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OYSTER MUSSELS (*Crassostrea gigas*) TRANSPORT SYSTEM (CASE STUDY IN KAMASHIMA COMPANY) IN HYOGO, JAPAN

Transportasi Kerang Tiram (Crassostrea Gigas)
(Studi Kasus Di Perusahaan Kamashima) Di Hyogo, Jepang

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ABSTRACT

Oyster culture is an aquaculture activity that is mostly carried out in Japanese waters. While in Indonesia, oyster shells are widely consumed, but they have not been produced through the culture process but are caught on the high seas. This study aimed to determine how the application of technology and transportation in the culture and sale of oyster in Japan. This study used a descriptive method with exploration in literature and direct observation method. Based on literature studies and activities at the Kamashima-Japan company, transportation is an important part of oyster farming activities. The result showed that oyster transportation technology carried out in two areas, namely sea and land, using open and closed dry transportation methods. Sea transportation use Hydraulic Cranes for Shipboard Use (Marine Cranes) technology, which was applied to special vessels 6-7 GT with the classification of truck-mounted cranes, while land transportation used styrofoam boxes equipped with ice blocks to immobilize the temperature. The wind speed that blows in the sea, the time of pick-up and delivery, and the number of oyster shells required were important factors in these transportation activities.

Keywords: *Aquaculture, oyster, Japan, transportation*

ABSTRAK

Budidaya kerang tiram merupakan kegiatan akuakultur yang banyak dilakukan di perairan Jepang. Sementara di Indonesia, kerang tiram banyak di konsumsi, namun belum dihasilkan melalui proses budidaya melainkan hasil tangkapan di laut lepas. Penelitian ini bertujuan untuk mengetahui bagaimana penerapan teknologi dan transportasi dalam kegiatan budidaya dan penjualan kerang tiram di negara Jepang. Penelitian ini menggunakan metode deskriptif dengan eksplorasi literatur dan metode observasi langsung. Berdasarkan studi literatur dan kegiatan di perusahaan Kamashima-Jepang, transportasi merupakan bagian penting dalam kegiatan budidaya kerang tiram. Teknologi transportasi kerang tiram saat ini dilakukan di dua area yaitu laut dan darat, menggunakan metode transportasi sistem kering secara terbuka dan tertutup. Transportasi laut menggunakan teknologi *Hydraulic Cranes for Shipboard Use (Marine Cranes)* yang diterapkan pada kapal khusus berukuran 6-7GT dengan klasifikasi *truck-mounted crane*, sedangkan transportasi darat menggunakan kotak *styrofoam* yang dilengkapi dengan balok es untuk menjaga suhu tetap pada rentang yang standar. Besar kecilnya angin yang berhembus di laut, waktu pengambilan-pengiriman, dan jumlah kerang tiram yang dibutuhkan menjadi faktor penting dalam kegiatan transportasi tersebut.

Kata kunci: *Budidaya, kerang tiram, Jepang, transportasi*

INTRODUCTION

Oyster Mussels (*Crassostrea gigas*) were one of the successful and widely cultivated species of marine life from the mollusk group. Foreign countries such as the United Kingdom, the United States, France, Japan, and many other countries have also cultivated oyster mussels (Zainura 2016). The consumption of oyster mussels among the public is commonly cooked or eaten raw. The public's interest in consumed oyster mussels is partly due to their good nutritional content, such as low calories (energy 78 kcal), protein 9.70g, fat 1.80g, sugar 5g, calcium 55mg, iron 3.60g, vitamin A 55 IU, vitamin B1 0.16mg, vitamin B2 0.32 mg, and vitamin C 4mg, so oyster meat was often traded by the public as a nutritious food (Kasmini 2019, Tan *et al.* 2021). Oyster mussels grew and developed started with a spat attached to a hard medium, where the spat was a μm oyster seed that sticks to hard media such as scallop clam shells, hard clams, or other hard media (Hasegawa *et al.* 2015). Oysters grew by eating phytoplankton of marine origin (Cassis 2012).

