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The Importance of Low-Cost Live Feed Culture Technology to the Marine Shrimp Industry during COVID-19

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Abstract The importance of live feed as a beginning diet in marine shrimp (*Penaeus* sp.) is largely dependent on careful management during the early stages of larval growth. The COVID-19 pandemic has a significant impact on Malaysian aquaculture, which is critical for seafood supply and security. Cladocerans are an alternative live feed species that outperform *Artemia* nauplii in terms of nutritional value, economic value, availability, and reproduction rate. In terms of supplying live feed for commercial aquaculture, cladoceran culture and cultivation can therefore be an economically viable, sustainable, and desirable live feed species. The purpose of this study is to collect information on low-cost live feed for marine shrimp used in aquaculture and how COVID-19 affects the sector. Thus, a survey was conducted at a private hatchery and farm in Pekan and Badong, Pahang, Malaysia to investigate the importance of low-cost live feed culture technology to the marine shrimp industry during COVID-19. A total of 20 respondents took part in the survey. During the COVID-19 period in Malaysia, data were gathered using a questionnaire that was planned to be completed via an online form from August 2020 through December 2020. The software utilised was a Google application (Google Form). The data gathered revealed the importance of utilising live feed for maintaining shrimp larvae production in the sector. The current data are critical for developing policy actions to support seafood industries affected by the pandemic at both the national and international levels.

Keywords Live Feed, Low-Cost, COVID-19, Marine Shrimp, Malaysia, Aquaculture Industry

1. Introduction

Aquaculture is an internationally prosperous sector that yields many important species of fish, crustaceans, and other aquatic organisms. It is one of the most significant industries in the world for providing the population with essential nutritional sources of protein, fat, minerals, and vitamins [1]. Aquaculture has the potential to boost the community's socioeconomic conditions by assuring food security [2]. In 2019, Malaysia's aquaculture business produced farmed organisms weighing in at 391,000 metric tonnes, with an estimated economic worth of USD 700 million. Larger size, higher nutritional content, and broad demand as a gourmet delicacy make the marine shrimp,

Penaeus sp., one of the most commercially significant native-farmed species in Malaysia.

COVID-19's effects have yet to be seen and are unpredictable due to its size and nature. However, it is well understood that these effects will have an impact on both small-scale agriculture and other production chain links [3]. Shrimp production was cut in half due to the COVID-19 pandemic, which had a major impact on market pricing and therefore on farmers' ability to make a living. Costs of production went up and income from farming went down as a consequence of the nationwide lockdown, which restricted both exports and movement inside the country. In response, farmers reduced personnel by an average of 42.8 percent, but even with the sale of co-cultured finfish, income fell by a similar amount [4]. Since COVID-19 has discouraged the well-to-do from going out to the store [5], lower-income consumers have favoured finfish over shrimp [6]. Since then, sales of shrimp at local stores have dropped.

In summary, COVID-19 threatens the incomes of tens of thousands of people who have no other means of support, deepening poverty and threatening future food supplies [5]. This study would investigate the effects of COVID-19 on the shrimp industry and the economy. Kembang Subur Sdn. Bhd. is a private corporation that manages shrimp hatcheries in Malaysia and Vietnam. In order to produce and sell specified pathogen free (SPF) nauplii and post larvae, the company primarily engages in shrimp grow-out farming and operates a marine shrimp hatchery. Hatcheries need a wide range of dietary resources for SPF broodstocks, such as *Artemia*, microdiet, and low-cost live feed [7].

The global transportation system has almost ground to a standstill owing to the restrictions imposed by the COVID-19 virus. It is challenging to import shrimp broodstocks with a higher SPF because of restricted borders and/or local limits. Having processing facilities, hatcheries, and farms in close proximity to one another may improve the efficacy of lockdown in countries that produce shrimp. The shrimp feed business is highly dependent on on-farm activities; as a consequence, a lack of on-farm activity has led to the reduction or closure of feed mills [7]. Shrimp still need frequent feeding to develop healthily and without illness. Inadequate or delayed feeding of shrimp might affect their mean harvested weight and, by extension, the total biomass collected [8].

The type of live feed used at different stages of the shrimp's life cycle is crucial for appropriate growth, survival, and nutrition. Live feed organisms have several benefits that make them preferable to artificial feeds in aquaculture. It is usual to employ *Artemia* nauplii, fairy shrimps, rotifers, cladocerans, copepods, and other live feeds. Although *Artemia* sp. has long been the most common live feed organism worldwide, because of its expensive cost and restricted availability, other potential alternatives, such as cladocerans, have long been explored. Cladocerans are a notable class of planktonic crustaceans since they are among the most common primary consumers group found in water bodies ranging from freshwater to marine with wide tolerance to wide salinity [9]. According to research, alternative live feed species such as cladocerans have superior nutritional levels, better economic values, more availability, and a higher reproduction rate than *Artemia* nauplii. Cladocerans such as *Moina macrocopa* have been employed as larval nutrition all over the world due to their rapid population growth, range of sizes from neonates to adults, and high protein content (70%) among other factors [10, 11]. Thus, the cladocerans are an excellent choice for a live feed to be cultured, and it has been claimed that they can partially replace the more expensive *Artemia* sp. and other seasonal zooplankton, like copepods, in larviculture [11, 12, 13]. Culture and cultivation of cladocerans species can thus be an economically viable, sustainable, and desirable activity in terms of live feed supply in commercial aquaculture. As a result, greater emphasis should be made on creating a superior mass culture and live feed cultivation techniques for the benefit of aquaculture worldwide.

This study aims to gather data on low-cost live feed for the marine shrimp in aquaculture industry and how the industry was affected during COVID-19.

2. Material and Method

2.1. Study Area

The study area was Kembang Subur (KS) Sdn. Bhd. at KS Pekan and KS Badong, Pahang, Malaysia. Kembang Subur Sdn. Bhd. operates shrimp hatcheries in Malaysia and Vietnam. Its principal activities involve the business of marine shrimp hatchery operation for the production and sale of specific pathogen free (SPF) nauplii and post larvae, as well as shrimp grow-out farming.

2.2. Survey

A questionnaire was used to collect data, and it was designed to be filled out using the online form, from August 2020 until December 2020 during the COVID-19 term in Malaysia; the software used was a Google application (Google Form). The questionnaire link was distributed via social media channels such as WhatsApp and e-mail. The questionnaire was distributed in both English and Malay languages. Twenty respondents from Kembang Subur Sdn. Bhd. hatchery at KS Pekan and KS Badong, Pahang, Malaysia, were selected to answer questions in four sections: Section A (personal information), Section B (live feed), Section C (use of live feed and its effect), and Section D (impact of COVID-19 on aquaculture) (Figure 1). All of the twenty staff from Kembang Subur Sdn. Bhd. hatchery at KS Pekan and KS Badong were selected to conduct this descriptive analysis.

