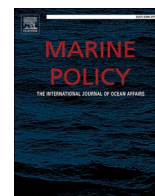




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The effect of COVID-19 pandemic on the shrimp industry of Iran

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ABSTRACT

The first case of COVID-19 was reported in December 2019, and then the virus has spread throughout the world, which led to lockdown in different countries, including Iran. Restrictions on transportation and travel of personnel caused some shortages in aquaculture, particularly in shrimp farms. This study aims to evaluate the impact of the COVID-19 outbreak on the shrimp farming industry in Iran. An online questionnaire was designed to collect information from shrimp farmers, material suppliers, food preparing factories, managers of shrimp hatchery centers, and shrimp exporters. Our results showed that the COVID-19 outbreak has significantly decreased the shrimp annual sales, export, and price in Iran. Also, the production of larvae was affected by COVID-19. Shrimp farming industries are still subject to impacts of the pandemic by reducing hatchery production, shrimp demand, and increasing production and transportation costs.

1. Introduction

The first COVID-19 case was reported in December 2019 in Wuhan, China [24], then the virus has spread throughout the world. So far, more than 254 million people worldwide have been infected with the disease, and more than 5.1 million people worldwide have died by 16, November 2021 (<https://www.worldometers.info/coronavirus/>). In Iran, the first report on COVID-19 was on December 21, 2019. Nearly 6.04 million people in Iran have been infected with the virus, and 128,272 people have died by the end of November 2021 (<https://www.worldometers.info/coronavirus/>). Lockdowns in some countries have led to logistical problems in the seafood trade due to shipping and border restrictions. Therefore, due to restrictions on transportation and travel of personnel during this period, some shortages of post-larvae (PLs), feed and aquaculture items have been reported, with special effects on the aquaculture industry [5].

At the beginning of the outbreak in Iran, despite the government's failure to quarantine cities, popular groups blocked public and private vehicles and passengers by blocking access to towns and imposing traffic restrictions due to fear of spreading the disease in the country [14]. In addition to creating disorder, this approach led to the disruption of all economic activities throughout the country. The restrictions lasted for nearly a month, and many local markets were closed. However, after people backed to their works, unfortunately, the country faced several wave peaks of the disease during this period. Sometimes during one day,

the COVID-19 deaths reached more than 500 people. This approach from the National Corona Headquarters to disease control has always been relaxing, so that from time to time, as the deaths from the disease increased, the road and social restrictions were performed.

On the other hand, due to the limits imposed on transfers between different countries and the increase in cases and mortality in the country, many international flights to or from Iran were canceled [20]. Unemployment due to the closure of many production units and the cessation of economic activities, especially in the manufacturing and service sectors on the one hand, and the shortage of labor in primary food production systems due to social and movement constraints led to economic recession in the world [6,17]. In this situation, Iran was not an exception; by May 2020, the number of people registered in the comprehensive system of labor relations (<https://prkar.mcls.gov.ir/>) of the Ministry of Cooperatives, Labor and Social Welfare was more than 2 million people [14]. Waiho et al. [23] reported that COVID-19 has reduced household incomes by 12% and laid off more than 2.4 million people in Malaysia.

In addition, export restrictions across countries have limited global food and agricultural trade and market access [12,16]. Therefore, the reduction of cargo capacity for commercial flights of agricultural goods led to disruption of the global supply chain [5,13,22]. In Iran, the effects of this event were significantly observed in different sections [14]. Despite the production of various vaccines by vaccine companies in the world and the implementation of vaccination programs in most

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countries, there is no comprehensive vaccination program in Iran to prevent and control coronavirus disease until June 2021. Therefore, simultaneously with the beginning of the fourth wave peak of COVID-19 in the country, many industries will face bankruptcy next year if this trend continues.

The global shrimp market value is estimated to be around \$ 25 billion by 2026 [4]. World shrimp production in 2019 exceeded 4.5 million tons, representing a relative increase in shrimp production compared to worldwide shrimp production [8].