The oceans in Indonesia have a coastline of 95,000 km^2, coupled with the sea area of 24.5 million hectares (Sukamto 2017) has the opportunity and potential for the development of oyster shellfish fishery activities. Oyster mussel activities in the Banda Aceh area were still carried out conventionally captured from natural products, not yet through directed cultivation activities (Kasmini 2019). In the coastal area of Banda Aceh City, precisely the Gampong Ulee Lheue area, an oyster fisherman can catch at least 5-10kg of oysters in one fishing period, and it was estimated that in a month about 700 kg of oysters were taken from their habitat. Continuous oyster mussel fishing activities lead to excessive exploitation and pollution of the quality and quantity of oyster mussels decreased (Octavina *et al*. 2014). In the studies that had been carried out, there were still none related to the cultivation of oyster mussels in Indonesia, the majority of what existed were only related to the biological aspects and growth of oyster mussels. Therefore, in the stuttering of aquaculture, precisely oyster mussels, transportation is an important factor to be considered.

Meanwhile, in Japan, since 1923, many oyster farming activities had begun to be developed (Fujiya 1970). There were about 200 types of oysters in the world, and about 30 of them live in waters near Japan. *Crassostrea gigas* or pacific oysters were one of the types of oysters that were currently massively cultivated (Fang *et al.* 2021). Pacific oysters can be found throughout Japan's waters from Hokkaido to Okinawa and inhabit the inner bay estuaries of sea areas to the open sea. It was recorded that in 2016 the number of oyster mussel production in Japan was 158.925 tons/year (Koike and Seki 2020).

Human needs are not always in the same location or close to consumers, and human needs cannot be obtained in any place, therefore transportation becomes a link between consumer areas, marketing areas, production areas, and raw material source areas (Lubis *et al.* 2010). In aquaculture, transport of live fish is to move aquatic biota alive by taking action to keep the survival rate high to the destination. Transportation of live fish is divided into two, namely transportation using water media or wet transportation and transportation without water media or dry transportation (Miranti 2011 in Hidayat *et al.* 2018). Therefore, in the stuttering of aquaculture, precisely oyster mussels, transportation is a crucial factor that needs to be considered.

There had not been many studies that discussed the cultivation of oyster mussels and the transportation system it implemented. This study aims to determine how the application of technology and transportation in the culture and sale of oysters in Japan, it was hoped that this paper can be a material for study and comparison in the development of transportation technology for marine fish commodities, as well as to contribute to starting oyster development in Indonesia in the future, especially for oyster cultivation.

METHODS

In this research, the methods used are descriptive methods of exploration in literature, Research Gate, Directory of Open Access Journals, and Google Scholar. Keywords used for relevant discussion topics, including, transportation systems, transportation of oyster mussel cultivation, Japanese oyster mussels. In addition, it uses a direct observation method with a case study at the Kamashima company. Thus, the theoretical framework can be arranged according to the subject matter of discussion.

The observation took place in Sakoshi Bay, Ako City, Hyogo Prefecture, Japan starting from January to April 2022. Observations were made to identify the types of transportation in oyster mussel cultivation activities with stages including, interviewing several oyster mussel cultivation companies to find out the activity procedures of each transportation system. Then, take measurements and documentation of the equipment used in the implementation of these transportation activities. In addition, collect a literature review to find out the basis of each treatment on transportation activities.

The processing of digital documentation uses IPhone Camera software, Adobe Photoshop applications, and Microsoft Word from Microsoft Office 365 which are used in the preparation of reports.

RESULTS

Oyster Mussel Cultivation in Japan

By 2010, Japan had produced 200,298 tons of oyster mussels (Table 1 and Figure 1). However, in the next 5 years Japan experienced a decline of tens of thousands of tons due to a large tsunami in 2011 which caused damage to fishery infrastructure including ships, ports, and aquaculture facilities (Wakamatsu and Miyata 2021).