2.3. Data Collection and Analysis

The survey is completely anonymous, and it is carried out based on the flowchart in Figure 1. There were numeric and narrative facts in some of the data. The data was then coded, summarised, processed, tabulated using simple statistical methods such as averages and percentages, and analysed using Microsoft Excel, as well as Statistical Package (SPSS) for Windows version 20.0.

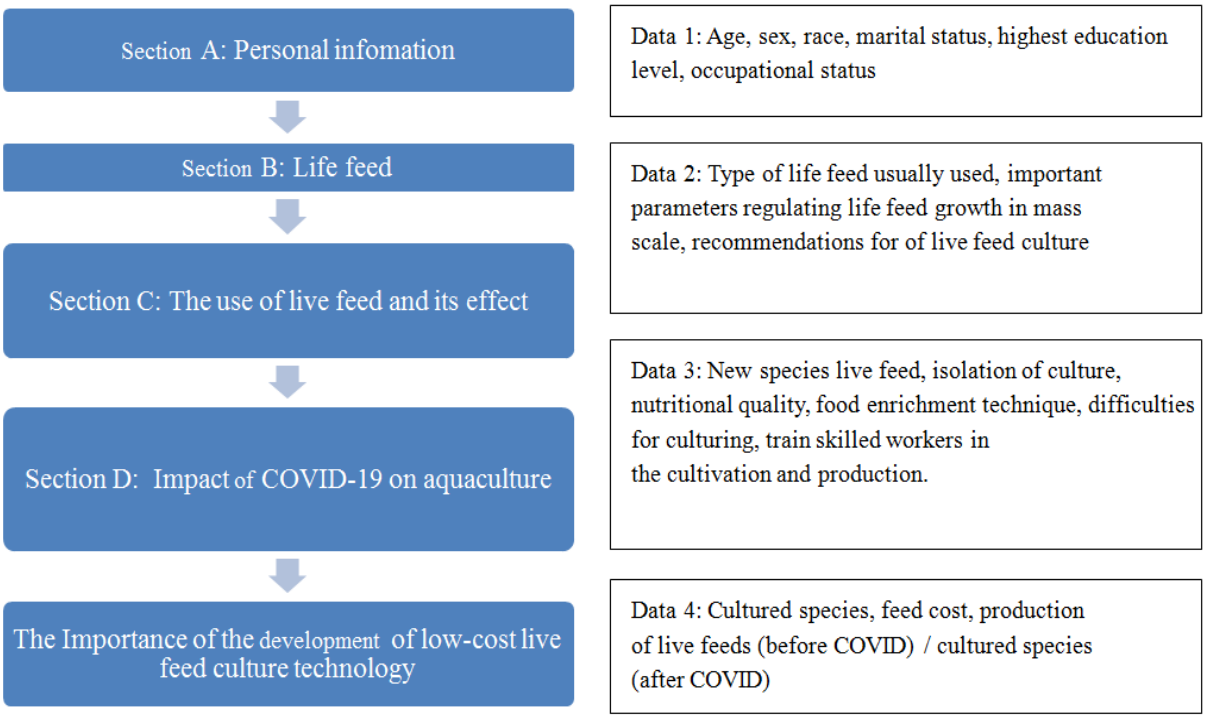

Figure 1. Flowchart of the study

3. Result

3.1. Demography of Respondents

A total of 20 responses were captured (Table 1). The results on the demographic status showed that most respondents were in the range of age from 20 to 29 years old. Age range among staff in the company may depend on the job scope and also the different department in both farms. Respondents were mostly male (70%) and Malay (95%). 14 respondents equal to 70% were still unmarried or single. More than half of the respondents had completed their university bachelor's degree (55%). The percentage of respondents is based on the occupational status in the hatchery. Most respondents were breeders in the hatchery (60%, 12 respondents), followed by sellers, lab technicians and lab assistants (15%, 3 respondents each) and students (interns) (10%, 2 respondents).

Table 1. Respondent's demography data

Age	Sex	Race	Marital_status	Education	Occupational
20 - 29	Female	Malay	Married	Master degree	Intern student
30 - 39	Male	Malay	Married	Bachelor degree	Breeder
30 - 39	Male	Malay	Single	Bachelor degree	Breeder
30 - 39	Male	Indian	Married	Bachelor degree	Breeder
20 - 29	Male	Malay	Single	Bachelor degree	Breeder
20 - 29	Male	Malay	Single	Bachelor degree	Seller
30-39	Male	Malay	Married	Bachelor degree	Breeder
20 - 29	Male	Malay	Single	Secondary school	Seller
20 - 29	Male	Malay	Single	Secondary school	Breeder
20 - 29	Male	Malay	Single	Secondary school	Breeder
20 - 29	Female	Malay	Single	Bachelor degree	Lab technician
20 - 29	Male	Malay	Single	Bachelor degree	Breeder
20 - 29	Female	Malay	Single	Bachelor degree	Lab technician
40 - 49	Male	Malay	Single	Secondary school	Breeder
20 - 29	Male	Malay	Single	Secondary school	Breeder
20 - 29	Female	Malay	Single	Bachelor degree	Lab assistant
20 - 29	Male	Malay	Single	Bachelor degree	Breeder
20 - 29	Male	Malay	Married	College degree	Seller
20 - 29	Female	Malay	Married	Bachelor degree	Breeder
20 - 29	Female	Malay	Single	Bachelor degree	Intern student

3.2. Commonly Used Live Feed

Based on Figure 2, the percentage of responses for commonly used live feed by hatchery staff is the use of zooplankton, *Artemia* sp. (20 respondents; 50%) and followed by the use of phytoplankton, which is microalgae from the genus of *Chaetoceros* sp. (35%), *Skeletonema* sp. (7%), *Chlorella* sp. (5%) and *Thalassiosira* sp. (3%).

