantine	%				9.1
	No quarantine	%				90.9
6	Seed size					
	Pepper crab	2.18 mm				78.9
	Watermelon crab	3.2 mm				21.1
7	Density of releasing crabs	crab/m^2	0.3	0.004	4.0	0.4
8	The number of times of releasing crabs/crop	time	4.9	1.0	24	4.2
9	The gap from the last time of releasing crabs to the last time of harvesting the crabs	month	3.0	1.0	6.0	2.5
10	The number of times of releasing shrimps/crop	time	5.6	1.0	24	4.1
11	Density of releasing shrimps	shrimp/m^2	1.8	0.03	25.0	2.6
12	Developing seed again before releasing					

Table 5. Continued

No.	Criteria	Metric unit	Mean	Min	Max	Standard deviation
	Having developing seed	%				14.0
	No development of seed	%				86.0
13	Distance from pond to main road	km	1.1	0.3	30.0	

Source: *compiled by the authors*

Due to the nature of the extensive farming model and the aspect of releasing crabs many times in one crop, the size of crabs in the pond is not uniform. Therefore, according to the recommendation of the Agricultural Extension Center (2019), households should develop the crabs within 15 days after catching crabs and before releasing them into ponds. However, only 14% of the total surveyed households develop crabs before releasing them into ponds, the remaining 86% of households release crab seeds directly into ponds. The average distance from the farming pond to the selling place is 1.1 km and the highest distance is up to 30 kilometres (km), with a fairly large standard deviation of 2.3 km. Distance from locations of crab ponds relative to water sources (rivers, canals) and roads are also important factors influencing the efficiency and convenience in the process of transporting crab seeds and harvesting crabs, and water quality (Kha, 2018)

N. Mangun *et al.* (2021) believe that the pond renovation process is substantial. The process of renovating extensive crab farming ponds in the Mekong Delta greatly influences the quality of mud crabs raised in the region. If the pond renovation is done well, a substantial number of natural foods in the mud crab farming ponds will be available, and mud crabs will not attack each other and quickly grow to have crab roe. This will increase the quality of mud crabs in the Mekong Delta at the production stage (Kamaruddin & Baharuddin, 2015). Furthermore, the survey results demonstrated that the household pond renovation process was relatively simple. As a result, only 125 households pumped water out of ponds, with an average pumping time of only 1.7 hours/1,000m^2/crop. There were still households pumping with a very low time of 0.02 hours/1,000m^2/crop. These were households that took advantage of the receding tide to release water and thus the amount of water left in the pond was miniscule. For the time of pumping water after renovating the ponds, there were 160 households pumping water out of the ponds in the total number of surveyed households of 308. The remaining households took advantage of the rising tide to get water into the ponds. The average time to pump water was 1.6 hours/1,000m^2/crop, which was similar to the time to pump water out of the ponds, only pumping more after taking advantage of the rising tide. Thus, the amount of fuel consumed for water pumping was low, an average of 1.9 litres/1,000m2/crop. Good water pumping time management and the number of pumping cycles will limit environmental contamination in the ponds, thereby ensuring the quality of mud crab products produced.

The extensive crab farming model with trash fish in the ponds was harmful to seed crabs, as it reduced the survival rate, causing high seed costs and low crab output. Therefore, killing trash fish is a requirement in the crab farming process. Currently, according to recommendations from the Department of Agriculture and Rural Development, fish medicine or saponin can be used for fish control, depending on high or low salinity. As a result, 73% of mud crab farming households use fish medicine with an average weight of 0.6kg/1000 m^2/crop. However, there is a high difference between households in the region, with some using up to 3.2 kg/1,000m^2/crop. Almost 33% of crab farmers use saponin for fish control with an average volume of 0.7 kg/1,000m^2/crop (Table 6).