As seen in Figure 2 in oyster mussel cultivation, seeds are collected from the sea by utilizing scallop mussels as a medium for sticking oyster spats (Koike 2015). Most seeds used in the cultivation of oyster mussels in Japan come from the city of Hiroshima or Miyagi, clam seeds from the Miyagi region are more often used for export, while clam seeds from hiroshima are preferred for local (Takahashi *et al.* 2016).

Oyster Shellfish Cultivation Media

Oyster shellfish cultivation in Japan utilizes rafts as a seeding medium (spat collector), enlargement, and harvesting that began in 1920 (Hasegawa *et al.* 2015). The raft used is made of a combination of bamboo, compos, wood and styrofoam tubes covered by *replaceable polyethylene jackets* and in Japanese it is called "Yoshoku ren" (Koganezawa 1978). As in the oyster mussel cultivation raft in Nagatsura-ura Lagoon, Sanriku Beach, Japan has a length of 28 m and a width of 5.5 m which can be seen in Figure 3.

Oyster Mussel Cultivation Cycle

The cycle of oyster mussel cultivation activities in Japan occurs seasonally, meaning that the stages in their cultivation activities are regulated and can only be conducted in certain seasons. For example, the annual schedule of oyster cultivation in Nagatsura-ura Lagoon, Sanriku Beach, Japan can be seen in Table 2.

Based on the information in Table 2 the first stage in oyster mussel cultivation is where oyster seeds attached to scallop clam shells are purchased from other bays in January to February; Second, oyster seed spats attached to scallop clam shells were deployed to rafts already installed in the restricted fishery area at Nagatsura-ura Lagoon from February to March; Thirdly, oyster mussels are allowed to grow naturally under the raft from June to October; and fourth, adult oysters are harvested and sold from November to the following April (Murata *et al*. 2021).

During the enlargement stage, harvesting activities for shellfish of commercially viable sizes are also taking place. In harvesting activities, oyster shells are transported from the raft using a special tow ship to land for processing (Kobayashi *et al.* 1997). After that, the shells will enter the selection process based on size, then enter the cleaning, processing, packaging, and then delivery to consumers.

Kamashima Oyster Clam Company

Fishing companies such as oyster mussels in Japan, are managed by local fishers who form a certain organization. Meanwhile, the local government is only entitled and obliged to determine the area for the cultivation site (Komatsu and Aoki 2020). Kamashima Company is one of the oyster mussels' companies originating from Japan, precisely in Sakoshi Bay, Ako City, Hyogo Prefecture since 1960. In addition to cultivating oyster mussels, Kamashima's company also produces a variety of foods made from oyster clams that are sold through its own food restaurant of the same name. The head of production and owner of the Kamashima company has been managing the company for more than 50 years (Kamashima 2022). The production of oyster mussels produced by Kamashima company has been widely shipped to all regions in Japan. Kamashima is one of the famous oysters producing companies. In 2012 Kamashima was voted the fourth best oyster mussel producing company in all of Japan by The Japan Oyster Association (Anon 2012).

In addition to Kamashima company as a case study, in this observation activity, information on oyster mussel cultivation was also collected through interviews with other companies in Sakoshi Bay. These companies include the Koyu, Kobayashi, Ueda, Okawa, Narubayashi, Matsumoto, Koe and Saishin company (Seat Sakana 2020). Based on the results of the interview, it was stated that each company has a different number of rafts or cages, but each raft has the same number of hanging ropes, which is around 950-1050 ropes per raft. The following is a table of raft data owned by each company in the bay of Sakoshi.

Based on Table 3 the Koe company has the largest number of rafts, with a total of 18-unit rafts so the number of oyster clam ropes harvested each season is 18000 ropes.

