A Seminar Paper on

Sustainable *Artemia* Culture: Methods and Production Perspective

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Sustainable *Artemia* Culture: Methods and Production Perspective[1]

By

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ABSTRACT

Artemia, also known as brine shrimp, is a small crustacean species that is widely used in aquaculture as a live food source for fish and shellfish larvae. However, the increasing demand for *Artemia* has put pressure on natural populations, which are declining due to overharvesting, habitat loss, and pollution. Therefore, sustainable methods of *Artemia* culture are necessary to meet the demand for this important live food source. The increasing demand for *Artemia* has led to the development of sustainable culture methods to ensure its availability without harming natural populations. This paper aims to evaluate the sustainable methods for *Artemia* culture and assess the production perspective of *Artemia* sp. The methods discussed include traditional and modern techniques, such as solar salt ponds, partial harvesting of *Artemia*, bio floc technology, culture with algae, providing a commercial diet, etc. All these methods have an impact on the yield, growth, and maturation of *Artemia* species. Overall, this paper emphasizes the importance of sustainable *Artemia* culture practices to meet the growing demand for this valuable live food source while minimizing the environmental impact of its production. The implementation of these practices will not only benefit the aquaculture industry but also promote the conservation of *Artemia* populations and their natural habitats.

Keywords: sustainable; live food; *Artemia*; crustacean; bio floc.

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CHAPTER I

INTRODUCTION

Aquaculture, also known as aquafarming is a rapidly growing industry that provides an alternative source of seafood to wild-caught fish and shellfish. There are different types of aquaculture systems, including recirculating systems, open-ocean aquaculture, integrated multi-trophic aquaculture, etc. Aquaculture is a growing industry, with an increasing demand for seafood and concerns about the sustainability of wild-caught fisheries. With proper management and responsible practices, aquaculture can provide a reliable food source while minimizing its environmental impact. Feed is a major factor contributing to the operational cost of fish farming, accounting for the production cost. Small-scale fish farmers are constrained in intensifying their aquaculture production due to the high cost of commercial feeds, which they find too expensive. Therefore, many of them are exploring alternative feeds as the rising cost of commercial feeds has become a major concern (Aya, 2017). The sustainability of aquaculture depends on several factors, including the minimum production cost with respect to the yield, the impact of unforeseen environmental conditions on the farm, and the effectiveness of management techniques employed on the farm itself. These components are all critical to maintaining a sustainable and profitable aquaculture operation. Live feeding is the primary requirement for producing larvae and fries for sustainable farming activities (Kassim *et al*., 2014). Dependence on foreign suppliers for inert or live feed will raise the price of production. Therefore, it is economically vital to continue screening, stocking, and preserving some indigenous species as a potential source of live feed. The live feed is more useful for fish in their earlier life stage. Fishes that are precocial and altricial have two different types of larvae (Mondal *et al*., 2018). Precocial larvae are those that, once their yolk sacs have been used up, resemble miniature adults with fully formed fins and an established digestive system. Such fish can eat and digest a specially-designed diet as their first food. Without a stomach, the digestive system is still quite basic. Such a digestive tract appears unable to metabolize a specially designed meal. Live feeds are continually accessible to the larvae since they may swim in the water column (Mondal *et al*., 2018). Prepared diets tend to clump together on the surface of the water or rapidly sink to the bottom, making them less accessible to the larvae compared to live feed. Zooplankton fauna is the most diverse and may be used for aquaculture practices by culturing them in the laboratory for fish larvae culture (Mondal *et al*., 2018). Zooplankton contains 25% protein, similar to artificial feed, which feeds fry and fingerlings (Gopalakrishnan, 1976). Zooplankton serves as a crucial source of nourishment for numerous species of fish and prawns, either as a temporary source of nutrition or as their primary food source throughout their lifespan. The reason behind this is because zooplankton contains a wealth of important nutrients such as protein, amino acids, lipids, fatty acids, minerals, and enzymes, making it a highly valuable source of sustenance. Live zooplankton is crucial for the nourishment of cultivable organisms like fish, rotifers, and copepods. Among the most widely accepted all over the world are rotifers, cladocerans, and brine shrimp (Carter, 2015). This zooplankton is successfully used in hatcheries due to their high nutritive value, higher yield, short generation time, capacity to grow in dense populations, and ease of production on a mass scale under controlled conditions. The larvae culture of fish and shellfish commonly uses live diets, and the nauplii of the brine shrimp *Artemia* are the most popular and widely used food source brine shrimp are also known as sea monkeys (Dhont *et al*., 2013).

Artemia culture utilizes a number of methods all throughout the world. This zooplankton can be cultured in several culture media such as sea salt solution, bio floc water, green water, microalgae, commercial culture media, etc. It's important to note that the specific formulation of the culture media can vary based on the specific needs of the culture, and factors such as temperature, salinity, and pH can also affect the success of the culture. It is used in aquaculture as a source of feed for fish and shrimp, and there are some small-scale *Artemia* farming operations in Bangladesh. There have been some research studies on *Artemia* in Bangladesh, including a study on the use of *Artemia* as a food source for larval fish in hatcheries, and a study on the potential use of *Artemia* as a source of protein for human consumption. Overall, while *Artemia* is not a major part of the aquaculture industry in Bangladesh, there is some interest in its potential as a source of feed and protein.

Based on the above facts the objectives of this reviewed paper are

- To evaluate the sustainable methods for *Artemia* culture
- To assess the production (yield, growth, maturation, etc.) perspective of *Artemia* sp.

