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The value chain analysis and the effect of COVID-19 on a small-sized blue crab manufacturer: A case study in Thailand

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Abstract

Blue crab is a high-value raw material and can be sold as a fresh raw material in both domestic and international markets. Unfortunately, during the COVID-19 crisis, the demand has decreased dramatically. The objective of this study was to investigate the value chain of blue crab for a small enterprise that processed blue-crab-based food in Surat Thani province, Thailand. The related stakeholders and their roles were identified. Next, the transactions of the manufacturer before and during the COVID-19 crisis were compared. The Integration Definition for Functional Modeling (IDEF0) was implemented to analyse the supply chain of products from blue crabs. The enterprise sales volume decreased by 60 percent during the crisis, and some customers could not pay with cash. The proportion of customers via an online platform and social media increased. There are eight components used in different products, with finger and fat being about 7.29 percent of the boiled crab weight, with a value lower than that of other components. In addition, the crab shell, which is about 43.89 percent of the raw crab weight, was thrown away. Consequently, the enterprise developed various products using these components and maximised the profit by determining which parts of the crab could be used to produce products to satisfy customers. Furthermore, the company should implement proper supply chain management. In the future, the government and universities can research how to utilise crab shells. This research could be a model for other SMEs to create more valuable products in order to survive during the crisis.

Introduction

In Thailand, the blue crab (*Portunus pelagicus*) is the principal species found in the Andaman Sea and the Gulf of Thailand (Oniam & Arkronrat, 2013). Demand for blue crab in the market has been increasing while the annual quantity of crab caught has been decreasing from the maximum volume in 2014 at 44,000 tons to 41,000 tons and 31,000 tons in 2015 and 2016, respectively. In 2017, Thailand announced the Royal Ordinance on Fisheries B.E. 2558 Amendment 2017, in which Thailand cooperated with international measures to effectively combat illegal, unreported, and unregulated fishing (IUU Fishing) since April 2015 in order to address the issue of resource use above natural production levels.

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The blue crab is also one of the marine animals that has been controlled under such measures. After the announcement of the ordinance, the quantity of crab caught decreased due to many factors, such as limiting the number of fishing boats and control measures for fisheries' days and fishery tools. This resulted in only 29,000 tons of blue crab being caught in 2017, and the Royal Thai government beginning to support the preparation of a blue crab bank in Thailand. Through the government's 520 blue crab restoration projects divided among 191 Departments of Fisheries and 329 different universities, the supply of blue crab resources has increased. The current assessment of blue crab resources in the Gulf of Thailand found that the highest yield is 30,000 tons per year, especially in the Andaman Sea, with 7,484 tons per year being a sustainable and catchable quantity for crab recovery throughout the year (Bank for Agriculture and Agricultural Cooperatives, 2020). In general, 70 percent of the blue crab is used domestically and 30 percent is exported. The export volume was approximately 5,000 tons valued at 1,650 million baht in 2018 and about 4,700 tons valued at 1,465 million baht in 2019. The areas in which crabs are most frequently caught are Surat Thani, Nakhon Si Thammarat, and Chanthaburi, including some in Phang Nga Bay (Sawusdee, 2020).

The problems of the blue crab supply chain before the COVID-19 situation were the reduction of the blue crabs in nature due to several factors such as catching blue crab with eggs, catching too small-sized crab, and using destructive fishing tools. Such destroyed the life cycle of the crab. During the COVID-19 situation, foreign tourists decreased and exports began to slow down, while the buying power of the domestic markets was reduced due to the lock-down measure and the effect of unemployment. Consumers avoided shopping at markets, hence the demand for the blue crab from this channel was dramatically reduced.