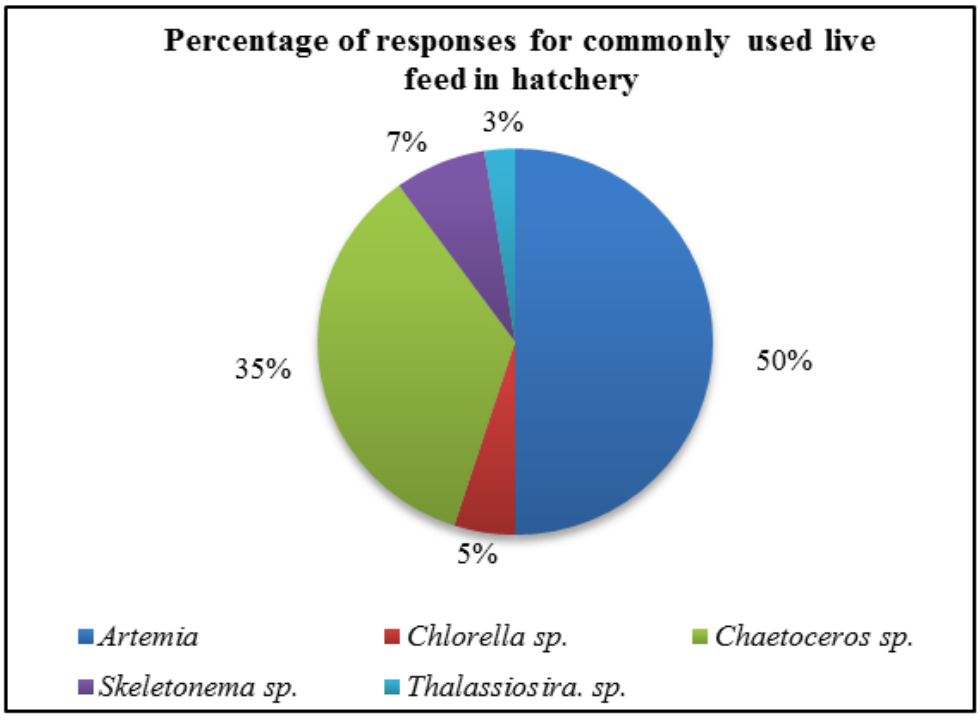

Figure 2. Percentage of responses for commonly used live feed in the hatchery

3.3. Important Parameters Regulating Zooplankton and Microalgae Growth

The most responded answer on important parameters that regulated the zooplankton growth population cultured in the hatchery was 'seed quality' (Figure 3) chosen by 13 respondents (65%). The least stated parameters were 'light' and 'salinity' chosen by one respondent (5%) each.

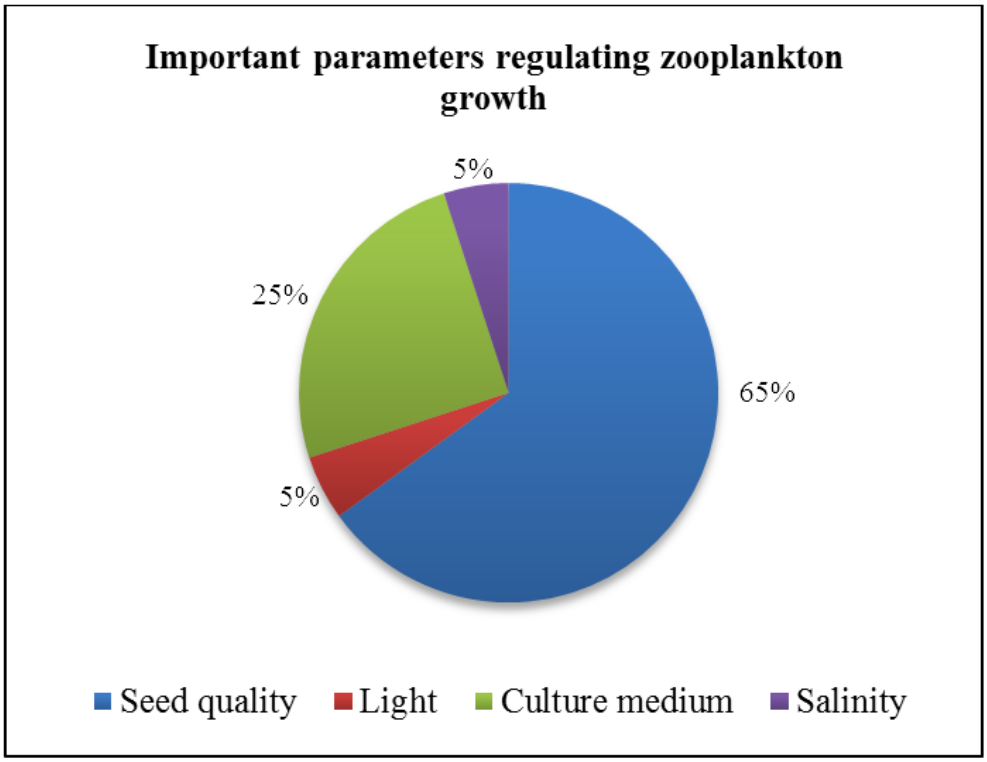

Figure 3. Percentage of responses on the important parameters regulating zooplankton growth

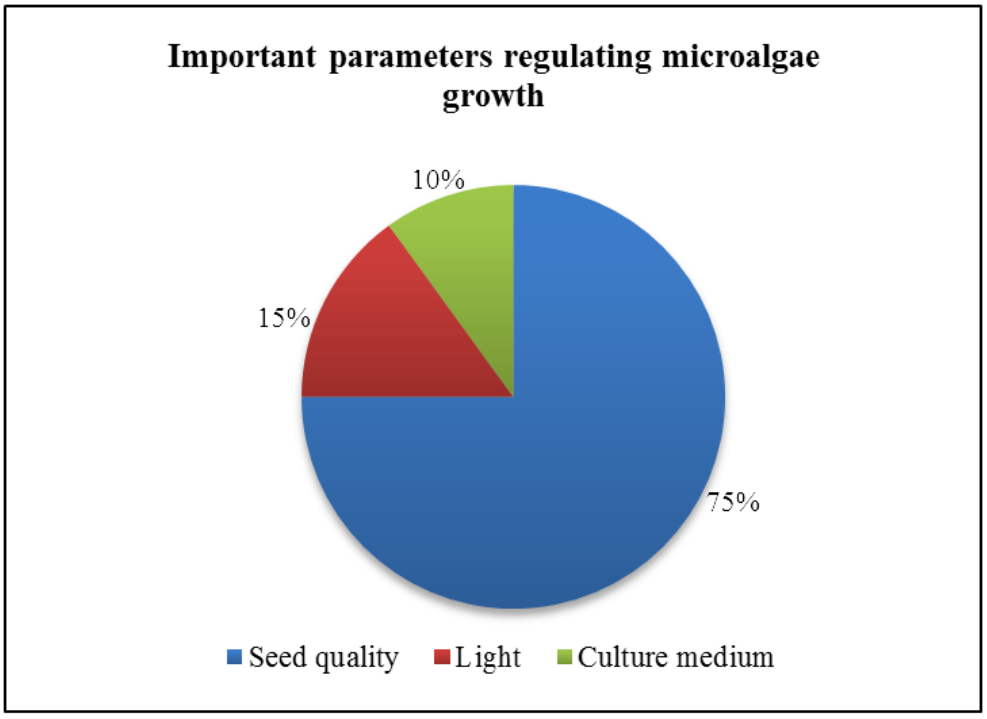

Figure 4. Percentage of responses on the important parameters regulating microalgae growth