CHAPTER II

MATERIALS AND METHODS

The scientific approach requires a close understanding of the subject matter. This paper mainly depends on secondary sources and data. Different published reports from different journals are mainly supported in providing data in this paper. This seminar paper is a review paper, meaning that all the information presented was gathered from secondary sources. The writings conducted a comprehensive study of various articles published in different journals, publications, proceedings, and dissertations available on the internet. All the information collected from secondary sources has been compiled systematically and chronologically to enrich this paper.

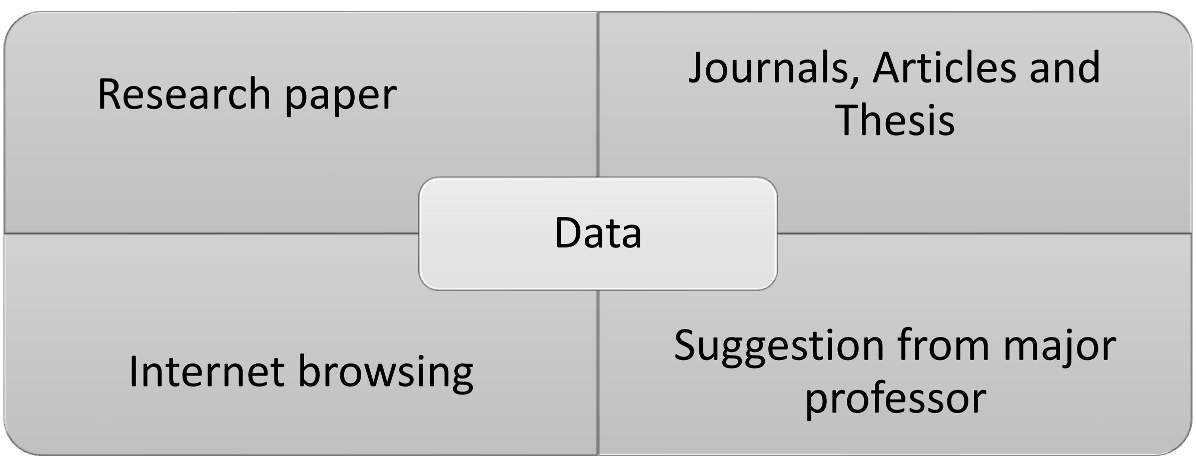

Figure 01. Sources of data and information used in the present paper.

CHAPTER III

REVIEW OF FINDINGS

Artemia culture, which is also referred to as brine shrimp culture, plays a significant role in aquaculture because *Artemia* nauplii, the larvae of brine shrimp, are a widely used food source for various aquatic animals including fish, shrimp, and crustaceans. Here is the classification of *Artemia* is:

Figure 02. A view of *Artemia* sp.

Scientific Classification:

Kingdom: Animalia

Phylum: Arthropoda

Subphylum: Crustacea

Class: Branchiopoda

Subclass: Sarsostraca

Order: Anostraca

Suborder: Artemiina

Family: Artemiidae (Grochowski, 1895)

Genus: *Artemia* (Leach), 1819

Different Methods and Production of *Artemia* Culture

3.1 The Simple Unit Method of *Artemia* Culture:

The Brine Shrimp o*r Artemia* can be cultured in concrete ponds, earthen ponds, plastic-lined ponds, tanks, etc. *Artemia* cysts can be collected from salt ponds or bought from suppliers. It is important to select good-quality cysts with high hatchability. The cysts should be hydrated and hatched in a clean, aerated container with seawater or saltwater mix, and air stones or diffusers.