Table 6. *Information on the pond renovation process of crab farming model in the Mekong Delta*

No.	Features	Unit	Observation (N)	Mean	Min	Max	Standard deviation
1	The water pumping time out of the pond	*Hour*	125	1.7	0.02	8.0	1.4
2	The water pumping time into the pond	*Hour*	160	1.6	0.07	10.1	1.4
3	Fuel quantity	*Litre*	166	1.9	0.06	16.7	1.8
4	The amount of fish medicine	*Kg*	221	0.6	0.003	3.2	0.4
5	The amount of saponin	*Kg*	99	0.7	0.05	4.4	0.6
6	Limestone	*Kg*	193	5.9	0.09	46.0	5.5
7	Calcium lime	*Kg*	55	9.9	0.8	31.0	5.8
8	Dolomite	*Kg*	14	5.9	0.20	20.0	5.8
9	Probiotics	*Kg*	94	0.3	0.08	2.4	0.5

Note: *metric unit: 1,000 m^2/crop*
Source: *compiled by the authors*

Effectively limestone usage is a decisive factor in the output of the extensive crab farming model in the Mekong Delta. As a result, 63% of mud crab households used limestone in the pond renovation process with an amount of 5.9 kg/1,000m^2/crop because the limestone had an alum reduction feature and a bactericidal feature. Thus, it is recommended to use limestone in the pond renovation process. In addition, calcium lime (CaCO3) was used by 18% of crab farming households with an amount of 9.9 kg/1,000m^2/crop, and dolomite lime (CaCO3 and MgCO-3) was used by 14 households, with an amount of 5.9 kg/1,000m2/crop in both the lime types, had the effect of increasing the pH and alkalinity of water. In addition, 31% of mud crab farmers use probiotics during their pond renovation process with an average amount of 0.3 kg/1,000m^2/crop to create a beneficial microbiological environment in the water to reduce pests caused by harmful microorganisms from the environment to ensure the quality of farmed mud crab meat.

Care processes. Good crab care management increases the rate of good-quality crabs and reduces the bucket crab rate. Furthermore, the management process of extensive crab and shrimp farming ponds in the Mekong Delta determines the success as well as the quality of the mud crab farming model. The survey results showed that 44% of mud crab farmers pumped water into ponds, with the average number of pumping times (12 times) and the average pumping time of only 5.1 hours/1,000m^2/crop. Thus, on average, each time the water pumping was 0.5 hours, this was consistent with the natural reality in the surveyed provinces in the Mekong Delta region. Each month farmers pumped more water into ponds once a month when the tide was high. However, there were still households that pumped water for a long time, with 50 hours/1,000m^2/crop because these households had unstable bank structures and they could not keep the amount of water in the ponds. The average quantity of fuel for water pumping during care was 1.9 litres/1,000m2/crop (Table 7).

Table 7. *Information on the care processes of the crab farming model in the Mekong Delta*

No.	Criteria	Unit	Observation (N)	Mean	Min	Max	Standard deviation
1	The number of water pumping times	*time*	134	12	1	121	18
2	The water pumping time into the pond	*hour*	134	5.1	0.2	50	8.1
3	Fuel quantity	*litre*	129	1.9	0.04	25	3
4	The amount of fish medicine	*kg*	53	1.1	0.06	5.4	0.9
5	The amount of saponin	*kg*	20	2.1	0.2	8.4	2.1
6	Algae remover medicine	*kg*	31	0.2	0.02	1.1	0.2
7	Limestone	*kg*	69	10	1.6	67.5	10
8	Calcium lime	*kg*	30	29	1.2	169	40
9	Dolomite	*kg*	15	43.5	4.4	200	52.7
10	Zeolite	*kg*	55	51.7	1.1	402	85.1
11	Probiotics	*kg*	64	0.8	0.02	7.5	1.4
12	The number of trash fish foods	*kg*	39	24.7	0.13	142	28
13	The number of snail foods	*kg*	29	44.7	3	267	63.7

Note: *metric unit: 1,000m2/crop*
Source: *compiled by the authors*

Survey results showed that only 17% of mud crab farmers used fish medicine and 20 households used saponin to kill impurities in the ponds with an average usage of 1.1 kg/1,000m^2/crop. Limestone is used in limited numbers. Only 69 mud crab farming households used limestone with an average of 10 kg/1,000m^2/crop, 10% of the households used calcium limestone with an average amount of 29 kg/1,000m^2/crop and 15 households used dolomite limestone with an average amount of 43.5 kg/1,000m^2/crop. Zeolite is recommended by the Department of Agriculture and Rural Development to be used in the farming process to help improve the water environment and improve the bottom to create natural foods in extensive crab and shrimp farming ponds. However, only 55 households used it with an amount of 51.7 kg/1,000m^2/crop. Probiotics are also rarely used, with 21% of the mud crab farming households using 0.8 kg/1,000 m^2/crop. Foods in the pond are a factor influencing the quality of mud crab products. If mud crabs lack food, the proportion of bucket crabs increases, thereby causing a reduction in the crab quality. According to survey results, the extensive crab and shrimp farming process mainly took advantage of natural food sources. However, when releasing mud crabs with high density, natural foods are not sufficient, and farmers also supplement foods for the crabs. The main foods are trash fish, with 13% of farmers supplementing it with an amount of 24.7 kg/1,000 m^2/crop and 10% of

farmers supplementing the snail food with an average amount of 44.7 kg/1,000 m^2/crop. The remaining farmers mostly took advantage of natural food sources.