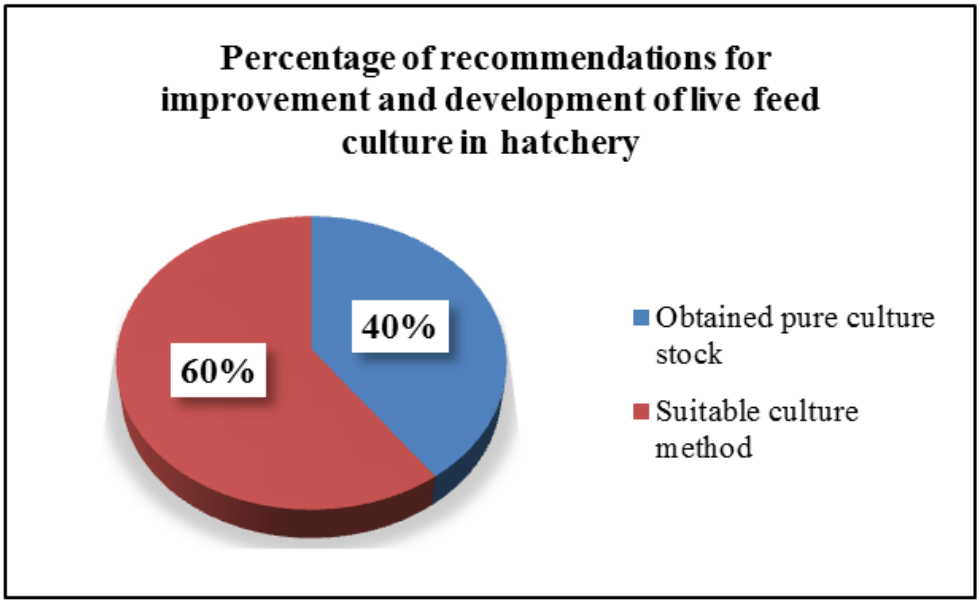

Figure 5. Percentage of responses on the recommendations for improvement and development of live feed culture in the hatchery

Apart from that, the most important parameter that regulated the growth of microalgae culture in the hatchery was also 'seed quality' (75%; Figure 4). The choosing of seed quality for pure stock culture of microalgae is very important to ensure the sustainability of microalgae production in the hatchery. While, the least important parameters for the growth of microalgae that were chosen are light (15%) and medium culture (10%) when only 3 and 2 people had responded to the answer respectively.

3.4. Recommendations for Improvement and Development of Live Feed Culture in Hatchery

The highest recommendation answered by respondents is 'suitable culture method' (12 respondents; 60%). The other option 'to obtain pure stock culture' for the improvement and development of live feed culture in the hatchery was chosen by eight respondents (40%) (Figure 5).

3.5. The Impact of Using Low-Cost Live Feed in Hatchery

In Section C of the questionnaire, seventeen questions were asked to identify the effect of using the low-cost live feed in the hatchery. Respondents were asked to express their answer using a 5-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = not sure, 4 = agree and 5 = strongly agree). The mean score, standard deviation, frequency and percentage of respondents' responses are shown in Table 2. Based on the descriptive data in Table 2, respondents have generally positive responses to all of the questions (mean = 4.40, SD = 0.60).

Table 2. Respondents' frequency and percentage of mostly chosen agree level on the questions of Section C: The use of live feed and its effect

Respondents' Knowledge of the Use of Live Feed and Its Effect	**Most responses (1 – 5; Strongly disagree – Strongly agree)**	**Mean ± SD**	**Frequency**	**Percentage (%)**
Does the introduction of new species of live feed can give a beneficial impact on your hatchery?	5	4.45 ± 0.61	10	50
Does the isolation of culture is a normal practice?	4	4.15 ± 0.59	13	65
Does produce live feed individually are economically beneficial in your hatchery?	5	4.50 ± 0.61	11	55
Does the nutritional quality of live feed adequate for good growth and survival of the target species?	5	4.50 ± 0.61	11	55
Does the live feed you produce is sufficient for the yield of your cultured animal?	4 and 5	4.35 ± 0.67	9	45
Advances in live food enrichment technique help to boost the importance and potential of a live food organism in the rearing of aquatic larvae species.	5	4.60 ± 0.60	13	65
Food nutrition is very important for the development of fish larvae and crustaceans.	5	4.75 ± 0.44	15	75
Providing appropriate live food at the proper time plays a major role in achieving maximum growth and survival of the young ones of finfish and shellfish.	5	4.60 ± 0.50	12	60
What is the range of difficulties for culturing live feed in hatcheries?	4	3.75 ± 1.02	8	40
The relationship between industry and IPTA can further improve learning outcomes in IPTA by applying the conditions of the aquaculture industry in Malaysia in the learning system.	5	4.55 ± 0.51	11	55
Train skilled workers in the cultivation and production of live food in larvae-rearing hatcheries.	5	4.50 ± 0.61	11	55
The goal of this collaboration has been to meet the needs of the industry to increase and enhance sustainable live food production.	5	4.55 ± 0.51	11	55
All of the hatcheries' workers successfully achieved live feed culture technique skills.	4	4.25 ± 0.64	11	55
The industry has learned new cultural techniques and understands the importance of using the new live feed to fully or partially substitute conventional live feed (*Artemia*).	5	4.40 ± 0.68	10	50
Can the introduction of new live feed species by university researcher help farmers and aquaculture industry practice?	4	4.30 ± 0.57	12	60
Does the survival and growth of cultured animal increase after using self-culture live feed as a food supplement?	4	4.45 ± 0.51	11	55
Can research data on live feed nutrition that potentially can be cultured and produced by the researcher encourage you to use it at the hatchery?	4	4.25 ± 0.55	13	65
Overall		4.41 ± 0.60		

*Numbers 4, and 5 indicated the scale of agreement with the statement provided.

3.6. Impact of COVID-19 On Industry (Before and After the Pandemic)

3.6.1. Cultured Species

The percentage of cultured species was not significantly impacted by the COVID-19 pandemic. Kembang Subur hatchery has increased and decreased the production of cultured species before and after Movement Control Order (MCO). According to Figure 6, the production of crustacean increased from before COVID-19 to after COVID-19 (90% to 95%). While, for the production of fish, the production decreased by half from 10% to 5% before COVID-19 and after COVID-19 respectively.