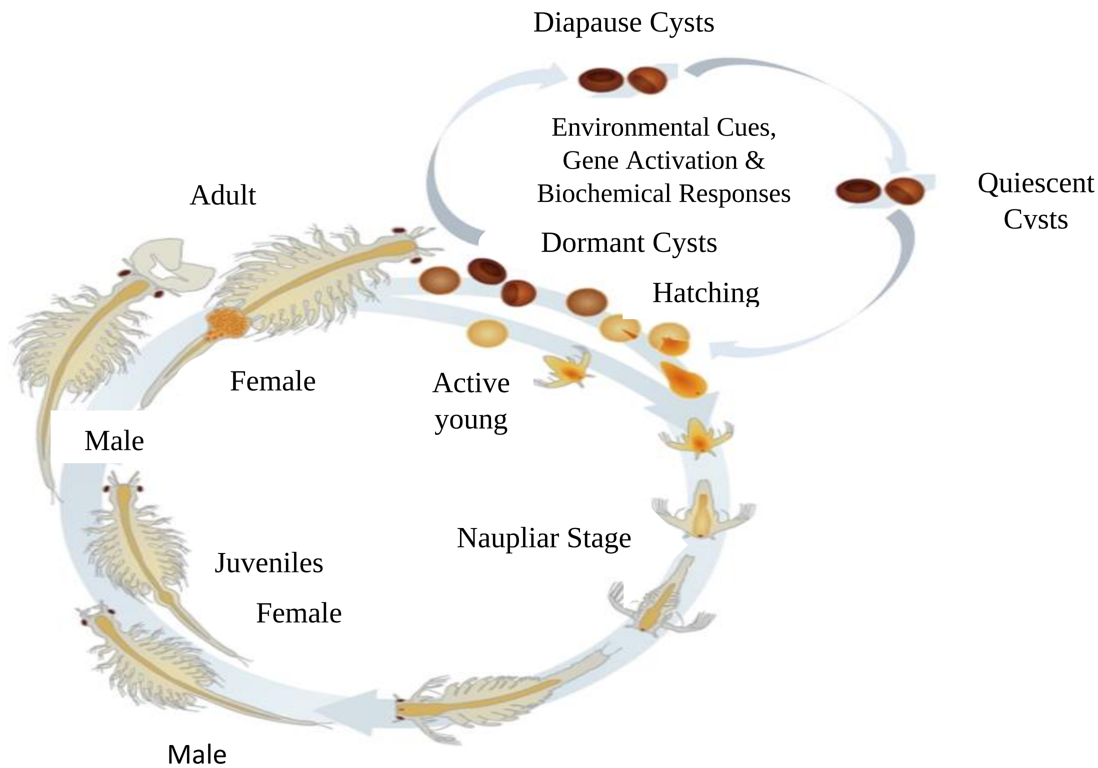

Figure 03. Embryonic development of *Artemia* (Marden *et al*., 2020)

The ideal temperature for hatching is between 25-30°C (Veeramani *et al*., 2018). After hatching, the nauplii will swim to the surface. They can be harvested using a fine mesh net or through a siphon tube. They can also be separated from the unhatched cysts by settling in a conical flask or container. The nauplii are fed with a mixture of yeast and spirulina powder. The mixture should be added in small amounts, and excess food should be removed to prevent water fouling. The culture should be regularly aerated, and the water should be changed regularly. The salinity level should be maintained between 25-35 ppt, and the pH level should be between 7.5-8.5 (Veeramani *et al*., 2018). Due to many natural calamities, the effect of salinity affects the production of *Artemia* which is described by (Toi *et al*., 2021).

Table 01. Individual length and survival of *Artemia*

Treatment	Length (mm)		Survival (%)	
	Week 1	Week 2	Week 1	Week 2
T1 (40%)	6.41 ± 0.52[a]	8.01 ± 0.91[a]	72.4 ± 10.8[a]	48.7 ± 8.5[a]
T2 (60%)	6.49 ± 0.61[a]	8.66 ± 0.39[a]	91.1 ± 6.1[ab]	61.2 ± 6.1[ab]
T3 (80%)	6.30 ± 0.52[a]	8.62 ± 0.66[a]	96.0 ± 2.9[b]	72.0 ± 3.8[b]

Source: Toi *et al*., (2021).

The reproductive capacity of *Artemia* is low when raised at a salinity of 10-50% compared to a salinity of 80%, but (Toi *et al*., 2021) showed that the reproductive capacity of *Artemia* cultured at 40 and 60% was higher than at 80%, and this may be related to the density of *Artemia* in the ponds. However, low salinity only affected *Artemia's* survival, resulting in a low cyst production, but the fecundity and growth of *Artemia* were not affected by low salinity.

Table 02. Fecundity (embryos female^{-1}) of *Artemia*

Treatment	Weekly Observation			
	Week 3	Week 4	Week 5	Week 6
T1 (40%)	178 ± 31[a]	251 ± 58 [a]	280 ± 47[b]	263 ± 41[b]
T2 (60%)	177 ± 35[a]	252 ± 51[a]	221 ± 44[a]	275 ± 50[b]
T3 (80%)	196 ± 46[a]	233 ± 33[a]	222 ± 42[a]	238 ± 46[a]

Source: Toi *et al*., (2021).

In addition, using brine water at a salinity lower than the recommended salinity for *Artemia* culture in earthen ponds can shorten the time to prepare and accumulate the saline water. The highly saline water in South-East Asia countries is obtained by evaporated seawater process over several days. It only took 12 days to prepare water at 40% and 16 days for 60%, but it took 23 days to reach a salinity of 80% (Toi *et al*., 2021). The shortened time to prepare highly saline water is one of the positive factors which make the *Artemia* farming season occur earlier in the year, due to the suitable temperatures for the *Artemia* cysts production in the early season and to the lower operating costs when time is saved during the highly saline water accumulation process.

As the nauplii grow, they can be fed with larger size foods such as microalgae or small plankton. They can be harvested when they reach the desired size for use as live feed in fish hatcheries. Some groups of scientists noted that partial harvesting of some species increases growth (Yu *et al*., 2009). It seems that a suitable approach to improve growth, reproduction, and biomass productivity in *Artemia* culture is to perform partial harvests of *Artemia* biomass every three days (Anh *et al*., 2010)

Table 03. Average *Artemia* biomass yield (mean ± SE) for the different partial harvesting intervals (kg WWha^{-1}) (Anh *et al*., 2010)

Harvesting strategies	Total biomass yield
1 day^{-1} (30 kg/ha)	1323 ± 116^{bc}
3 day^{-1} (90 kg/ha)	1587 ±128^{c}
6 day^{-1} (180 kg/ha)	1091 ±101^{ab}
9 day^{-1} (270 kg/ha)	975 ± 112^{a}

Note: Values with different letters (a-c) in a row are significantly different

3.2 *Artemia* Culture in Bio Floc:

Bio floc is a technology used in aquaculture that involves cultivating microorganisms such as bacteria, algae, and other microbes in water, which serve as a natural food source for farmed aquatic animals such as fish and shrimp. The technology is based on maintaining a high concentration of these microorganisms in the water, which can help improve water quality, reduce disease, and increase production yields. Bio floc technology is increasingly being used in aquaculture because it can improve the sustainability and profitability of fish and shrimp farming operations. By reducing the need for artificial feeds and improving water quality, bio-floc systems can help to reduce production costs and improve the health and growth of farmed animals. Yao *et al*. in 2018 noted that a significant difference was observed in terms of crude protein content (35.59% ± 0.2%) for E-flocs, 29.29% ± 0.95% for T-flocs, 70.01% ± 0.92% for E-*Artemia* and 65.63% ± 0.89% for T-*Artemia* also the survival rate of E-*Artemia* was 22% ± 0.02%, significantly higher than that of T-*Artemia* (16% ± 0.02%). Ronald *et al*. (2014) set up an experiment was conducted in the Mekong Delta, where different ratios of carbon to nitrogen (C:N) were tested by combining tapioca with a variety of organic and inorganic fertilizers.The goal was to boost *Artemia* pond production through bio-floc production. The addition of carbon to *Artemia* had a positive impact on their growth, as well as the quality of the water they were living in, and also led to an increase in the diversity of microorganisms present in the environment.