Classification criteria of mud crabs in the Mekong Delta. There are 4 types of crabs in the Mekong Delta based on the criteria used to evaluate the quality of mud crab output at the production stage (such as size, proportion of meat in the body, gender, dirt, parasites clinging to crab, and reflexes). According to the criteria for evaluating Y1 crabs in the Mekong Delta, crabs were larger than 270g in size, did not lose appendages, were free from dirt and parasites, had good reflexes and had a meat percentage of over 70%. According to survey results, the Y1 crab type in the Mekong Delta region accounted for 35%, the highest type in the 4 types of crabs. Y4 crabs were similar to Y1 crabs, which were meaty, but the size was smaller from 180 to 256 g and accounted for 33% of the entire region. These two types of crab meat accounted for 68% of mud crab output throughout the supply chain. The fat crab was the type of crab that is raised to collect crab roe and was classified according to the roe criteria of 200g or more and must ensure that all parts were intact, free from dirt or parasites, had good reflexes and had dark yellow roe. This fat crab accounted for very low output, only 16% of the total mud crab output in the entire supply chain, while the type of fat crab had a very high economic value compared to other types of mud crabs. Lastly, bucket crab accounted for a large rate of 16% of the total mud crab output throughout the supply chain. Bucket crab was the type of crab that was poor-quality and did not meet the quality criteria of the above crabs (Fig. 3).

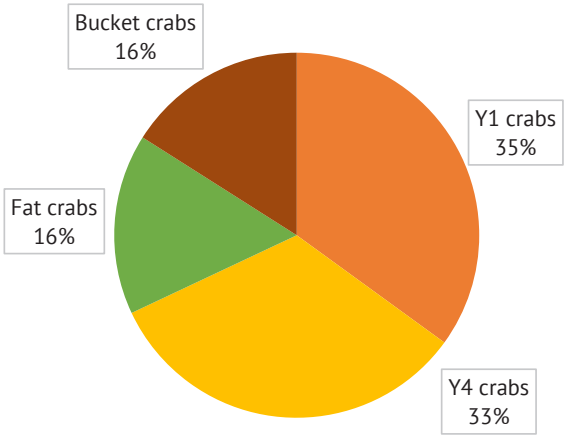

Figure 3. *Classification of mud crabs based on criteria of mud crab quality assessment in the Mekong Delta*
Source: *compiled by the authors*

Factors influencing mud crab quality in the production stage in the Mekong Delta. Management of farming techniques will increase the quality of mud crabs in the Mekong Delta, especially the rate of firm-shell crabs and help reduce the rate of bucket crabs. Therefore, the study used an ordinary least squares (OLS) regression model to analyse factors influencing mud crab quality at the production stage, thereby proposing solutions to help mud crab farming households increase mud crab quality. The dependent variable of the model was bucket crab output in total with harvested crab output (Y) and 8 independent variables consisting of 1) the experience of crab farmers; 2) technical training; 3) the number of harvests in the season; 4) the decision to catch Y4 crab; 5) the number of crab traps; 6) the farming time; 7) pond renovation; and 8) breeds (Fig. 8).

Table 8. *Factors influencing mud crab quality in the production stage in the Mekong Delta*

Factors	Metric unit	Estimated coefficient	Standard error
Dependent variable	Bucket crab output (poor-quality crabs)/ (Total crab output)		
Independent variable			
Experience	The number of years of farming crabs (year)	-0.0017^{ns}	0.0012
Training	(Receiving the value 1 in the case of participating in training and otherwise, receiving the value 0)	-0.0097^{ns}	0.016
The harvest times	The number of harvest times in a crop (time/crop)	-0.0009^{ns}	0.001
The decision to catch Y4 crabs	(Receiving the value 1 in the case of catching crabs and otherwise, receiving the value 0)	**0.0558*****	**0.016**
The number of used crab traps	**The number of crab traps (trap/1,000m^2)**	**0.0012***	**0.0006**