3.6.2. Production

On the other hand, the percentage of production costs before and after the COVID-19 pandemic have different results (Figure 7). The production cost of less than RM10k decreased by 5% from before COVID-19 to after COVID-19 (35% to 30%), while the production cost of higher than RM50k until RM80k was increased by 5% from 5% before COVID-19 to 10% after COVID-19. This increase might be because of limitations that occurred during MCO. The industry needed to buy a lot of artificial live food to ensure no difficulties during MCO. The production cost from RM10k to RM50kremained unchanged before and after COVID-19.

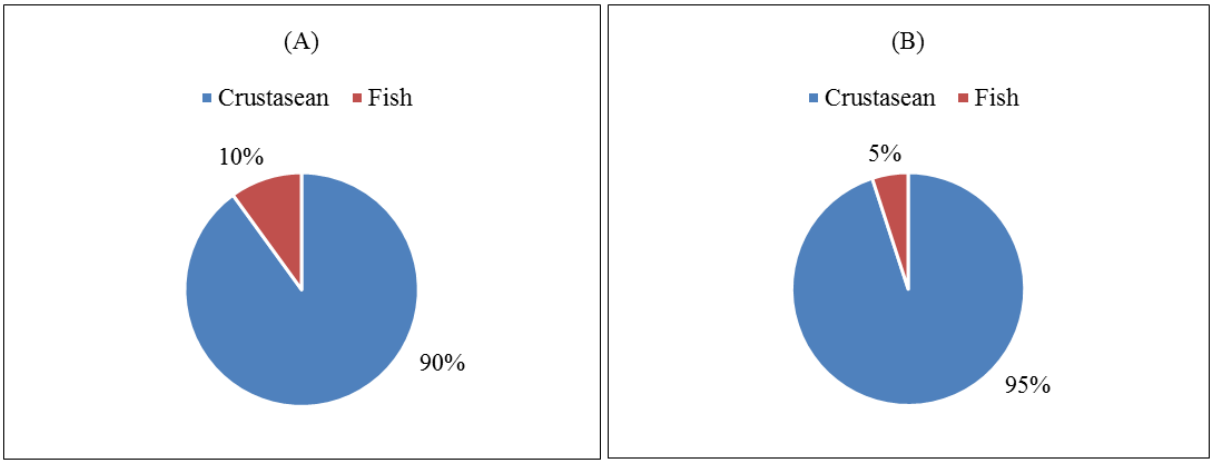

Figure 6. Percentage of cultured species before COVID-19 (A) and after COVID-19 (B)

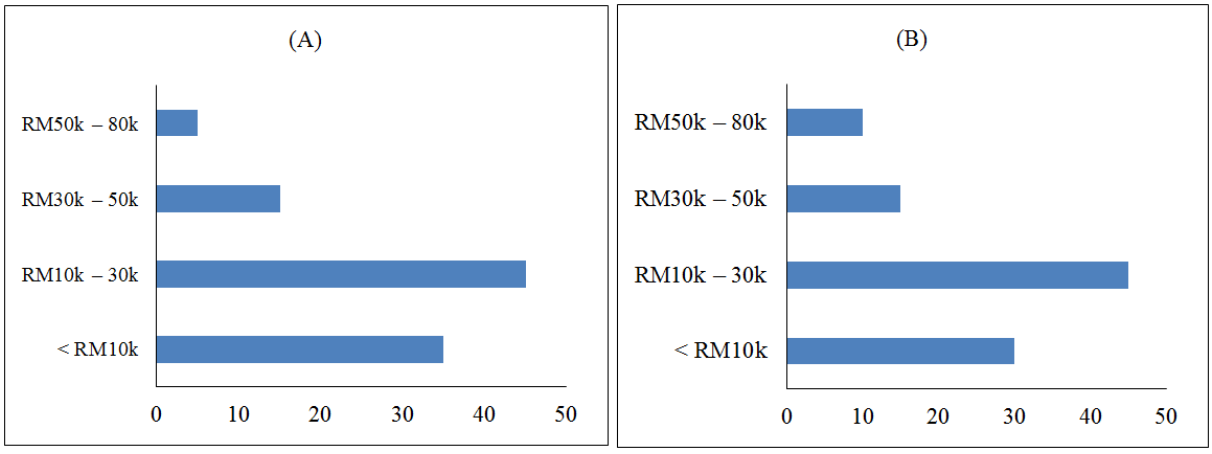

Figure 7. Percentage of production cost before COVID-19 (A) and after COVID-19 (B)

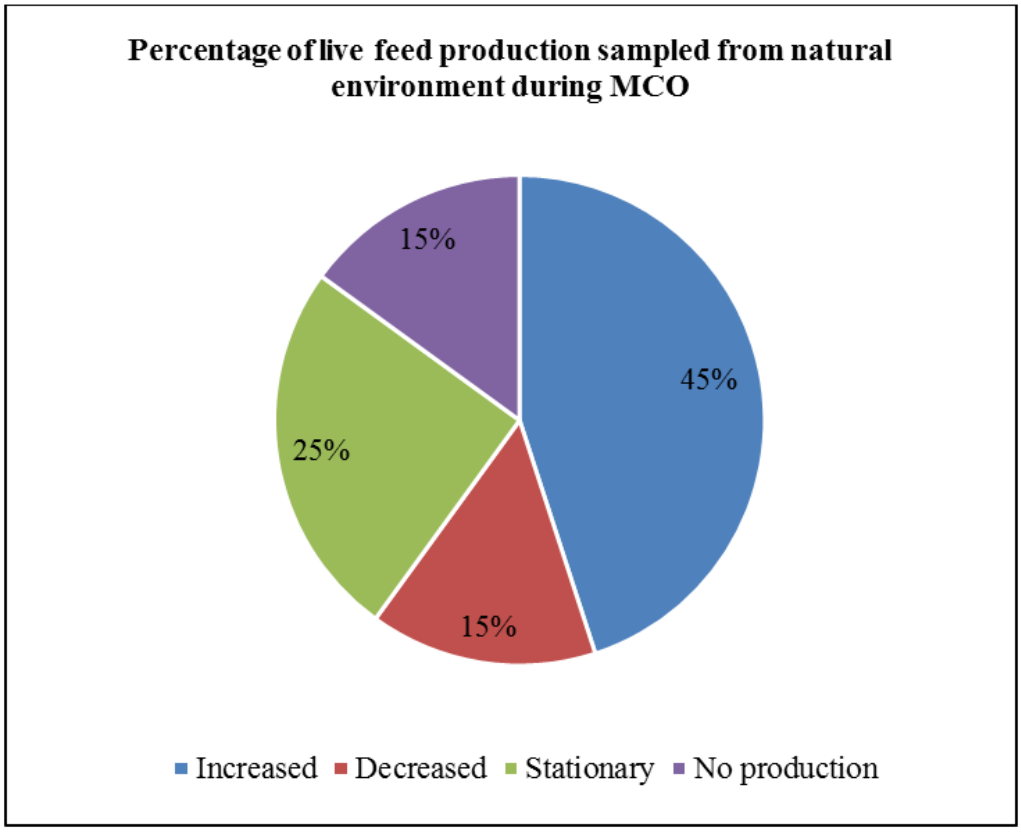

Figure 8. Percentage of live feed production sampled from the natural environment during MCO