Table 1 Oyster mussel production in Japan (2010-2016) (Koike and Seki 2020)

Year	2010	2011	2012	2013	2014	2015	2016
Hiroshima	107.320	107.383	114.104	106.111	116.672	106.851	95.634
Miyagi	41.653	13.221	5024	11.581	20.865	18.691	19.061
Okayama	19.017	17.724	17.926	19.366	16.825	10.657	15.461
Iwate	9578	3288	565	2074	4774	5755	6024
Total in Jepang	200.298	165.910	161.116	164.169	183.685	164.380	158.925

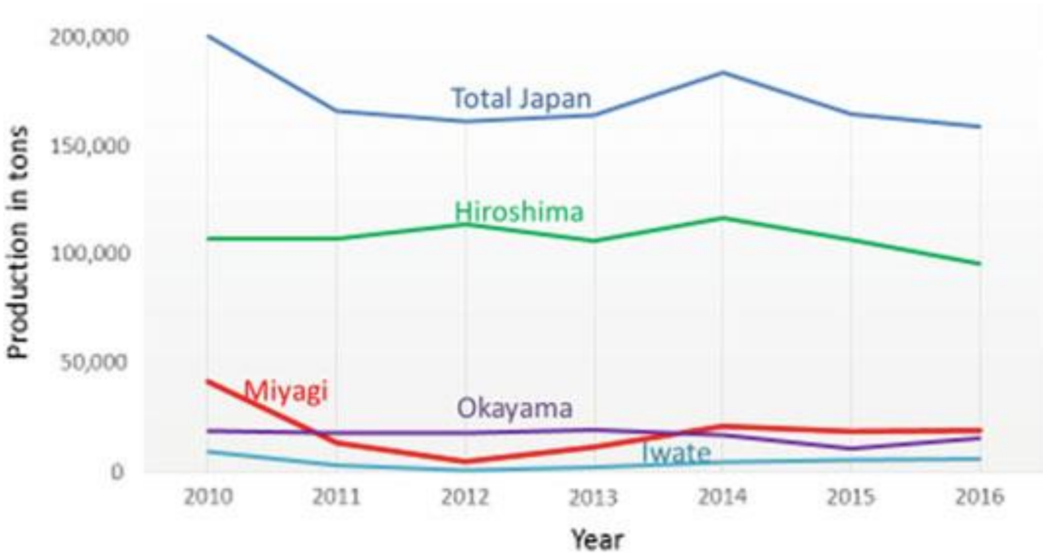


Figure 1 Graph of Oyster mussel production in Japan (2010-2016) by Japanese Statistics (Koike and Seki 2020)

Figure 2 Scallop clams plastered with oyster clam spat

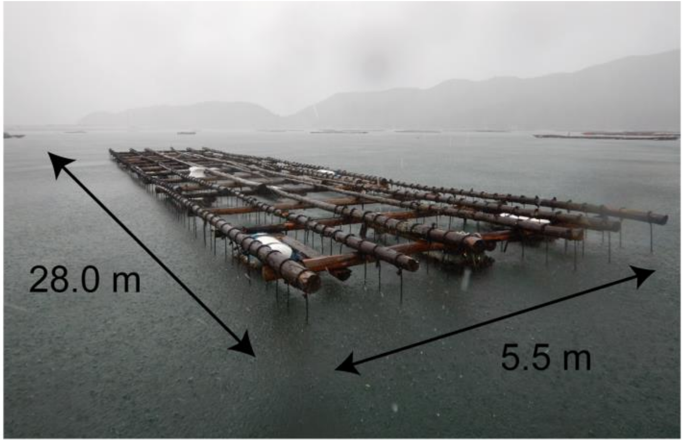


Figure 3 Raft of oyster clam cultivation at Nagatsura-ura Lagoon, Sanriku Beach, Japan. (Murata *et al.* 2021).