More than 25 years have passed since the beginning of the shrimp industry in Iran. Shrimp farms in Iran were built on a semi-intensive system. Shrimp farming was initially started by native species such as *Penaeus semisulcatus* and *P. indicus*. Still, due to the prevalence of white spot syndrome viral disease (WSSV) and the damage caused by the outbreak of this disease in 2004, the Iranian Fisheries Science Research Institute (IFSRI), with the aim at species diversity and combating WSSV, introduced a non-native species named *Litopenaeus vannamei* to the Iran shrimp industry [18]. Now, the shrimp farming industry with an area of 11,000 ha is located on the southern and northern coasts of the country, including Khuzestan, Bushehr, Hormozgan, Golestan, and Sistan and Baluchestan provinces. Because of the country's climatic conditions, the shrimp farming period, except for farms located in Hormozgan province, is once a year, which usually lasts from May to November. Today, up to 90% of the shrimp produced is exported through ports to China, Europe, and the Arab countries of the Persian Gulf. Because of the imposition of international sanctions against Iran in recent years, the farming industry is considered one of the most profitable industries. According to statistics provided by the Fisheries Organization of Iran in 2019, this industry can be profitable amounted to \$220 million by producing 47,000 tons of shrimp [11].

To prevent white spot virus disease, shrimp farmers obtain their post larvae from reputable hatcheries under the supervision of the Iran Veterinary Organization (IVO). Also, shrimp feed is usually supplied from domestic or imported sources during the culturing season. Each of the industries (feed factory and processing centers, shrimp hatcheries, and culturing) related to the shrimp farming industry may be located in the shrimp farming province or neighboring provinces. Therefore, road restrictions affected this industry at some point in time. FAO [6], in its initial assessment of COVID-19, showed that the shrimp industry around the world has been disrupted by the loss of larval supply chains, labor shortages, and the loss of the sales market. Therefore, examining the immediate and long-term consequences of this epidemic is vital for the global network of agricultural and food systems [2].

This study investigates the effects of COVID-19 on each of the active sectors in the shrimp industry in Iran to help reduce these effects and develop the industry by offering various solutions through flexible policies.

2. Materials and methods

In this study, information was collected through an online questionnaire due to the prevalence of coronavirus COVID-19, which also helps us obtain data quickly [7]. The online questionnaire consisted of two parts: the first part included questions about the identity information of the respondents and their participation in the shrimp farming industry. The second part consisted of three different sets of questions about (i) Shrimp farmers, material suppliers, and food factories, (ii) Managers of shrimp hatchery centers; (iii) Shrimp processors and exporters. In all three series, some common questions were asked to obtain participants' comments about COVID-19 impacts on different production processes. The questionnaire was prepared using the online Google platform [1]. The survey was open to all shrimp aquaculture activists who had access to digital operating systems and social applications. The shrimp aquaculture activists who work in Iran's shrimp industry were introduced by the Iranian Fisheries Organization and related unions. On April 12, 2020, the link to the questions was sent to shrimp aquaculture

activists in Iran through WhatsApp groups and other social networks. Within a week, 568 industry activists representing farmers, material suppliers, and feed producers (68.38%), hatchery centers (21.48%), and processors (10.14%) worldwide responded to questions. Phone calls were made to verify the information collected through the online survey. The data were statistically analyzed based on the ranking. Microsoft Office Excel 2016 was used to estimate the potential economic impact on the shrimp industry.

3. Results and discussion

The results are presented and discussed in four sections: (I) Production and supply of shrimp larvae (shrimp hatchery centers), (II) shrimp farming, (III) processing and marketing, and (IV) Overall impact and economic losses of the sector as a whole.

3.1. Shrimp hatchery centers

In this study, indicators related to the effects of the COVID-19 outbreak of hatchery centers included problems related to the breeding technician, labor force, transportation, supply of broodstocks, larval food, required materials, equipment, and production of post-larval, sale, and costs of the breeding period.

L.vannamei is currently considered the first farmed species in Iran. The origin of this species was imported to the country from Molokai, Kona bay company, and The Oceanic Institute of Hawaii Pacific University regions. In recent years, due to international sanctions, fluctuations in the dollar price, and the devaluation of the national currency, there have been no imports of broodstocks of shrimp into the country. The last shipment of SPF (Specific Pathogen Free) broodstocks of *L.vannamei* to the country was from Molokaei Broodstock Company (MBC) in 2016 [19]. During this period, shrimp industry activists (private sector) cooperated with organizations such as the Iranian Veterinary Organization, IFSRI, and the Iran Fisheries Organization domesticated farmed shrimp-produced broodstocks of *L.vannamei* in the country. Therefore, during the outbreak of COVID-19 in the country, the hatchery centers did not have any problems supplying SPF broodstocks of *L.vannamei* [14]. Thus, each commercial shrimp hatchery center provided their required broodstocks by developing selective breeding programs. Therefore, broodstocks transfers between centers were rare, except on a few occasions. However, the problems related to their supply and transfer had the lowest percentage of problems (26.7%). While, in India and many other countries, SPF broodstock imports from the United States, Madagascar, and Mexico have been hampered by border closures [15].