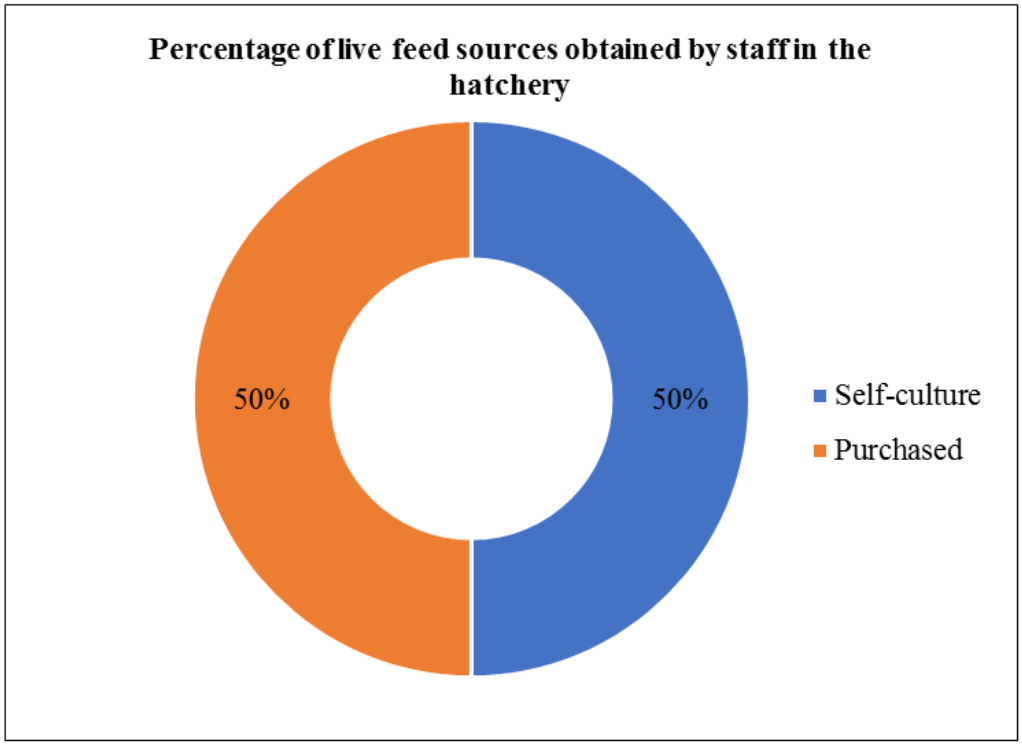

Figure 9. Percentage of live feed sources obtained by staff in the hatchery

During MCO, the percentage of sampled live feed increased up to 45% compared to decreased (15%), no production (15%) and stationary (25%) (Figure 8). These results show that there is a relationship between the staff

duties and department with the production of species that can be sampled. Laboratory staff chose no production as they could not have any microalgae pure stock culture to maintain microalgae growth in their lab.

3.7. Sources of Live Feed during COVID-19 Pandemic

Based on Figure 9, the percentage of live feed sources obtained from self-culture and purchased shows a comparable result when half of the respondents responded to 'self-culture' (50%) and the other half chose 'to purchase' (50%).

4. Discussion

In the aquaculture sector, live food culturing is vital as the primary food for fish and crustacean seed farming. The problems with the feed, particularly the high price and nutritional level, are factors in the decline of shrimp farming [2]. Understanding the effect of feed on the efficiency of shrimp and prawn rearing is critical. Thus, Universiti Malaysia Terengganu (UMT) and Kembang Subur Sdn. Bhd. worked together to effectively introduce low-cost live food species that could be cultivated in hatcheries. The development and survival of cultured animals can be implemented by improving and manipulating live food nutrition. According to the current study, the global pandemic of COVID-19 had a negative influence on shrimp production and supply [14]. Department Statistics, Malaysia 2022, stated that the production of crustacean and molls decline until 2018 and slightly increased (19.9%) in 2019 compared to 2018. However, it tends to decrease during the COVID-19 pandemic [15].

COVID-19 is a health concern, but if appropriate actions are not implemented, it might also pose a threat to food security. Previous pandemics have demonstrated that quarantines and fear not only harm human activities and the economy but also damage aquatic food systems and all types of agricultural operations [6]. In addition to the high cost of commercial feeds, which fluctuates over time, the production of shrimp is hampered by the aforementioned issue [16]. However, via cooperation between UMT and Kembang Subur Sdn. Bhd., the usage of cladoceran has aided the shrimp industry in supplying a sustainable feed for the raising of shrimp larvae by substituting 50% of purchased live feed with self-cultivation. The selection of zooplankton as live feed for larvae is complemented by important considerations such as availability, nutritional requirements of fish and shellfish larval and size of feed that suits the mouth gape [17]. Cladocerans constitute over 620 different species and generally fall in the size ranges of 0.2–18 mm [18]. *Daphnia magna* (small, 1.4 mm), (medium, 2.5 mm), and (large, 3.1 mm), *Daphnia pulex* (2–3 mm), and *Ceriodaphnia dubia* (<1.4 mm) [19, 20]. While, the average length of shrimp larvae size was 0.65 mm, and the body length of the females reached 2.37 mm at maturity [21].