Table 2 Oyster Mussel Cultivation Cycle 1 Year

Stages	Months	Activity
1	January-February	Purchase of A Scallop Spat
2	February-March	Planting Spat on the raft
3	Juny-October	Enlargement
4	November-April	Harvesting & selling

Source: Murata *et al.* 2021

Table 3 Number of rafts owned by each company in Sakoshi Bay, Japan

Company Name	Number of Rafts (Units)	Total Number of Hanging Ropes (x1000 rope/Raft)
Kamashima	12	12000
Koyu	6	6000
Okawa	12	12000
Ueda	12	12000
Narubayashi	6	6000
Matsumoto	12	12000
Kobayashi	6	6000
Saishin	12	12000
Koe	18	18000
Total	96	96000

Types of Oyster Clam Transportation

Sea Transportation

In the harvesting stage of oyster clam cultivation, there is a sea transportation stage where the clams are transported from the enlargement raft to the landing site. At Kamashima company, sea transportation transports the harvest of oyster mussels that are 6-9 months old to be adult or fit for consumption. According to Kobayashi *et al.* (1997) oyster farmers in Japan start harvesting oysters during the winter of their first year when oysters are only 6-9 months old, this is aimed at avoiding death during the summer. The transportation of oyster mussels is conducted on a raft or cage that has been placed in the middle of the open sea, so that in this sea transport a special ship is needed (Figure 4a). At the Kamashima company, the special ship used measures 13.5 m in length or about 6-7 GT (Sunardi *et al.* 2019). The average size of special vessels used in the cultivation of oyster mussels in Japan is 12-20 m (Kusuki and Aratani 1986). In addition, such special vessels are equipped with *Hydraulic Cranes for Shipboard Use (Marine Cranes)* technology, originating from the Japanese TADANO company with the ZR500MR series capable of lifting loads up to 960kg in one transport (Tadano 2014). Based on a book issued by *Occupational Safety and Health Branch* (2017) entitled *Code of Practice for Safe Use of Mobile Cranes*, the crane technology of this TADANO company (Figure 4b) including *truck-mounted cranes* or cranes mounted on vehicles where the control engine is separated from the main vehicle.

In the process of its transport, the ropes hanging in the cage are collected and hooked in one large hook, then transported by the crane of the ship which finally when the bottom of the crane wire is released the oyster slides down onto the deck of the ship as shown in Figure 5. In one transport process, the crane can lift 10-20 ropes weighing about 30-60 kg/rope. According to Fujiya (1970) it is appropriate where the weight of one rope can reach 30-50 kg or even more. Furthermore, the results of transporting oyster mussels were brought ashore for later processing. This marine transportation system is included in the open dry system transportation. According to Kusyairi *et al.* (2013) dry system transportation is transportation system that does not use water as a medium, but nevertheless the environment or container used is made into a damp.

Based on Murata *et al.* (2021) the number of ropes on the cultivation raft in the Nagatsura-ura Lagoon, Sanriku Beach, Japan (Figure 3) amounted to 38 elongated and 23 sideways or about 874 ropes. In addition, in Kusuki and Aratani research (1986 in Menzel 1991) stated that each raft can hang up to 700 ropes. This contrasts with the number of ropes on the cultivation rafts at Kamashima company, including other companies in Sakoshi Bay which amount to 1000 ropes/rafts (Table 3). The difference occurred because in the middle of the raft along with between the styrofoam buoys, tubes were also added to the oyster ropes. In addition to maximizing production, this is also an effort to protect shellfish from predator attacks so that only the edges of the raft are affected by predator attacks.

After the results of sea transportation are landed, the oysters will go through two different processing processes including, open shells (shucked shells) and closed shells (for large ones) which will directly go through a cleaning process from parasites attached to their shells (Kawabe *et al.* 2019). After the oysters are processed, the oysters will go by land transportation for consumers to receive.