The outbreak of coronavirus disease coincided with the start of shrimp hatchery centers. Due to traffic restrictions and the fear of individuals and drivers, inter-provincial transfers were challenging to carry out, although there were no road restrictions on public transport. At the beginning of the global crisis, most airlines were shut down, and even commercial cargo flights significantly reduced the cargo capacity of agricultural goods, disrupting the global supply chain [13].

Since the production of larvae in the hatchery centers has been performed by technicians of Southeast Asia, especially from Thailand, the Philippines, Malaysia, India, and Ecuador, the closure of the air and land borders causes multiple problems in their travels. Although two months have passed since the beginning of the breeding season in the country, some hatchery centers did not have breeding technicians. During this period, Iranian technicians started producing larvae based on work experience. Nevertheless, the larval production of breeding centers was severely reduced. Therefore, the results showed that the biggest problem of hatchery centers was preparing international plane tickets for the breeding experts and traveling to Iran with 93.3% and 70%, respectively. In comparison, the problems related to the local labor force had a lower percentage (50%).

Also, because of the lack of larval feed production factories in Iran,

Table 1
Impact of COVID-19 lockdown on shrimp hatchery centers.

No	Impact on shrimp hatchery centers on account of access to	Percentage	Rank
1.	Breeding expert force	70.00	6
2.	Preparation of international plane tickets	93.33	1
3.	local worker force	50.00	7
4.	Supply of broodstock	25.45	14
5.	Transmission of broodstock	26.67	13
6.	Providing larval food	76.52	5
7.	Transmission of larval food	90.00	2
8.	Supply of Imported equipment	78.65	4
9.	Supply of Iranian equipment	43.33	8
10.	Larval production	40.00	9
11.	Demand for the purchase of post larvae	10.14	16
12.	Larval transfer	30.00	12
13.	Shrimp disease diagnostic tests	33.15	11
14.	Production costs	80.00	3
15.	Infection of personnel by COVID-19	36.67	10
16.	Cost of personnel COVID-19 detection tests	23.21	15

most activists buy all their equipment and feed during the larval period from unreliable centers in Southeast Asia, especially Thailand. Usually, lack of a valid certificate and IVO obstruction on importing these goods into the country leads to illegal import through the UAE. Coinciding the COVID-19 disease with Thai airways closure and the non-issuance of licenses to cargo, in addition to higher transportation costs, led to the import of these materials and equipment with a three-month delay from the beginning of the breeding season. Thus, restrictions in the supply of equipment and materials for reproduction were observed mainly due to problems related to the transfer of larval food and equipment (including micro nets, water diagnostic kits, and more) into the country (90% and 78.65%, respectively).

Since culturing period in most shrimp farming areas of Iran is once a year, delay in larval production due to problems caused by the outbreak of coronavirus disease disrupted larval supply and demand at the beginning of rearing season in Iran. One of the industry's main problems was the fluctuations of the dollar price and the devaluation of the national currency and international sanctions, which in addition to imposing high costs on the industry, disrupted the transfer of money and goods internationally [3,10].

Because of the economic problems in the country and high unemployment, despite the outbreak of coronavirus disease and road restrictions on the movement of people from different areas, there was no particular problem in discussing the labor force working in hatchery centers. On the other hand, due to the isolation of hatchery centers and the lack of entry and exit of various people or the relationship of the staff of these centers with other people and most importantly, health issues from the beginning to the end of the breeding season, no reports of infection or death were provided.

Other issues discussed in hatchery centers, purchase, and supply of food and materials needed personnel and broodstock of shrimp included squid, sea worm, *Artemia*, etc. International sanctions, the devaluation of the national currency, and the closure of air and land borders had made it difficult for suppliers of materials and food factories across the country to meet the daily needs of breeding center staff and broodstocks of shrimp. Sometimes the managers of hatchery centers had to pay more for the supply of these materials than last year, which led to an increase in the cost of selling larval shrimp. Other problems in the larval production sector include the increased cost of performing diagnostic tests by veterinary diagnostic laboratories. It is noteworthy that due to the dependence of these laboratories on imported diagnostic kits, the increase in the cost of the dollar, international sanctions, and finally the closure of air borders, in addition to disrupting the supply of these kits, the cost of diagnostic tests was significantly increased (80%) (Table 1).