According to the survey data, COVID-19 had no effect on shrimp output at the Kembang Subur hatchery; nonetheless, production grew by just 5 % from before COVID-19 to after COVID-19. However, the output of fish as a side culture species in the hatchery decreased by around 5 % during the pandemic. Previously, live feed organisms such as *Artemia* sp. (brine shrimps) were preferred for rearing fish larvae, but the use of other live feed species such as cladocerans has been underexplored despite their various advantages [22]. Based on Figure 2, the most used live feed by hatchery staff was *Artemia* sp. (50%) followed by phytoplankton, which is microalgae from the genus of *Chaetoceros* sp. (35%), *Skeletonema* sp. (7%), *Chlorella* sp. (5%) and *Thalassiosira* sp. (3%). In industrial larviculture, feeding of penaeid shrimp begins with live microalgae, and brine shrimp supplementation often starts at the mysis stage. According to de Moraes [23], microalgae used in shrimp larviculture belong to the genera *Chaetoceros*, *Tetraselmis*, *Isochrysis*, *Pavlova*, *Phaeodactylum*, *Dunaliella*, *Skeletonema*, and *Conticribra* (*Thalassiosira*). Microalgae species such as *Chlorella* sp. may be used as a natural food for freshwater zooplankton such as cladocerans. Zooplankton enriched with *Chlorella* sp. can be used as food for fish, shrimp, and shellfish, which can considerably increase the growth and development index of cultured animals [24]. The most common recommendation for sustained feed production that was answered by respondents was 'suitable culture technique' (60%) compared to 'pure stock culture' (40%) for the enhancement and development of live feed culture in hatcheries. Live feed culture methods in the hatchery can be improved and developed through the use of a suitable culture method [25]. Further advancements in enrichment technology and bio-encapsulated diet formulation are likely to lead to a gradual substitution of live feeds for alternative sources in the future. Supplying healthy and cost-effective postlarvae is critical to the success of the shrimp industry. Alternative live feeds are gaining popularity due to the high expense of *Artemia* in larval production [26].

COVID-19 has substantial challenges, including production, product demand, culturing techniques, parameters, and pure seed supply. Employee-related issues, on the other hand, were found to be less common. The largest problem for the Malaysian aquaculture industry is a drop in sales owing to the pandemic. According to Dao [27], the pandemic appeared to have an impact on the supply chain, lowering fish imports and distribution, as well as aquaculture product supply and distribution [27]. Domestic demand for luxury seafood had decreased, and markets for Vietnamese shrimp and other aquaculture products had collapsed. The implementation of the Movement Control Order (MCO) had a significant impact on domestic demand for fish and

seafood as a result of food service closures, a halt in tourism, and a shift in consumer spending patterns.

COVID-19 is expected to reduce household wages by 12% for more than 2.4 million Malaysians [28]. Stanciu and Mihăilescu [29] found that as household income falls, so does purchase power [28]. A study by Kongmanee and Ahmed [3] found that, during COVID-19, 93.6% of farmers had decreasing incomes, 47.7% had adequate household incomes, and 38.5% had an economic dependency, such as borrowing money from the system. Seafood products, which are generally more expensive than poultry and beef meat, would no longer be deemed requirements and might be skipped in favour of the less expensive protein option. As a result of the epidemic, global demand for marine products fell. China is the world's third-largest seafood importer [28]. As China implemented a state-wide lockdown, international fish trade between China and other seafood-supplying countries, notably Malaysia, has declined [30]. Due to the termination of seafood export contracts and selective purchases from importing countries, Malaysia's seafood export business experienced uncertainty, as did that of most other countries. Malaysia's aquaculture sector has already begun to experience the effects of declining worldwide seafood demand, with seafood exports from Malaysia to Singapore down by 50% by mid-February 2020 [31].

5. Conclusions

COVID-19 had a direct impact on sales, which altered aquaculture demand in Malaysia. Shrimp aquaculture has a wide range of environmental and social benefits. The shrimp industry has been marketed as a viable alternative to fisheries production, providing rural residents with a variety of job options. Relationship and cooperation between universities and industry is very crucial to sustain better food production in aquaculture sectors. Knowledge transfer of new culture protocols and feed technology to hatcheries staff in industries can help industries improve and develop their production, especially in marine shrimp production. The collaborations between Universiti Malaysia Terengganu and Kembang Subur Sdn Bhd on the use of low-cost live feed technology has developed new ideas and potential for the industry to explore new feed that can sustain their farming operations and reduced the cost of relying on highly cost imported *Artemia* cyst, especially during COVID-19 pandemic. Therefore, future development and collaborations of researchers and industry still need to ensure sustainable production of food sources such as fish and crustaceans' production in order to fulfil human demand around the world. Cladocerans have the potential to be an effective live feed in aquaculture and can be enhanced nutritionally using low-cost enrichment techniques. In both marine and freshwater larval rearing, the characteristics of live feeding are crucial. Therefore, nutrition for the larval rearing stage must be increased, and better nutritional sources must be used, in order to boost growth productivity and bring new livestock species into the aquaculture industry. In addition, the natural eating patterns of fish necessitate protein-rich, living food for enhanced growth, reproduction, and survival. Common enrichment techniques, such as oil emulsion, are often expensive, which raises hatcheries' overall production costs. The issues have prompted scientists to focus their efforts on the development of low-cost live feed substitutes to assure the success of larval feeding in aquaculture. The performance of larval feed is directly impacted by improvements in low-cost live feed technologies for enhanced zooplankton and phytoplankton production. The increased need for seafood as a source of protein for human consumption necessitates advancements in the development of aquaculture technology, with a focus on enhancing the availability of live food organisms to aid in the larval growth process.

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REFERENCES

[1] Tidwell, J.H. & Bright, L. A. (2018). Freshwater Aquaculture, Encyclopedia of Ecology, pp. 91–96.

[2] Aizam, N. A. H., Abdullah, M. I., Jaafar, S. N. A., Abd Razak, M. R., Mashkor, M. I., & Mubarak, A. (2021). Effect of Training Intervention on Knowledge and Attitude towards Giant Freshwater Prawn Rearing among Students of Rehabilitation Institute in Malaysia. Agricultural Research, 9(4), 111-118. DOI: 10.13189/ujar.2021.090402.

[3] Kongmanee, C., & Ahmed, F. (2021). COVID-19 Impacts on Rubber Farmers in Thailand: A Study of Behavioral Change and Livelihoods. Universal Journal of Agricultural Research, 277-288. DOI: 10.13189/ujar.2021.090606.

[4] Bashar, A., Heal, R. D., Hasan, N. A., and Haque, M. M. (2021). Effect of COVID-19 on shrimp aquaculture in Bangladesh. Available at SSRN 3867896.

[5] Mandal, S., Barnett, J., Brill, S. E., Brown, J. S., Denneny, E. K., Hare, S. S., Heightman, M., Hillman, T. E., Jacob, J., and Jarvis, H. C. (2021). 'Long-COVID': A cross-sectional study of persisting symptoms, biomarker and imaging abnormalities following hospitalisation for COVID-19. Thorax, 76(4), 396-398.

[6] Sunny, A. R., Sazzad, S. A., Prodhan, S. H.,

Ashrafuzzaman, M., Datta, G. C., Sarker, A. K., Rahman, M., and Mithun, M. H. (2021). Assessing impacts of COVID-19 on aquatic food system and small-scale fisheries in Bangladesh. Marine Policy, 126, 104422.

[7] Jhajhria, A., Kandpal, A., Balaji, S., Jumrani, J., Kingsly, I., and Kiran Kumar, N. V. (2020). COVID-19 lockdown and Indian agriculture: Options to reduce the impact. Delhi: ICAR-National Institute of Agricultural Economics and Policy Research.