Table 04. The final content of Total Phosphorus (TP), Total Nitrogen (TN), Dissolved Organic Carbon (DOC), and survival rate of *Artemia* in the culture medium when supplementing sucrose at different C/N ratios

	Control	Su5	Su15	Su30
TP (mg/ml)	2.53 ± 0.08^{a}	2.59 ± 0.12^{a}	2.17 ± 0.23^{b}	0.62 ± 0.17^{c}
TN (mg/ml)	8.35 ± 0.22^{a}	9.02 ± 0.28^{a}	8.47 ± 2.44^{a}	5.86 ± 0.43^{b}
DOC (mg/ml)	61.75 ± 3.08^{c}	58.98 ± 0.39^{c}	84.70 ± 8.43^{b}	181.68 ± 18.87^{a}
Survival rate (%)	27.5 ± 5.2^{c}	43.3 ± 3.2^{b}	75.5 ± 2.3^{a}	56.1 ± 3.5^{b}

Source: Wang *et al*., (2019).

Bacteria play a crucial role in the nitrogen cycle in bio floc systems, where they convert ammonia to nitrite and nitrate. The nitrate is then consumed by the microbial community, which is in turn consumed by the aquatic animals, closing the nutrient loop. Bacteria can be cultured in live or dead biomass of halophilic bacteria with standard gnotobiotic *Artemia* at a salinity relevant to a field situation (100 g l^{-1}) and at seawater salinity (35 g l^{-1}) (Lopes-dos-Santos *et al*., 2019). Fatty acid β-hydroxybutyrate and its polymer poly-hydroxybutyrate were added in quantities of 100 mM to the culture water of *Artemia* nauplii that were infected with the *Vibriosis campbelli* strain which dramatically boosted the nauplii's survival rate (Defoirdt *et al*., 2007). In order to keep the microorganisms in a bio floc system healthy, it is crucial to regularly check the levels of bacteria present and to create conditions that are favorable for the growth and proliferation of beneficial bacteria. This can be achieved through regular water quality testing, proper feeding management, and maintaining a balance between the carbon and nitrogen sources in the system. The effect of bio floc and green water conditions on the survival, growth, reproductive traits, and fatty acid composition of the brine shrimp *Artemia franciscana* was noted by (Ogello *et al.*, 2022). In 30 days of the experiment, they found *Artemia* cultured in a BFT environment had higher levels of myristic acid, oleic acid, palmitic acid, linoleic acid, and arachidic acid. The use of nutritious bio floc and algal materials in BFT conditions could have improved the reproductive and nutritional characteristics of *Artemia*. BFT and CME offer a significant opportunity to create a diet that is rich in nutrients for *Artemia*. The changes in growth and survival of *Artemia franciscana* are shown below

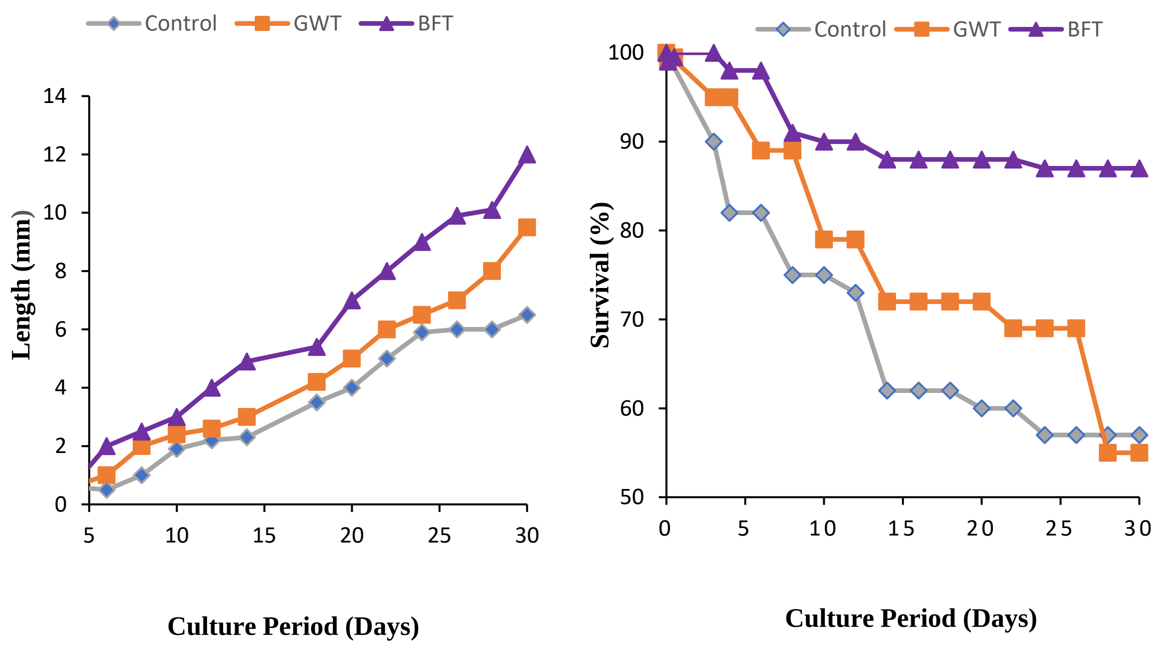

Figure 04. The proportion of length and surviving *Artemia* cultured in green water technology (GWT), bio floc technology (BFT), and Control using normal seawater for 30 days (Ogello *et al.*, 2022).