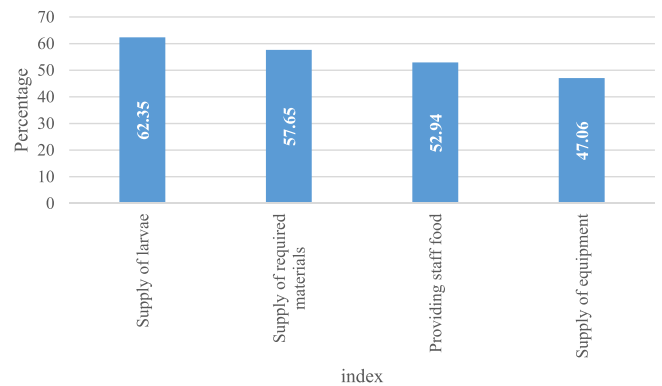


Fig. 1. COVID-19 impacts on shrimp farming supplies.

3.2. Shrimp farming

Shrimp farming in Khuzestan, Bushehr, Golestan, and Sistan and Baluchestan provinces last once a year from May to Oct. Only in Hormozgan province is the breeding period done twice a year, from March to Oct. However, this did not happen this year due to problems caused by coronavirus disease. About 27% of farmers prepared their ponds for secondary stocking did not work due to larval supply problems, lack of feed and other necessities, and unpredictable market conditions. Also, shrimp farming was disrupted due to a deficiency of post larvae early in the rearing period and increased demand. Therefore, the most critical problems in the farms included problems related to the supply of post larvae, equipment (Electric water pump, aerator, etc.) and materials, labor, shrimp sales, road and quarantine restrictions, acceptance of shrimp in processing and production costs. The results showed that due to the prevalence of COVID-19 disease and other problems of hatchery centers, larval production was severely reduced, so the supply of post larvae compared to items such as shrimp feed, equipment, and materials needed the highest amount (Fig. 1). Thus, 50.94% and 61.18% of shrimp farmers agreed on increasing the cost of post larvae and production, respectively.

The main labor force working in Iran's shrimp farms includes indigenous people and migrant workers from neighboring countries, especially Afghanistan. In this regard, despite the increase in the prevalence of coronavirus disease in the country and the increase in daily losses during the rearing period, nevertheless, the existence of quarantine and inter-provincial traffic restrictions due to economic problems in the community, issues related to it, this disease had little effect on the shortage of labor on farms.

Shrimp farms in Iran are farming complexes and are close to each other. Non-observance of the social distance between labor forces working in farms and sometimes movement of asymptomatic people between farms with no protective equipment such as masking caused an increase in the spread of the disease among workers, resulting in a disturbance in shrimp farming. However, 60.15% of farmers had difficulty hiring rearing workers, while 43.53% and 61.22% had difficulty hiring skilled expert and shrimp harvester workers, respectively. The shrimp feed industry is heavily dependent on-farm operations, so poor post larval stocking in-farm has led to the reduction or closure of farm shrimp feed mills. On the other hand, lockdown affects the transportation of raw materials such as fish meal, soybean meal, and fish oil and hinders the operation of feed mills. Therefore, other problems during the growing season were rising shrimp feed prices and running farm costs. The main reasons for this event could be the closure of borders and the reduction of imports of materials for the disease coincided with the devaluation of the national currency and rising economic shrimp feed factories and other needs due to coronavirus outbreak disease in the world. However, the farmers of view were related to larval transport (38.82%), food transport (45.06%), road restrictions

Table 2
Impact of COVID-19 lockdown on shrimp farming.

No	Impact on shrimp farming on account of access to	Percentage	Rank
1.	Supply of post larvae	62.35	4
2.	Supply of required materials	57.65	8
3.	Providing staff food	52.94	10
4.	Supply of equipment	47.06	13
5.	Larval cost	50.94	11
6.	production costs	61.18	6
7.	Expert force	43.53	15
8.	worker force	60.15	7
9.	Shrimp harvest worker	61.22	5
10.	Foreign Shrimp Customer	95.29	1
11.	Domestic shrimp customer	70.59	3
12.	Reduce the price of shrimp	90.59	2
13.	Transport of material and post larvae	38.82	16
14.	Transport of shrimp food	45.06	14
15.	Road restrictions	49.41	12
16.	Acceptance of crop in shrimp processing centers	56.47	9

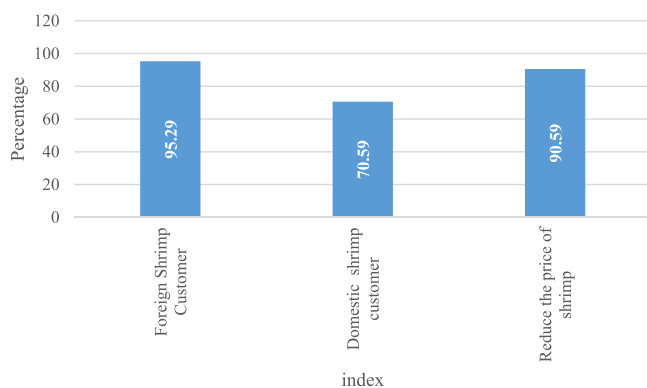


Fig. 2. COVID-19 impacts on shrimp sales.