The Integration Definition for Function Modeling (IDEF0) was used to analyse the business process in several industries, such as a cold chain logistics service provider (Pradita & Ongkunaruk, 2019), a container yard (Tangkham & Ongkunaruk, 2019), a HORECA business (Ongkunaruk & Kessuvan, 2013), a raw milk collection centre (Chueprasert Ongkunaruk, & Ongcunaruk, 2016), an organic rice supply chain (Prasertwattanakul & Ongkunaruk, 2018), a chilled beef supply chain (Neisyafitri & Ongkunaruk, 2020), a cordyceps beverage manufacturer (Poochinya & Ongkunaruk, 2020), a chili paste supply chain (Srilarp & Ongkunaruk, 2020), etc. The following value chain research was investigated: a study on the impact of reorganising the value chain for lobster (Botha, 2020), a study on the beef value chain evaluating climate change adaptation and investment options in the semi-arid areas of northern Kenya (Ndiritu, 2020), a study on the value chain analysis of the Philippine milkfish industry (Salayo, Marte, Toledo, Gaitan, & Agbayani 2020), and a study on the value chain analysis of small-scale fisheries in the Philippines (Rosales et al., 2017).

This research focused on a small-sized blue crab manufacturer located in Surat Thani Province in Thailand, which is the best location for blue crab. The objectives were to study the supply chain of blue crab and identify the current problems in the supply chain, especially in the case study. It was found that the supply quantity of blue crab is insufficient. In addition, the price and quantity fluctuate seasonally, and the manufacturer found that there is waste from blue crab shells and low value for some parts of the blue crab. At present, the waste is disposed of, which can raise significant environmental issues and costs for proper management. Hence, it is worth studying how to increase the value of this waste and other parts of the blue crab to encourage a sustainable economy in the local area. Furthermore, analyses was done on how the COVID-19 crisis has affected the blue crab supply chain.

Methodology

Value Chain Analysis

First, the related information about the blue crab supply chain of the case study was collected through in-depth interviews with the owners of the small-sized blue crab manufacturers, two fishermen, two middlemen, the logistics service provider and the officer of the Department of Fisheries. Literature related to the blue crab supply chain was reviewed from previous research and news. The questions were related to the stakeholders in the value chain, their role and relationships, activities creating value, cash flow, problems, and challenges in the value chain. Then, the blue crab supply chain was visualised to present the related stakeholders and their roles. Next, the proportion of transaction and credit term in this case study were analysed and compared before and during the COVID-19 crisis. Later, the business process modelling was analysed using IDEF0 Level 1 or the major activities level, which is a model that aids in visualising the process of organisation as a schematic diagram. The diagram shows the relationship between internal activities in the target organisation. The model contains an input, output, and control activity for each stakeholder or activity. The names inside the box represent activities such as plan, source, make, delivery, and return. Each box is labelled with a code in the bottom right

corner under the name of the activity, such as A1, A2, A3, A4 and A5 respectively, in order to conduct the activity in order. The relationship between activities is explained by the arrows to and from the activity box. There are four types of arrows: first, the input is presented with the arrow entering into the box, implying what are needs for that activity; second, the output is presented by arrows leaving the box, implying the product or result of doing that activity; third, the control is presented with the arrow pointing down from the upper side of the box, implying the standard or other factors used to control the activity. Finally, the mechanism arrow is shown pointing up from the lower side of the box, implying the resources used in the activity. The study focused on the business process model level 1 or on major activities only. There are two types of lines. First, a solid line identifies the current situation (As Is). Second, the dashed line identifies things suggested to be improved (To Be).

Crab Component Analysis

To identify the components and their proportion of fresh, boiled and peeled blue crabs, using convenience sampling, the fresh crabs were sampled with 53 crabs, and the weight of fresh blue crab was sampled for each item. Then, each item was boiled and weighed. After that, the blue crabs were peeled and each component weighed by skilled workers. Then, the proportion of components and yield of boiling and peeling processes was calculated. Next, the yield of each component was analysed, and the expected values and profit of different sizes of blue crab were calculated from the multiplication of value and proportion of all components. Finally, we summarised and proposed how to add value to the enterprise and how to create value of crab shells at the macro level.

Results and Discussion

The Blue Crab Value Chain Analysis

The case study involved an original brand manufacturer (OBM) that processes blue-crab-based food. There are two main sources of blue crab i.e. fishermen and middlemen and the manufacturer communicates using telephone and Line application. Boiled crab and value-added processed crab food products are 80 percent made to order and 20 percent made to stock. Customers order 1–2 days in advance via telephone or social media such as Line and Facebook. Currently, there are ten types of products or stock keeping units (SKUs). The stakeholders of the crab value chain and their roles are explained in Table 1. The supply chain of the case study is explained in Figure 1.