[8] Kakoolaki, S., Ebne al-Torab, S., Ghajari, A., Anvar, A., Sepahdari, A., Ahari, H., and Hoseinzadeh, H. (2020). Socio-economic impacts of Coronavirus (COVID-19) outbreak on world shrimp aquaculture sector. Iranian Journal of Aquatic Animal Health, 6(1), 1-18.

[9] Yuslan, A., Najuwa, S., Hagiwara, A., Ghaffar, M. A., Suhaimi, H., & Rasdi, N. W. (2021). Production performance of *Moina macrocopa* (Straus 1820) (crustacea, cladocera) cultured in different salinities: the effect on growth, survival, reproduction, and fatty acid composition of the neonates. Diversity, 13(3), 105.

[10] Kandathil Radhakrishnan, D., AkbarAli, I., Schmidt, B. V., John, E. M., Sivanpillai, S., & Thazhakot Vasunambesan, S. (2020). Improvement of nutritional quality of live feed for aquaculture: An overview. Aquaculture Research, 51(1), 1-17.

[11] Suhaimi, H., Yuslan, A., Azani, N., Habib, A., Liew, H. J., & Rasdi, N. W. (2022). Effect of dietary enhanced *Moina macrocopa* (Straus, 1820) on the growth, survival and nutritional profiles of hybrid Nile tilapia fry. The Egyptian Journal of Aquatic Research, 48(1), 67-73.

[12] Islam, M. R., Hassan, M. R., Begum, M., Punom, N. J., Begum, M. K., Sultana, N., & Rahman, M. S. (2017). Effects of feeding zooplankton, *Moina macrocopa* (Straus, 1820) on the growth of Nile tilapia *Oreochromis niloticus* L. Bangladesh Journal of Scientific and Industrial Research, 52(2), 81-88.

[13] Kamrunnahar, K., Md, A., Jeong, U. C., & Kang, S. J. (2019). Mass culture of *Moina macrocopa* using organic waste and its feeding effects on the performance of *Pagrus major* larvae. The Egyptian Journal of Aquatic Research, 45(1), 75-80.

[14] Kumaran, M., Geetha, R., Antony, J., Vasagam, K. K., Anand, P., Ravisankar, T., Angel, J. R. J., De, D., Muralidhar, M., and Patil, P. K. (2021). Prospective impact of Corona virus disease (COVID-19) related lockdown on shrimp aquaculture sector in India – a sectoral assessment. Aquaculture, 531, 735922.

[15] Jabatan Perangkaan Malaysia (2022, August 5). Production of Crustacean & Molluscs (Brackishwater Aquaculture), Malaysia. Retrieved from, https://www.data.gov.my/data/ms_MY/dataset/production-of-crustacean-molluscs-brackishwater-aquaculture-malaysia

[16] Rasdi, W. N. N. W., Abdullah, M. I., Azman, Syamimi, Karim, Murni, Syukri, Fadhil, & Hagiwara, Atsushi (2021). The effects of enriched *Moina* on the growth, survival, and proximate analysis of marine shrimp (*Penaeus monodon*). Journal of Sustainability Science and Management, 16(3), 56-70.

[17] Jeffs, A., & O'Rorke, R. (2020). Feeding and nutrition of Crustacean larvae. The natural history of the Crustacea: Developmental biology and larval ecology, 7, 309.

[18] Karuthapandi, M., & Rao, D. V. (2016). Cladoceran diversity, distribution and ecological significance. In Arthropod Diversity and Conservation in the Tropics and Sub-tropics (pp. 183-196). Springer, Singapore.

[19] Lennuk, L., Kotta, J., Taits, K., & Teeveer, K. (2015). The short-term effects of crude oil on the survival of different size-classes of cladoceran *Daphnia magna* (Straus, 1820). Oceanologia, 57(1), 71-77.

[20] Jaikumar, G., Brun, N. R., Vijver, M. G., & Bosker, T. (2019). Reproductive toxicity of primary and secondary microplastics to three cladocerans during chronic exposure. Environmental Pollution, 249, 638-646.

[21] Ismailovna, T. G. Cladocera Cultivation in Different Ways in the Laboratory. International Journal on Integrated Education, 4(2), 125-129.

[22] Chakraborty, S., and Mallick, P. H. (2022). Cladocera as a substitute for *Artemia* as live feed in aquaculture practices: a review. Sustainability, Agri, Food and Environmental Research, 11(1).

[23] de Moraes, L. B. S., Santos, R. F. B., Gonçalves Junior, G. F., Mota, G. C. P., Dantas, D. M. D. M., de Souza Bezerra, R., & Olivera Gálvez, A. (2022). Microalgae for feeding of penaeid shrimp larvae: an overview. Aquaculture International, 1-19.

[24] Morris, H. J., Carrillo, O., Almarales, A., Bermúdez, R. C., Lebeque, Y., Fontaine, R., Llauradó, G. & Beltrán, Y. (2007). Immunostimulant activity of an enzymatic protein hydrolysate from green microalga *Chlorella vulgaris* on undernourished mice. Enzyme and Microbial Technology, 40(3), 456-460.

[25] Kandathil Radhakrishnan, D., AkbarAli, I., Schmidt, B. V., John, E. M., Sivanpillai, S., and Thazhakot Vasunambesan, S. (2020). Improvement of nutritional quality of live feed for aquaculture: An overview. Aquaculture Research, 51(1), 1-17.

[26] Paz, P. E., López-Cabús, A. J., Cárdenas-Nieto, L. X., and Pejuán, W. (2020). Replacement of *Artemia* spp. with zooplankton in *Penaeus vannamei* larviculture. Latin American Journal of Aquatic Research, 48(4), 700-704.

[27] Dao, T. (2020). Coronavirus outbreak to hit Vietnam's pangasius, shrimp exports in short-term. Seafood Source, I Portland, USA: Diversified Communication, 3.

[28] Waiho, K., Fazhan, H., Ishak, S. D., Kasan, N. A., Liew, H. J., Norainy, M. H., and Ikhwanuddin, M. (2020). Potential impacts of COVID-19 on the aquaculture sector of Malaysia and its coping strategies. Aquaculture Reports, 18, 100450.

[29] Stanciu, M., and Mihăilescu, A. (2014). Purchasing power of the low income population from Romania during the crisis. Procedia Economics and Finance, 8, 466-473.

[30] Haddad, F. S. (2020). The year of COVID-19. The Bone & Joint Journal, 102(12), 1597-1598.

[31] Aruno, C., Lai, A., Timbuong, J., and Aravinthan, R. (2020). Seafood export to Singapore down by half. The Star Online.