Land Transportation

In addition to sea transportation, there is also land transportation of oyster mussels that occurs during the oyster delivery process to other parties, one of which is the consumer. The handling process in transportation activities is especially important for fishery products, starting from the fish being landed to reaching the hands of consumers or their hinterlands (Lubis *et al.* 2010). Based on the observations, land transportation at Kamashima company and other companies utilizing styrofoam box type containers. The oysters sent can be in the form of shucked shells or intact ones with their shells. The type of styrofoam boxes used by Kamashima company including other oyster clam companies in Sakoshi Bay, in land transportation activities can be seen in Table 4.

Transportation using styrofoam boxes themselves has several types of sizes depending on the number and size of shells requested (Table 4). In addition, in the styrofoam box the oyster clams must first be wrapped using plastic and added wrapped blocks of ice (Figure 7) to keep the temperature below the optimum temperature so that there is a slowdown in damage to the oyster clam organs. Based on the research of Kitabayashi *et al.* (2019) it was stated that the decrease in temperature has an impact on reducing oxygen consumption and decreasing metabolic products that can be toxic both in the form of CO_2 gas and ammonia in the form of NH_3. Prastyo *et al.* (2018) in his research also stated that in the transportation of dry systems, ice is a crucial factor in maintaining fish quality. In addition to lowering the temperature to remain low, the presence of ice blocks is an attempt to reduce oxygen consumption and delay the metabolism that becomes toxic.

Based on Table 4, oyster's mussels that are ready to be shipped are weighed first according to the number of consumer orders, then put in a plastic bag (if the weight of the order reaches between 10-15 kg per box). Next, the oyster mussels are placed in a styrofoam box (Figure 7a) and added a block of ice (Figure 6), then sealed tightly using adhesive tape (Figure 7b). In the transportation of dry system, the container used must be able to maintain the temperature of the product according to the provisions, not be penetrated by heat from outside the container, not polluted by water, gas, air, dirt, and others that can interfere with the health of the product and be able to transport the product (Pongsetkul *et al.* 2022). Based on the results of an interview with Kamashima's company, it was stated that the use of styrofoam as a transportation container because the styrofoam box has the properties of a container that is not penetrated by water or heat, can minimize temperature rise, and is easy to transport.

Based on research by Kusyairi *et al.* (2013) land transportation at Kamashima's company is included in, closed dry system transportation. The dry transportation system applies the principle of conditioning aquatic biota in a state of low metabolism and respiration so that the resistance outside their living habitat is high. (Heriyati and Kasman 2017).

Factors in the Transportation of Fishery Products

Based on records in marine transportation observation activities, it is known that marine transportation activities must pay attention to the size of the wind that blows, the time of picking, and the number of oyster mussels needed to be processed (Table 5). Imanto (2008) in his research stated that there are crucial factors in the transportation activities of live marine fish, namely, sea transportation, fasting, cooling, and supplying oxygen. Then, on land transport, temperature satisfaction, anesthesia media, decreased salinity, fish volume ratio, and medium and oxygen.

4a **4b**

Figure 4 (a) Tadano Marine Cranes in Kamashima Company (b) Tadano Crane Control Machine Specifications Inc. (Tadano 2014)

Figure 5 Oyster shells transported from rafts

Table 4 Types of styrofoam boxes for ground transportation

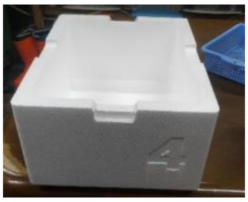
Box Code	Volume (p x *l* x t) cm	Full Weight (kg)	Figure
1	30 x 18 x 11	1-1.5	
2	30 x 23 x 14	2	
3	33 x 26 x 14	3	
4	33 x 26 x 14	4	
O-30	40 x 33.5 x 27	10	
O-37	38 x 28.5 x 18	10	
O-37-1	38 x 29 x 19	10	
A-50	44.5 x 40 x 28	15	

Figure 6 Ice Block for styrofoam Box

A B

Figure 7 (a) Styrofoam boxes without plastic bags, (b) Styrofoam boxes ready for shipment