The price of blue crabs depends on the demand and supply in terms of quality and quantity. However, there is no reference price from the central market and there is no crab association. The manufacturers who export crab products have an important role in determining the price of blue crabs. The domestic market uses the exporter price as the reference and adds 5-10 Baht to motivate the fishermen to sell to them. The blue crab price is determined daily, and the manufacturer determines the price a day in advance. This concludes that the bargaining power of large-sized buyers (the exporters) is higher than that of the suppliers due to the high volume of blue crab export. In addition, blue crabs cannot be kept for more than a day without boiling due to deterioration in its freshness and odour. Hence, the fishermen must sell on daily basis. The peak season of the blue crab is between May to October. Then, the manufacturer will keep boiled crabs as

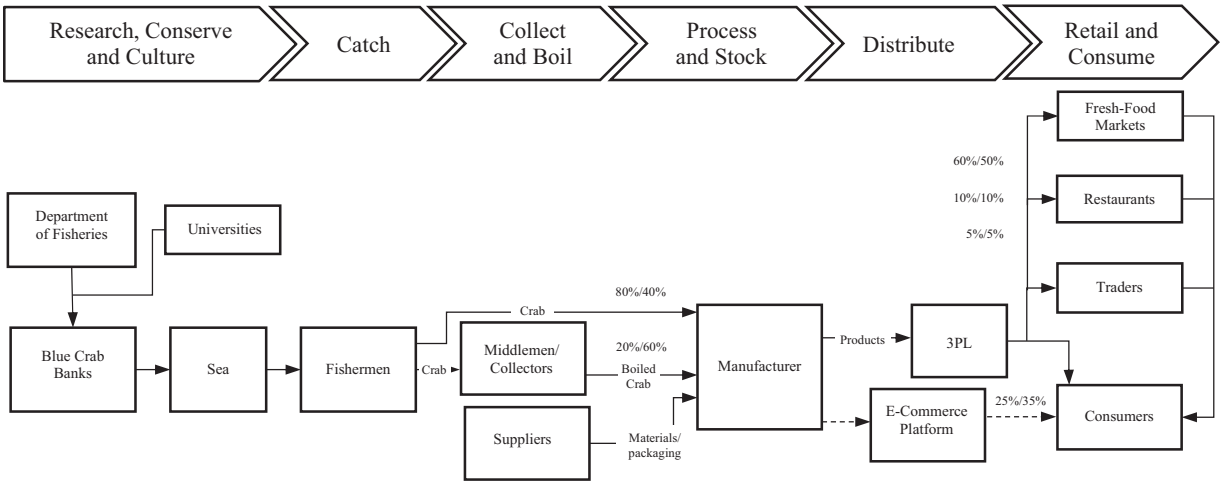

Figure 1 The blue crab supply chain of the case study

Table 1 Stakeholders and their roles in the blue crab value chain

Stakeholders	Description	Roles
The Department of Fisheries	Take action to control and balance the supply and demand of blue crab by initiating the crab bank	Control, conserve the natural resource, support the community by initiating a project
Universities	Research projects to develop a sustainable crab supply chain. For example, Walailak University established the crab bank project to engage with the community in Nakhon Si Thammarat Province (Sawusdee, 2020).	Research and development
Blue crab banks	A crab bank is a hatchery centre for blue crab situated in the local area. There are many blue crab banks in Thailand, established under government projects and community initiatives. One of the crab banks in Phum Riang District was founded by a leader in the community who wanted to conserve natural resources. It can be a tourism place and help generate sustainability for the local community.	Blue crab culture centre
Sea	The natural habitat for blue crab. This research focused on Phum Riang Bay, Surat Thani Province.	Source of blue crabs
Fishermen	Local fishermen within 10 kilometres of the manufacturer's location due to the freshness and quality of blue crabs. They catch blue crabs and sell them directly to local manufacturers. The fishermen who are located more than 10 kilometres from the manufacturers may sell to middlemen, who come to buy blue crab from fishermen.	Catch blue crabs
Middlemen/ Collectors	Local collectors buy the blue crab directly from fishermen within a 20-kilometre radius of Phum Riang Bay. They boil crabs to extend the shelf life since crabs will deteriorate in a short time. Then, the boiled crab is transported and sold to nearby manufacturers. However, the quality of crab bought from middlemen is poorer than that bought from fishermen.	Collect and extend shelf life
Suppliers of other materials	Suppliers of other raw materials for food processing, including packaging materials	Source of other raw materials
The manufacturer	The small-sized enterprise that produces blue crab based products such as boiled meat crab, crab curry paste (to eat with rice noodles), crab chili sauce, deep fry crab meat rolls, crab balls, etc.	Process and stock boiled blue crabs
Third-party logistics (3PLs)	The temperature-controlled logistics provider offers delivery service to consumers throughout Thailand. There are drop-off and pickup centres throughout the country to serve local customers.	Distribute