(49.41%), and acceptance of crops in shrimp processing centers (56.47%) due to lack of worker force. The outbreak inflation increased current running costs by 20%, but farmers made significant profits last year due to rising dollar prices (Table 2).

Kumaran et al. [15] reported that losses caused by the COVID-19 outbreak in India on shrimp production are estimated at more than 40%, worth \$ 1.50 billion. If the lockdown and other restrictions continue in the next crop season, the overall economic damage will be much more significant than expected. On the other hand, consumers are now paying more money for aquatic products, but dealers pay less to buy these products from farmers [9].

However, the main problems related to shrimp farming were the lack of shrimp customers, both foreign and domestic, and the reduction of shrimp prices (Fig. 2).

3.3. Shrimp processing centers

Iranian farmed shrimp is considered one of the world's organic products due to the non-use of antibiotics and other additives. However, due to the country's international sanctions and the problems caused by the movement and transfer of these products to global markets, shrimp customers are reluctant to enter the Iranian shrimp market due to fear of heavy fines in international forums. However, most Iranian shrimp is exported through illegal sources. This has caused many shrimp buyers to buy the product at lower prices than the actual prices due to Iran's economic situation.

The global lockdown has put much pressure on the natural processing supply chain of shrimp exports. Hesitation in the entry of traders and issues related to orders and exports led to the continuation of the policy of waiting and non-return of capital. These influences spread

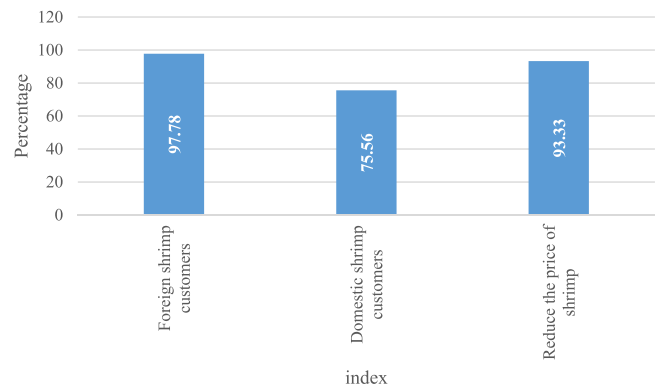


Fig. 3. COVID-19 impacts on shrimp sale and export.

rapidly from exporters to retailers, processing plants, and reproduction centers. Because many links in the export value chain have been broken, breeders have not been able to sell their harvested crops on time due to a lack of customers. The outbreak of coronavirus disease and the seizure of Ecuadorian and Saudi shrimp shipments in China due to the contamination of packages with the coronavirus had prompted the veterinary organization and processing centers to make special arrangements [14, 21]. These precautions included using masks and not using infected people in shrimp processing centers and disinfecting equipment to prevent contamination of processed shrimp and packages with the coronavirus. Therefore, the sensitivity on the disinfection of the packages and the non-detection of the virus on the packages by 82.22% and 90.14%, respectively, had caused concern among the managers of the processing centers.

On the other hand, the prevalence of personnel infection to COVID-19 and the cost of diagnostic tests in personnel at 55.56% and 48.89%, respectively, was the most important concern of the managers of processing centers. Aquatic products are one of the main components of a healthy diet and are safe to eat. Due to the COVID-19 disease prevalence, misleading perceptions in some countries have led to a reduction in these products' consumption. However, the coronavirus cannot infect aquatic animals (finfish, reptiles, amphibians, and invertebrates such as crustaceans and mollusks), so these animals have no epidemiological role in the transmission of COVID-19 to humans [5]. Although there is no case of people getting COVID-19 disease through aquatic food or food packaging there is an emphasis on implementing strong health measures to protect fishery and aquaculture products from contamination.