Table 8. Continued

Factors	Metric unit	Estimated coefficient	Standard error
The farming time	**The number of months in a farming crop (month/crop)**	**0.0136*** **	**0.0039**
Pond renovation	Receiving the value 1 in the case of having pond renovation and otherwise, receiving the value 0	-0.015ns	0.0179
Breeds	(Receiving the value 1 in the case of having breed quarantine and otherwise, receiving the value 0)	0.0119ns	0.0265
F-statistic	3.940		
Prob (F-statistic)	0.000		
N of valid cases	308		

Note: ****, **, *, and ns are significance levels of 1%, 5%, 10% and no statistical significance respectively.*
Source: *compiled by the authors*

The correlation results show that there is no autocorrelation between each pair of variables at the 0.6 level. The estimated results in the model are statistically significant at the 1% significance level. The variance inflation factor (VIF) of the variables is 1.22 which is much smaller than 10, showing that the variables included in the model do not have multicollinearity. At the same time, the White test result has a p-value coefficient of 0.523 (greater than 5%), showing that the model does not have heteroskedasticity. Prob > Chi-Square (Chi-Square = 0.000) shows that the significance level of the F test of all coefficients of the variables in the model has results that are different from 0 and the model is suitable.

The results of regression analysis coefficients show that 3 statistically significant independent variables are factors influencing the quality of mud crabs in the farming stage in the Mekong Delta. In particular, the variable – the farming time is statistically significant at the 1% significance level and the estimated coefficient of the variable is -0.0136. This means that when the farming time of the household increases to 1 month, the rate of bucket crabs in total crab output decreases by 1.36%, This reduces the number of bucket crabs in the ponds and increases the quality of mud crabs in the model. It could be attributed to the long farming time, with more time for crabs to develop from soft-shell crabs to firm-shell crabs and the rate of fat crabs that are high-quality crabs and have high economic value increases. This is determined by the average time to raise fat crabs being 6 months. In addition, the increased farming time allows farmers to have the opportunity to develop soft-shell crabs into firm-shell crabs, which also increases the output of high-quality crabs in the ponds. This result is similar to previous research by some previous authors (Mojibar *et al.,* 2017; Long, 2019).

For the variable – the decision to catch Y4 crabs, the estimated coefficient is 0.0558 (significant at the 1% significance level), which denotes the moment when crab farmers decide to catch Y4 crabs that are young male crabs, with the proportion of bucket crabs in total mud crab output increasing by 5.58%. This can be explained by the fact that mud crab farming farmers catch Y4 crabs early, which increases the output of bucket crabs in the total output during the farming process. This means that the output of Y1 crabs and fat crabs will decrease, thereby causing a reduced good-quality crab output. In addition, when farmers decide to catch Y4 crabs, which are young crabs that can easily break claws or sticks during the harvesting process, the output of bucket crabs in the total harvest output also increases. The results of this study are consistent with previous research on mud crab farming techniques (Mojibar *et al.,* 2017; Long, 2019)

For the variable – the number of crab traps, the estimated coefficient of the variable is 0.0012 (significant at the 10% significance level) and this means that when the number of crab traps in a crab farming household increases to 1/1,000 m^2, the bucket crab rate in total output of the model increases by 0.12%. The diminished yield of bucket crabs in the ponds can be attributed to the strategic placement of crab traps by crab farmers in suitable locations. According to survey results, the average number of crab traps for crab farming households was 4/1,000 m^2, more than the recommendation of the agricultural extension centre of 2/1,000 m^2 and studies on crab farming techniques researchers (Mojibar *et al.,* 2017; Long, 2019). This created labour waste because of putting many crab traps, collecting the crabs from the traps, and reducing the quality of mud crabs in the model.

For the non-statistically significant variable of training, previous studies suggest that farmers who undergo extensive technical training and acquire new knowledge can effectively control the quality of farmed mud crabs (Additionally, concerning the variable of experience, farmers with substantial experience are likely to manage crab farming models more efficiently, leading to an improvement in the quality of farmed mud crabs (Mangun *et al.,* 2021; Phong *et al.,* 2021).