The e-commerce platform and social media	Lazada and Shopee are the topmost online platforms to match demand and supply for sellers and buyers. The manufacturer pays both the commission fee and transaction fee. Line official account and Facebook are used to communicate with customers and consumers.	Marketing channel
Fresh food markets	The famous fresh food markets are located in Bangkok and metropolitan areas such as Or Tor Kor Market, which is one of the greatest fresh wet markets in Bangkok, Talaad Thai, which is the greatest central market in Thailand, and Yoawarat, or China Town, located in the centre of Bangkok.	Retail
Restaurant traders	The seafood restaurants in Bangkok The middlemen who buy and sell products to buyers through to markets or web pages	Retail and service Retail
Consumers	The end customers who love to consume seafood products	Consume

inventory in cold storage for six months and use them for processing according to demand for products. The comparison of the proportion of transaction volumes and credit terms between stakeholders in the blue crab supply chain before and during the COVID-19 crisis is shown in Table 2. It illustrates that manufacturers were impacted by the COVID-19 crisis. The demand for products decreased in quantity and frequency by about 60 percent resulting in changes to credit terms for middlemen and some buyers such as fresh food markets and traders. The proportion of the supply coming from fishermen during the crisis has been reduced due to fishermen illegally using small nets to catch small crabs, which destroys the source of crabs. When the crab in the area is reduced, the manufacturer has to buy crabs from middlemen who collect crabs from other areas. In addition, last mile delivery services in the local area encourage fishermen to sell crab directly to customers. Hence, the proportion of buying from fishermen is reduced. Similarly, the demand-side shifts from 10 percent of fresh food markets to an online platform due to customer behavior changes from buying or dining out to online shopping. Hence, the manufacture adjusted the business model to focus more on online marketing such as advertisement, promotion, and free shipping. Besides, the manufacturer recruited new traders in other

Table 2 Comparison of the proportion of transaction volume and credit terms between stakeholders in the blue crab supply chain of the case study before and during the COVID-19 crisis

Transactions	Proportion		Credit Terms	
	Before crisis	During crisis	Before crisis	During crisis
Buy from fishermen	80%	40%	Cash	Cash
Buy from middlemen	20%	60%	Cash	3 days
Sell to fresh food markets	60%	50%	Cash	15 days
Sell to restaurants	10%	10%	30 days	30 days
Sell to trader	5%	5%	Cash/30 days	On the condition
Online platform/social media	25%	35%	15–30 days	15–30 days

regions. During the crisis, the credit terms of the middlemen and fresh food markets were increased to lengthen the cash payment due to the difficulty of cash flow of the manufacturer and the fresh food markets, respectively.

On the other hand, the credit term of traders was reduced since some of them did not pay bills on time. Hence, the credit term was changed depending on the condition. If the trader had not payed the previous bill, he/she could not get the next order to avoid generating bad debt.