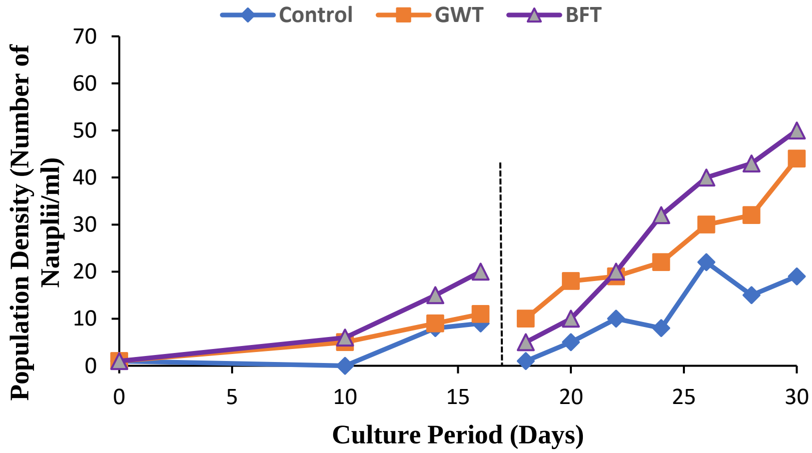

Figure 05. Population density (individuals/ml) of *Artemia* cultured in green water technology (GWT), bio floc technology (BFT), and Control using normal seawater for 30 days. Partial harvesting was done on day 17 by replacing half of the culture medium with new media as indicated by the dotted lines (Ogello *et al*., 2022).

Browne *et al*., (1984) stated that *Artemia* displays two of its reproductive patterns including oviparity (release cysts) and ovoviviparity (release nauplii), and which of these happen to depend on a lot of environmental factors such as food availability, stress, salinity, and temperature changes. Growth and reproduction of *Artemia* increased in bio floc water with several culture days (Nguyen, 2009). A week from stock, the survival was recorded in the 85% - 97.7% range and then slowed down around 7-10% more on day 14th. However, there was no statistical difference between treatment on survival at both sampling times (DAH7 and DAH14) (Hong Van & Toi, 2019).

Table 05. Reproductive traits of *Artemia* cultured using bio floc technology (BFT), green water technology (GWT), and the control treatments in normal seawater for 30 days

Reproductive traits	Control	GWT	BFT
Female pre-reproductive period (days)	22 ± 0.5^{b}	21.8 ± 0.7^{b}	15.6 ± 0.6^{a}
Female reproductive period (days)	15.8 ± 1.9^{b}	16.4 ± 2.3^{b}	20.9 ± 2.6^{a}
Total broods per female per day	2.5 ± 0.3^{c}	3.5 ± 0.2^{b}	4.3 ± 0.3^{a}
Ovoviviparous broods per female	2.4 ± 0.4^{b}	2.5 ± 0.3^{b}	4.4 ± 0.5^{a}
Oviparous broods per female	1.4 ± 0.2^{b}	0.7 ± 0.2^{c}	0.5 ± 0.1^{a}
Total offspring per female	42.6 ± 12.1^{b}	66.2 ± 7.9^{b}	73.5 ± 6.1^{a}
Brood interval (days)	2.5 ± 0.4^{a}	1.7 ± 0.3^{b}	1.6 ± 0.3^{b}

Note: Different letters indicate significant changes Source: Ogello *et al*., (2022).

In addition to the essential nutrients in bio flocs, such as crude protein and fatty acid, the presence of bacteria in bio flocs is believed to play a prominent role in the value of the bio flocs as a food source for aquatic animals and bacterial enzymes in bio flocs were detected in many research studies (G. Luo *et al*., 2014). An experiment showed that the survival of *Artemia* nauplii was lower after 48 h of incubation but the rate increased after adding bio floc into culture media (Crab *et al.*, 2010).

3.3 *Artemia* culture in algae-limited condition:

Algae require various nutrients to grow, including carbon, nitrogen, phosphorus, potassium, sulphur, magnesium, and trace elements such as iron, copper, and zinc. Carbon is the primary building block of all organic matter and is obtained from carbon dioxide in the atmosphere or dissolved in water. Nitrogen is an essential component of proteins, nucleic acids, and chlorophyll, and can be obtained from various sources such as ammonium, nitrate, or urea. Phosphorus is necessary for DNA, RNA, and cell membrane synthesis, typically obtained from water phosphate ions. Potassium is important for regulating osmotic balance and enzyme function, while sulphur is a component of certain amino acids and vitamins. Magnesium is a component of chlorophyll and is essential for photosynthesis, while trace elements such as iron, copper, and zinc are important co-factors for various enzymatic reactions. *Artemia* culture in algae-limited conditions can increase the growth and production yield and also noticed that utilized more bacteria in algae-limited conditions (Toi *et al*., 2013; Thanh Toi & Thị Hong Van, 2017) and also *Artemia*-fed flocs mixed with Chlorella were significantly higher than that of the *Artemia*-fed-only Chlorella (G. Z. Luo *et al*., 2017). Researchers conducted an experiment in a laboratory to examine how well the macroalgae *Gracilaria caudata* and microcrustacean *Artemia franciscana* could remove nutrients from aquaculture effluents that contained mixed cultures of *Artemia* and algae with different frequencies. (Marinho-Soriano *et al*., 2011). A particular emphasis has been directed on development of the sustainable approaches to coastal aquaculture to increase production. Using a mixed model to predict the total amount of harvestable cysts produced by an *Artemia franciscana* population in a culture pond based on the volume of biomass is a highly attractive approach for farm applications (Baert *et al*., 2002).