There were no specific restrictions on the employment of labor in shrimp processing centers. However, due to the outbreak of shrimp white spot virus disease at the end of the rearing period and the concerns of farmers about the damage caused by the outbreak of white spot disease, many shrimp processing centers were faced with a massive volume of harvested shrimp. Therefore, some of these processing centers operated in two to three shifts of 8 h a day. Nevertheless, according to a survey conducted by managers of shrimp processing centers, supply of materials, employment of labor, lack of shrimp collecting trucks, road restrictions, and shrimp exports due to the lack of vehicles and ship with 57.78%, 60.00%, 37.78%, 64.44%, and 60.34% major problems, respectively.

On the other hand, many activists in this industry bought and processed shrimp beyond their capacities, despite the declining demand for shrimp in global markets due to coronavirus disease outbreaks. They hoped that shrimp customers, primarily Chinese traders, would buy shrimp. According to the survey, the lack of shrimp customers, both domestic and foreign, and the reduction of shrimp prices were the most critical problems of processing centers' managers (Fig. 3).

Despite the prevalence of coronavirus disease in the country and the increase in cases and deaths during the shrimp harvest period, evidence has shown no interruption in shrimp harvest and transfer from farms to

Table 3
Impact of COVID-19 lockdown on shrimp processing centers.

No	Impact on shrimp processing on account of access to	Percentage	Rank
1.	worker force	60.00	10
2.	Lack of collecting car	37.78	14
3.	Shrimp export (no ships or vehicles including trucks to port)	60.34	9
4.	Supply of materials	57.78	11
5.	Road and quarantine restrictions	64.44	7
6.	Infection of personnel	55.56	12
7.	The cost of diagnosis	48.89	13
8.	Product export tests (Antibiotic, Afflation, and heavy metal)	62.22	8
9.	Concerns about product packaging	90.33	3
10.	Coronavirus detection on packages	66.67	6
11.	Disinfection of product packaging	82.22	4
12.	Foreign shrimp customers	97.78	1
13.	Domestic shrimp customers	75.56	5
14.	Reduce the price of shrimp	93.33	2

processing centers and export.

The short-term and long-term effects of COVID-19 marginalize coastal communities that have previously been vulnerable to many social and environmental changes [2]. This year, despite the increase in shrimp production in the country and the increase in production costs, and the devaluation of the national currency, unfortunately, the decline in consumer demand, especially in shrimp-buying countries, has been severely fallen due to the closure of international markets cause of the outbreak of coronavirus disease, travel restrictions in tourist countries around the world and the closure of restaurants. Until December 2020, less than 60% of the harvested shrimp has been exported, and most of the shrimp produced is stored in cold storage. Since December 2020, the harvested shrimps have gradually been sold and exported at lower prices than the same period of last year. However, the lower price was compensated by the decrease in Rials value against the US Dollar. Nevertheless, a little cash was paid to farmers, and farmers did not fully pay their debts to the suppliers. Given that the next rearing season in the country has just started, the industry will face bankruptcy if this situation continues. Last year, with a production of more than 47,000 tons of shrimp, it had a profit of \$220,000. However, this year, despite the production of more than 48,000 tons, declining demand and the closure of international markets cause a decrease in this industry's profitability (Table 3).

4. Conclusion

In hatchery centers, materials such as larval food and equipment were arrived delayed due to closed or restricted borders. Although the hatchery centers did not have a problem supplying the broodstock, the mentioned conditions drastically reduced larval production. Stocking post larvae in shrimp farms were limited due to the reduction of larval production in hatchery centers. Furthermore, close restaurants and global tourism crises after the outbreak of Covid-19 reduced global shrimp demand and its price. The return on investment was delayed due to a massive drop in sales to domestic and foreign customers. Moreover, our results showed that the purchase of disinfectants during processing incurred high costs to the shrimp processing companies.

On the other hand, the shrimp production level in the country is lower than in other countries such as India, China, and Indonesia. Perhaps one way out of this problem is to sell the shrimp produced in the domestic markets. However, due to the devaluation of the national currency, the increase in inflation, and the cost of living of Iranian citizens, the domestic market cannot support this industry. Since this industry is always considered a profitable industry for the country, it is suggested that the government help the survival of this industry by providing support packages and pre-purchasing shrimp produced at reasonable prices and facilitating processed shrimp export and cash

transactions.

CRedit authorship contribution statement

Mohammad Khalil Pazir: Developed the theory and performed the statistical analysis and supervised the findings of this work. **Amirhossein Ahmadi:** Wrote the manuscript and discussed the results. **Parisa Hossein Khezri:** Analysis of study results.

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