Business Process Analysis of the Blue Crab Manufacturer

The in-depth business processes of internal activities can be analysed by using IDEF0 Level 1. The main activities consist of a plan, source, make, deliver, and return. Every activity should be controlled by standard and specification and facilitated by tools as shown in Figure 2. There were recommendations for activities to improve the efficiency in supply chain management as in Table 3. First, in the planning process, the manufacturer will contact fishermen or collectors about the quantity and price of crab a day in advance. It is just short-term planning, hence the manufacturer should collect historical data of raw materials, buying and selling price, order quantity from customers. Then, the demand and supply forecast of quantity and price of blue crabs should be established. Next, information such as the weight of crab components, the recipe, cost of raw materials, price of products, and demand for products is collected to determine the optimal products and research and develop the proper products based on the optimization model. Then, due to the increase of online channels, the manufacturer should determine the optimal online marketing strategies such as advertisement amount and target, sales promotion, cash on delivery (COD), and free shipping, etc. to raise the sales volume via e-commerce and social media. Second, in the sourcing process, the government, community, and related stakeholders in the blue crab supply chain should establish sustainable sourcing strategies such as restoring the crab banks, stopping illegal catching of blue crabs and stopping the buying of blue crab with eggs. Then, establish the supplier relationship, supplier evaluation, and inventory control of boiled blue crabs. Third, in the making process, implement the value chain analysis to increase the value of blue crab components, especially in crab shells. Then, establish good manufacturing practice (GMP), which needs to invest in infrastructure, and revise the plant layout. GMP should be maintained throughout the supply chain until the products reach consumers. Next, contact the government agency to provide skilled workers or set up the training program for unskilled workers. Fourth, in the delivery process, the manufacturer should establish the evaluation of the quality of delivery service and establish the optimal

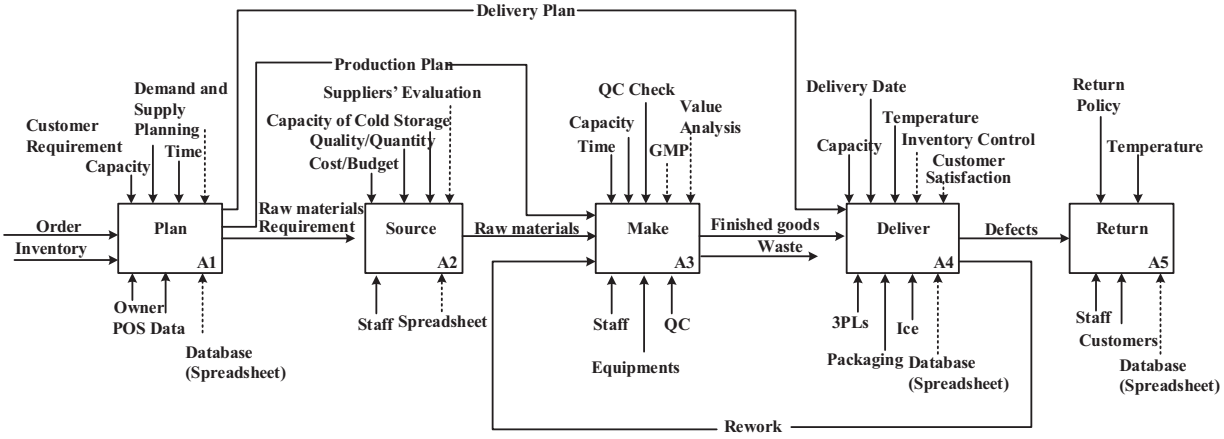

Figure 2 The business process of the blue-crab-based food manufacturer (IDEF0 Level 1)

Table 3 Summary of current problem (As Is) and proposed solutions (To Be) for the main activities of the blue-crab-based food manufacturer

Activities	As Is	To Be
Plan	- No database - No record of daily price and quantity of blue crab - Experience-based production planning	- Demand and supply planning - R&D on new product - Product Optimization - Optimal online marketing
Source	- Supply shortage - Daily price fluctuates - Seasonal quantity of blue crabs - No proper inventory management - No supplier evaluation	- Establish sustainable sourcing strategies - Establish relationships with local fishermen - Implement the inventory policy based on demand and price - Suppliers' evaluation
Make	- Waste from shells is high - No good manufacturing practice (GMP) certification - Insufficient worker capacity, resulting in high overtime costs	- Value chain analysis - Establish GMP - Worker training
Deliver	- Outsource to several 3PLs - No proper inventory control of finished goods	- Evaluate 3PLs and record information - Establish a proper inventory policy
Return	- Return due to defective product on account of long time delivery	- Collect information and find root causes

inventory policy for finished goods from historical data and situation analysis. Finally, in the returning process, some complaints occurred due to the long time delivery. Hence, the manufacturer should collect the data and find the root causes. Then, collaborate with the 3PL to reduce the causes of the problem. Finally, the manufacturer should use a spreadsheet as the database for collecting data and decision support.