Table 06. Some work reporting *Artemia* sp. growth with different microalgal species (Seixas *et al*., 2009)

Microalgae species used to feed *Artemia* sp.	**Culture method and nutrient concentration**	**Best microalgal diet**	**Length-of *Artemia* sp.**	**Authors**
(i)*Tetraselmis suecica* *(ii)Chaetoceros muelleri*	Semi-continuous with the daily harvest of a partial volume. f/2 medium	*T. suecica* *C. muelleri*	4.5 mm (day 10) 3.7 mm (day 10)	Godínez *et al*., (2004)
i)Chaetoceros muelleri *ii)Isochrysis galbana* T-ISO	Semi-continuous with a daily renewal rate of 25%. f medium	*C. muelleri* *I. galbana* T-ISO	6.0 mm (day 7) 4.2 mm (day 7)	Lora-Vilchis *et al*., (2004)
i)Dunaliella tertiolecta (Two-strains: 19/6B; 19/27) *ii)Tetraselmis suecica* (Two-strains: 66/4; 66/22A)	Batch, harvest in the middle of exponential growth or in stationary (both conditions) Walne medium	*T. suecica* 66/4 *T. suecica* 66/22A *D. tertiolecta* 19/6B	3.5 mm (day 6) 4.0 mm (day 6) 3.2 mm (day 6)	Marques *et al*., (2006)
i)Tetraselmis suecica, ii)Rhodomonas lens, ii)Nannochloropis gaditana, Isochrysis galbana Parke	Semi-continuous with a daily renewal rate of 30%. Nutrient saturated (2or 4 mM N l^{-1})	R. lens	3.6 mm (day 5) 4.9 mm (day 8)	Seixas *et al*., (2009)

Microalgae have important applications in the aquaculture industry due to their remarkable nutritional value, especially the high contents of carotenoids. The presence of fatty acids and carotenoids from algae significantly positively impacted *Artemia*'s growth and overall health (Gui *et al*., 2022).