Table 5 Important Factors in Sea and Land Transportation

Sea Transportation	Land Transportation
Temperature Fasting	Temperature Fasting
Wind Speed	Container/Carousel
Weather (Transportation Time)	Temperature Control
Number of fish	Fish Ratio/Volume
Oxygen	Oxygen

Source: Imanto (2008)

DISCUSSION

Shellfish cultivation activities have grown rapidly in the world (Wijsman *et al.* 2018 in Abe 2021). Pacific oysters (*Crassostrea gigas*) are the most widely cultivated species of clams worldwide, and selective breeding programs have been started to improve growth rates, disease resistance, shell, and meat quality (Wan *et al*. 2020). In Japan, oyster cultivation has been a productive undertaking for years (Koike and Seki 2020). Japanese oyster mussels are cultivated under conditions of low density and a sea level rich in plankton. Under these conditions, the growth rate is extremely high, and they can be marketed within a year before they mature (Komatsu *et al*. 2018). The production of oyster mussels in Japan consumed by local people is sold without shells or have been shucked reaching 16-41 tons/ha/year (Murata *et al*. 2021).

According to Kasmini (2019) the optimum temperature for oyster growth ranges from 25 – 30^{o}C. The shelf life of live oysters with shells is known to be about 3 days under cooling in the Japanese market (Kawabe *et al.* 2019). Then, according to Rajagopal *et al.* (2005) *Crassostrea gigas* is known to have good tolerance to temperature range and environmental conditions. *Crassostrea sp.* can grow at temperatures of 4 – 35^{o}C and can still withstand temperatures of 3 ^{o}C (Qurani *et al.* 2020).

There are several ways of handling fish in dry system transportation, by using anesthetic methods that marginalize fish. The anesthetic method is a method widely used in the transportation of dry systems with the aim of maintaining the level of life ability through the slowdown of the metabolism of its body (Saskia *et al*. 2012). Such as the use of rambutan leaf extract in crayfish (*Procambarus clarkii*) (Syamsunarno *et al.* 2019), clove oil in baronang fish (*Siganus sp*) (Hidayat *et al.* 2018), and picung leaf extract in tilapia fish (*Oreochromis niloticus*) (Munandar *et al*. 2017). Based on the observations, the handling of oyster mussels at Kamashima's company does not use the anesthetic method. The handling conducted only uses the method of temperature imotilization (Temperature handling). This is because oyster mussels can last in fresh conditions for 3 days and the farthest areas shipped by Kamahsima company are Okinawa Island, Hokkaido Island, and Kyushu Island.

Based on the research of Ramadhaniaty *et al.* (2021) stated that Indonesian waters have suitable conditions as a place for the cultivation of *Crassostrea gigas* oysters as developed in Japan based on the parameters of temperature, salinity, pH, and DO. So that Indonesia can start producing oyster shells with cultivation without having to catch them from the sea. Then, prevent over-exploitation and pollution of the quality and quantity of oyster shells that decrease (Octavina *et al.* 2014).

CONCLUSIONS

The transportation system in oyster shellfish cultivation activities in Japan is divided into two areas, namely sea and land. In sea transportation, the transportation activities use Hydraulic Cranes for Shipboard Use (Marine Cranes) technology which is attached to boats measuring 6-7 GT with the classification of truck-mounted cranes. Meanwhile, in land transportation, it uses the styrofoam box as a transportation container equipped with ice blocks to immobilize the temperature. Therefore, that the transportation technique in the cultivation of oyster mussels in Japan applies the transportation technique of the closed and open type of dry system. Wind speed, transportation time, and the number of oyster mussels needed to be processed are crucial factors in transportation activities, qualities, and process.

SUGGESTION

To get more information related to the oyster clam cultivation business, further research can be conducted regarding the feasibility of oyster clam cultivation, procedures for oyster clam cultivation, and the utilization and processing of oyster shells. So that in the future Indonesia can also contribute to the production of world oyster shells.

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