Crab Component Analysis

In this section, the components, proportions, and yield of crab after boiling and peeling were analysed. There are three sizes of crabs: small, medium, and large. However, most of the large-sized blue crab is bought from middlemen in boiled crab. Hence, the study started with available sizes. Then, 28 small and 25 medium-sized blue crabs were sampled and experimented with. Interestingly, the yield after boiling and peeling of small-sized blue crab was slightly higher than that of medium-sized blue crab, as shown in Table 4. Similarly, when considering the yield of crab meat, the highest yield goes to small-sized blue crabs. On the other hand, the shell proportion of small-sized crabs is slightly larger than that of medium-sized blue crabs. The expected value and profit of the small-sized crabs are less than those of medium-sized crabs, about 62.20 and 18.04 Baht/kg, respectively. The expected profit was calculated by subtracting the purchasing cost, washing, and peeling cost from the expected value. The washing and peeling costs of small-sized crabs are higher since it takes longer time and is more difficult. Although the small-sized crab is the cheapest, it has the most yield and shell proportion. However, the price of boiled medium sized-crabs is higher than that of small-sized crabs due to consumer behavior, which leads to a higher expected value. This amount can be a guideline to determine whether the business is making a profit or the purchasing and selling price should be revised accordingly.

Based on the enterprise utilisation, there were eight components of crab meat and shells, as shown in Table 5. There are seven components of meats with different prices. These prices fluctuate, so the latest price was used. The complete breasts were from medium and large-sized crabs only, hence, the price will be more expensive. On the other hand, the breast was from small-sized crab, where its price is lower, and it is difficult to peel. Similarly, the paddle fin of medium-sized crabs is more expensive than that of small-sized crabs. The results compared the mean and coefficient of variation (CV), which is the ratio of standard deviation and mean, of two different sizes and all sizes. The high CV implied the high fluctuation of the weight of that component i.e. fat and egg because out of 53 crabs, there were only 8 crabs with eggs and 10 crabs

Table 4 Comparison of the average proportion of yield after boiling and peeling, purchasing cost, and expected value of different sizes of blue crabs

Size of Blue Crab	Weight per item (grams)	Average Proportion of Yield				Purchasing Cost (Baht/kg)	Expected Value (Baht/kg)	Expected Profit (Baht/kg)
		After Boiling	After Peeling	Crab Meat	Shell			
Medium	(100–200]	84.30%	79.48%	35.51%	43.97%	140	373.59	120.35
Small	≤ 100	85.85%	81.30%	36.18%	45.11%	100	311.39	102.31
Total	-	85.12%	80.44%	35.87%	44.57%	-	340.73	110.82

Table 5 Summary of the mean and coefficient of variation of the proportion of boiled crab components in sampling medium- and small-sized crabs on average and current selling price

Components	Medium Size		Small Size		All Sizes		Selling Price
	Mean	CV	Mean	CV	Mean	CV	(Baht/kg)
Shell	55.48%	0.09	55.72%	0.12	55.61%	0.11	0
Fat	0.37%	2.81	0.62%	2.48	0.50%	2.63	150
Finger	6.94%	0.41	6.65%	0.33	6.78%	0.37	250
Manus	6.21%	0.20	5.46%	0.51	5.81%	0.38	400
Breast	0.00%	-	10.58%	0.30	5.59%	-	500
Complete Breast	11.52%	0.23	0.00%	-	5.44%	-	600
Merus	5.69%	0.24	6.04%	0.51	5.88%	0.41	650
Egg	0.38%	5.00	1.90%	2.53	1.18%	3.19	700
Paddle Fins S	0.00%	-	13.03%	0.15	6.88%	-	1,400
Paddle Fins M	13.40%	0.08	0.00%	-	6.32%	-	1,700