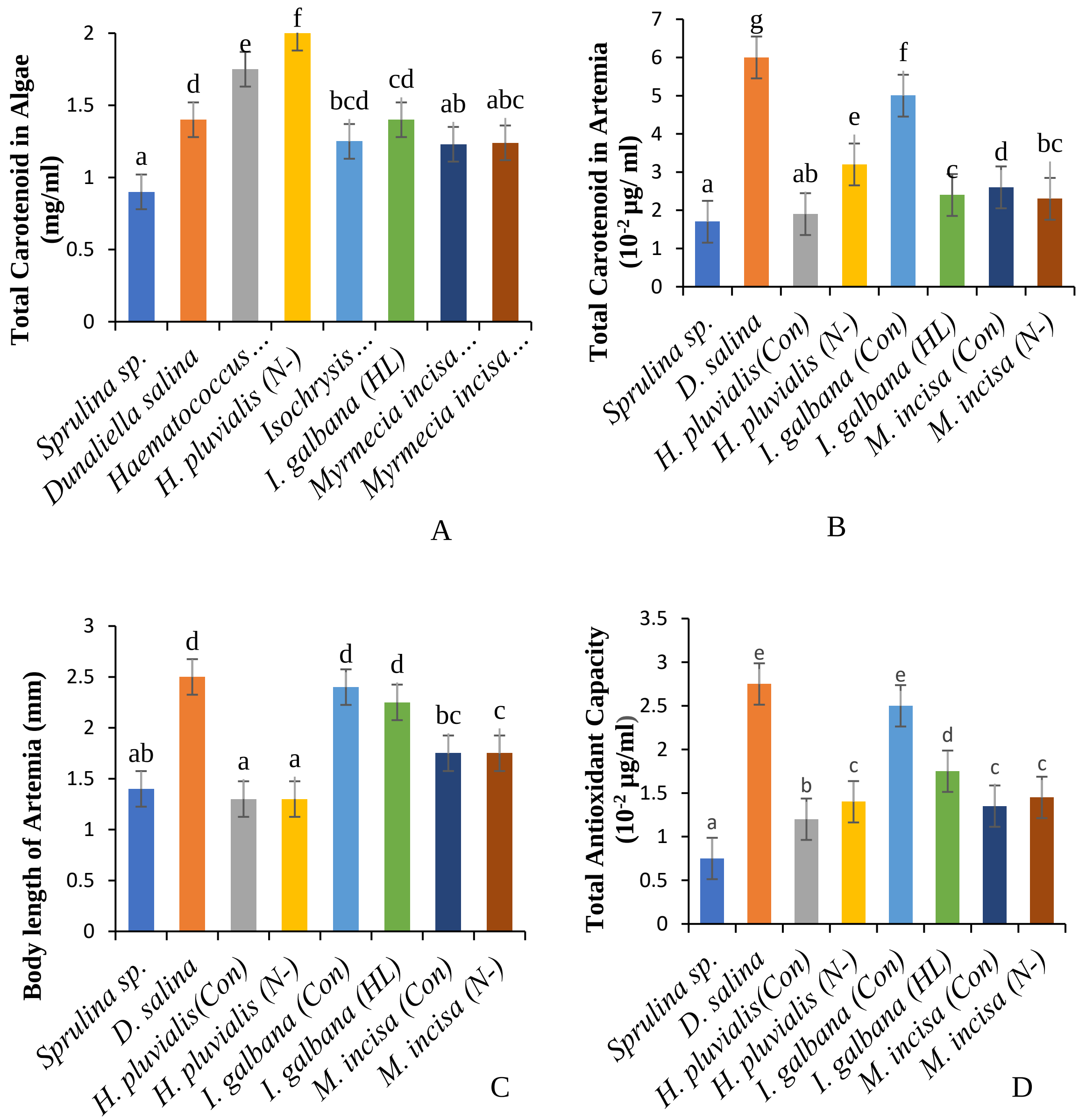

Figure 06. Production performance of *Artemia* in algae limited condition A) total carotenoid content of algae (B) total carotenoid content of *Artemia* (C) body length of *Artemia* (D) total antioxidant capacity. Note: "Con" refers to normal culture condition; "N-" refers to nitrogen deficiency stress; "HL" refers to high light stress; Different lowercase letters indicate significant differences (Gui *et al*., 2022).

In table 07 provides evidence that the immunity of *Artemia* nauplii was strengthened, as they demonstrated strong resistance against infection induced by *Vibrio parahaemolyticus.*

Table 07. Daily survival (%) of *Artemia* fed with different microalgae from day 1 to day 5 and Effects of *Vibrio parahaemolyticus* (10^6 CFU / mL, LC_{50}) on the survival rate of *Artemia*

Strain	Survival rate (%)					
	Day 1	Day 2	Day 3	Day 4	Day 5	24 hours (After Bacterial inoculation)
No feed	90 ± 6.7	76.7 ± 8.8	2.2 ± 3.8	0.0 ± 0.0	0.0 ± 0.0 ^{a}	
Spirulina sp.	97.8±1.9	85.6 ± 1.9	76.7± 3.3	70.0± 3.3	67.8 ± 1.9^{cd}	52.22 ± 1.92^{ab}
D. salina	97.8±1.9	95.6 ± 1.9	90.0± 0.0	88.9± 1.9	87.8± 1.9^{f}	78.89 ± 5.09^{c}
H. pluvialis (Con)	94.4±1.9	87.8 ± 3.8	73.3± 3.3	64.4± 1.9	57.8± 1.9^{b}	43.33 ± 17.32^{a}
H. pluvialis (N-)	92.2±1.9	84.4 ± 1.9	76.7± 3.3	71.1± 1.9	65.6 ± 1.9^{bc}	51.11±10.72^{ab}
I. galbana (Con)	98.9±1.9	94.4 ± 1.9	86.7± 3.3	85.6± 5.1	84.4 ± 6.9^{ef}	85.56 ± 3.85^{c}
I. galbana (HL)	97.8±1.9	88.9 ± 5.1	84.4 ±5.1	82.2 ±6.9	76.6 ± 6.7^{de}	64.44 ± 5.09^{b}
M. incisa (Con)	96.7±3.3	90.0 ± 3.3	84.4 ±3.8	76.7 ±5.8	71.1 ± 5.1^{cd}	55.56 ± 6.94^{ab}
M. incisa (N-)	92.2±1.9	87.8 ± 5.1	80.0 ±5.8	73.3 ±5.8	68.9 ± 6.9^{cd}	51.11 ± 7.70^{ab}

Source: Gui *et al.*, (2022).

3.4 *Artemia* culture with Commercial diet:

Supplementary feed is essential for the successful culture of *Artemia*, as it provides additional nutrients for the growing nauplii and helps to maximize their growth and survival rates. There are several types of supplementary feeds that can be used in *Artemia* culture, including microalgae, fishmeal, yeast, egg yolk, chicken manure, rice bran, wheat bran, pig manure, etc. When selecting a supplementary feed for *Artemia* culture, it is important to choose a feed that is appropriate for the developmental stage of the nauplii and to ensure that it is free from contaminants and pathogens. Additionally, the feed should be provided in appropriate quantities and at regular intervals to ensure optimal growth and development of the nauplii. Anh *et al*. (2009) found that survival, total length, yield, and maturation percentage of *Artemia* were reared with different supplementations.

Table 08. Survival, total length, individual weight, and maturation percentage of *Artemia* reared with different supplementations

	GW	GW + PM	GW + PM + RB	GW + PM + SB
Survival (%)				
Day 5	75.4 ± 1.8[a]	75.8 ± 1.0[a]	69.2 ± 4.1[a]	70.7 ± 1.3[a]
Day 11	52.1 ± 1.8[a]	53.1 ± 1.5[a]	54.0 ± 2.8[a]	52.9 ± 2.1[a]
Length (mm)				
Day 5	5.0 ± 1.1[a]	4.8 ± 0.9[a]	5.0 ± 1.0[a]	4.9 ± 1.1[a]
Day 14	8.8 ± 1.0[a]	9.2 ± 0.7[b]	9.4 ± 0.6[b]	9.4 ± 0.6[b]
Day 21	9.3 ± 0.8[a]	9.5 ± 0.6[a]	9.6 ± 0.5[b]	9.7 ± 0.5[b]
Weight (mg)				
Day 5	3.2 ± 0.1[a]	3.2 ± 0.3[a]	3.1 ± 0.2[a]	3.1 ± 0.3[a]
Day 14	7.5 ± 0.9[a]	8.4 ± 0.8[b]	9.1 ± 0.8[bc]	9.3 ± 0.8[c]
Day 21	11.2 ± 0.3[a]	11.5 ± 0.3[b]	11.6 ± 0.2[bc]	11.8 ± 0.2[c]
Maturation (%)	83.6 ± 6.8[a]	95.2 ± 5.9[b]	98.6 ± 2.0[bc]	99.7 ± 0.6[c]