The remaining variables of the analytical model including experience, training, the number of harvests, pond renovation, and breeds also influence the quality of mud crabs in the farming stage, however, they are not statistically significant at the 10% significance level. However, in reality, if there are many harvests in one crop, it will increase the output of crabs because many crabs that fall into traps can easily break their claws and sticks. In addition, production experience will help

farmers predict when the crabs will be firm and when the crabs will be shrivelled for a reasonable harvest, helping reduce the bucket crab output and increase the quality of fat crabs in the farming model.

CONCLUSIONS

Mud crabs exhibit favourable traits such as rapid growth, resilience to environmental changes, substantial size, and economic viability. However, the burgeoning mud crab farming industry faces challenges like disrupted plans, increased disease prevalence, and heightened competition leading to falling prices due to an oversupply of seafood products. The Mekong Delta's highest-quality seafood products hail from Ca Mau, Kien Giang, and Bac Lieu provinces. Key factors impacting mud crab quality during farming include farming time, the number of crab traps used, and the decision to catch Y4 crabs. To enhance profitability, farmers should adhere to safe farming practices, abstain from banned chemicals, invest in water retention machinery, avoid harvesting on tidal days, and harvest crabs at night to minimize waiting times. Longer farming periods allow crabs to develop into high-quality specimens with economic value. A conducive farming environment, encompassing water quality control, temperature regulation, and cleanliness, accelerates growth. Adequate and quality food provision, along with pest prevention, is crucial. Regular monitoring using tools and equipment facilitates the adjustment of farming processes.

Survey results show that crab farming households exceed the recommended trap density, necessitating calculation adjustments based on pond area and crab density. Proper trap maintenance and regular checks ensure effective crab capturing. Adjusting trap numbers based on farming time and conditions is vital for efficiency. The decision to catch Y4 crabs increases the proportion of bucket crabs in the harvest, requiring farmers to choose an appropriate harvesting time and use suitable traps to avoid harm. Catching Y4 crabs too early may lead to small sizes, emphasizing the importance of utilizing traps with small holes for safe capture.

The scientific arguments presented provide a clear understanding of the existence of various factors (such as the decision to catch crabs at the fourth moult stage (Y4), the number of crab traps used, and the duration of the farming period) influencing the quality of farmed mud crabs. Research on these factors is a prerequisite for scientifically explaining the quality of farmed mud crabs in the agricultural domain. However, a limitation of the study is the inability to identify a significant relationship between variables such as experience, training, the number of harvests, pond renovation, and breeds with the quality of farmed mud crabs. Therefore, the focus of the scientific discussion aims to determine the key factors influencing the quality of mud crabs, expanding the scope of the research, and increasing the sample size to uncover factors that have not been investigated in this study.

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CONFLICT OF INTEREST

None.

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Аналіз факторів, що впливають на якість вирощених грязьових крабів у дельті Меконгу, В'єтнам

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Анотація. Підвищення якості вирощених грязьових крабів є вирішальним елементом для підвищення продуктивності, якості та економічної ефективності в секторі вирощування грязьових крабів. У цьому дослідженні вивчалися фактори, що впливають на якість вирощених крабів у дельті Меконгу, В'єтнам. У дослідженні використовувались описові статистичні методи та підходи до синтезу для аналізу поточної ситуації в крабовому господарстві в дельті Меконгу, В'єтнам. Крім того, в дослідженні використовується багатовимірний регресійний аналіз для визначення факторів, що впливають на якість вирощеного краба в дельті Меконгу, В'єтнам. Результати опитування 304 крабових фермерів у дельті Меконгу, В'єтнам, показують, що загальна площа дельти Меконгу у В'єтнамі становить 465 тисяч гектарів, а обсяг виробництва – 68 тисяч тонн. Серед провінцій дельти Меконгу, В'єтнам, К'єнжанг, Камау та Бакльеу входять до трійки лідерів за площею та обсягами виробництва. Крім того, при аналізі факторів, що впливають на якість крабової продукції

в процесі вирощування, було виявлено три основні фактори: рішення про вилов крабів на четвертій стадії линьки (Y4), кількість використовуваних крабових пасток і тривалість періоду вирощування. Це дослідження є першим дослідженням якості крабів, вирощених у дельті Меконгу, В'єтнам. Таким чином, отримані результати надають рекомендації щодо поліпшення якості вирощеного краба і слугують основою для подальших досліджень у цій галузі

Ключові слова: рішення про вилов крабів; дельта Меконгу; якість грязьового краба; фермерство