with fat. The other components had low to medium CV which implied that the average could be acceptable. The crab shell, which was about 44.57 percent of the raw crab weight, was mostly thrown away. There were two components i.e. fat and finger which were about 7.29 percent of the boiled crab weight having a value lower than that of other components. The enterprise has considered creating value for crab shells and other low-value meats through product development to utilise fingers and fat to add value in the form of items such as crab curry paste, crab chili sauce, deep fry crab meat rolls, crab balls, etc. These components could make the product more appealing and increase the value from the customer's viewpoint. Currently, most shells are thrown away and some are used in the value added product such as deep-fried crab meat. Hence, there is an opportunity for the community or the local government to collect crab shells to increase the value. In the future, linear programming can be formulated to maximise the profit by determining which parts of the crab can be used to produce products to satisfy customers.

Value Creation Opportunity for Crab Shells in Thailand

Considering the macro view of crab shells in Thailand, 28,000 tons of blue crabs were caught in 2019. This implies that there were about 12,289.20 tons of crab shells left in Thailand. There is research related to applications for crab shells as follows:

1. In agriculture: Shells can be used as crab shell powder as an additive in the composting of green waste (Zhang & Sun, 2018). The nanofibre complex was extracted from crab shells by a simple mechanical treatment with a high-pressure water-jet system as an efficient fertiliser for hydroponic tomatoes (Aklog et al., 2016).
2. In civil construction: using biopolymers in crab shells in Portland Cement for civil construction. It supported changes in consistency, diminished setting time of pastes and mortars, and increased strength for the axial compressive (Júnior, Montel, Silva, Ascêncio, & Luz 2019)
3. In alternative energy: calcium oxide extracted from crab shells infused on Na-ZSM-5 is a catalyst in biodiesel production from neem oil (Shankar & Jambulingam, 2017).
4. In functional food production: red crab shells are used as a coagulant in soybean curd production (Jun et al., 2019). Chito-oligosaccharide, which can protect and lessen the growth rate of pathogenic bacteria, is synthesised from chitin deacetylation from crab shells in Indonesia. It is used to produce functional food, such as symbiotic tofu as a prebiotic and natural preservative (Harti, 2015). Chitosan, a derivative of chitin in crab shells, can serve as a prebiotic in metabolic effects and effects on the gut microbiota composition (Lopez-Santamarina et al., 2020). More related research was found in Ayisi, Apraku, and Afriyie (2017).
5. In wastewater treatment: calcium-rich biochar extracted from crab shells is used as adsorbent to remove dyes from wastewater (Dai et al., 2018).

In summary, it would be of benefit to the community and the environment if the government or large-sized manufacturers could invest in one or more of these applications to create the value chain in Thailand.

Conclusion and Recommendations

The research studied the blue crab value chain of a small enterprise in Thailand that identified related stakeholders and their roles, compared the transactions of the manufacturer before and during the COVID-19 crisis, analysed the business process of the enterprise by IDEF0, and analysed the crab components and their yields. It showed that finger and fat components were about 7.29 percent of the boiled crab weight with a value lower than that of other components, whereas the crab shell, which is about 43.89 percent of the raw crab weight, was thrown away. In 2019, 28,000 tons of blue crabs were caught in Thailand, which implies that there was about 12,289.20 tons of crab shell left . It would be of benefit to the community and the environment if such could be used in the above applications. Considering the yield of

crab meat, small-sized blue crabs outperform medium-sized blue crabs while the expected value and expected profit of medium-sized blue crabs outperform. In addition, the enterprise should develop various products that use low-value components and maximise their profits by determining which parts of the crab can be used to produce products to satisfy customers using spreadsheet and optimization model. Furthermore, the enterprise should improve the supply chain management, such as collecting information, evaluating suppliers, establishing relationships with fishermen, and establishing GMP and inventory management. This research could be a model for other SMEs to implement proper supply chain management, create more valuable products, and respond to the COVID-19 crisis more effectively. In the future, the sampling of more large blue crabs can be pursued to further analyse the value chain. Also, the Royal Thai government and universities could facilitate research projects to utilise crab shells.

Conflict of Interest

There is no conflict of interest.

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