Source: Anh *et al*., (2009)

The total yield of *Artemia* biomass with different food supplements affects the production perspective of *Artemia*. In comparison to the control group, the use of supplemental diets led to a notable increase in biomass production, with values ranging from 1.79 to 2.44 tons of wet weight per hectare after 12 weeks of culture. The control group, on the other hand, had a biomass production of only 1.06 tons of wet weight per hectare (Anh *et al*., 2009). Cumulative cyst yield was observed to vary in the 28 to 38 kg wet range per treatment during week 3 to week 6 of the culture period (Ronald *et al*., 2014). Changes in the total yield of different supplemental feeds are shown in figure 08.

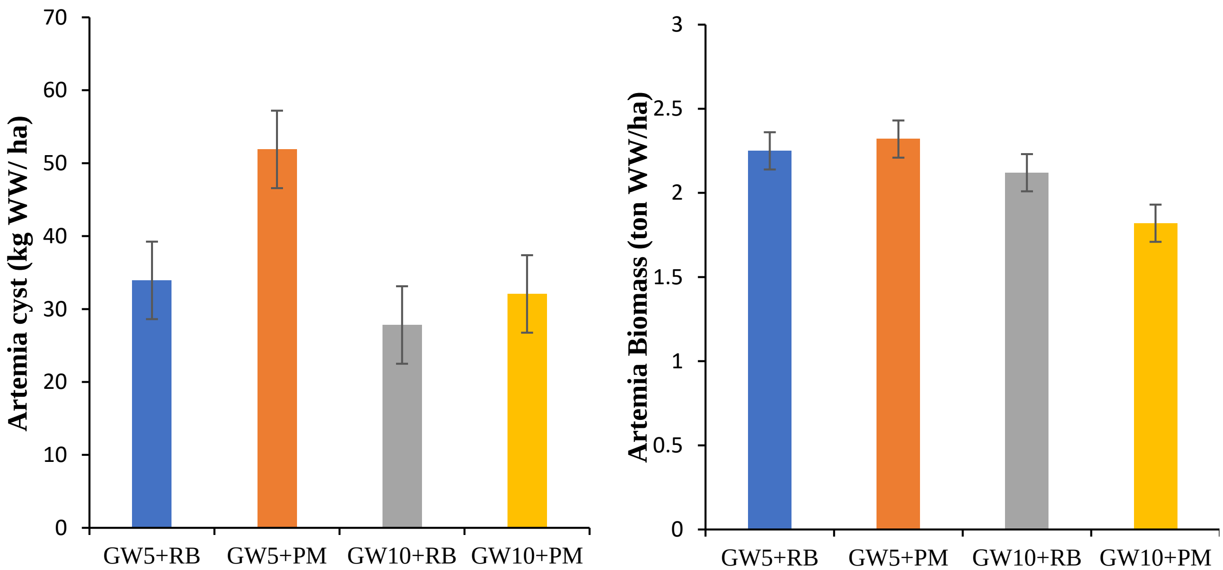

Figure 07. The average yield of *Artemia* cyst and biomass cultured with different green water sources and supplementary feeds for 12 weeks (Anh, 2015).

The effect of food supplementation on female fecundity was similar to growth performance and maturation rate. Anh *et al*. (2009) noted that the relatively high number of offspring recorded for the first brood in the two groups supplemented with rice bran or soybean meal also supports the hypothesis of initial good trophic conditions. The researchers observed that fecundity in *Artemia* decreased as ovoviviparity increased, likely due to heightened competition within the later generations and they also made note of how the addition of supplementary feed impacted the reproduction of *Artemia* by Anh, (2015). The effect of different culture sources of feed is shown in table no 09.

Table 09. Reproduction characteristics (percentage of ovoviviparity and brood size) at first spawning and average values of the whole culture period of *Artemia* biomass cultured with different green water sources and feed supplement

		Description	
		Effect of Green water	Effect of feed supplement
First spawning	Ovoviviparity (%)	GW5	GW5
		GW10	GW10
	Brood size (No. nauplii female^{-1})	GW5	GW5
		GW10	GW10
Whole culture period	Ovoviviparity (%)	GW5	GW5
		GW10	GW10
	Brood size (No. nauplii female^{-1})	GW5	GW5
		GW10	GW10

Source: Anh, (2015).

When properly used, the supplemental feed can increase the biomass and reproductive rate of *Artemia*, leading to higher yields and more consistent production. However, it is important to note that overfeeding or using improper feed can result in water quality issues, which can negatively affect *Artemia* growth and survival. Therefore, careful monitoring of water quality parameters and feeding rates is crucial in *Artemia* culture.

CHAPTER IV

CONCLUSION

Artemia is a widely used live feed for various aquatic animals, especially in aquaculture, as it is rich in protein and highly nutritious. The development of sustainable *Artemia* culture can help reduce the environmental impact of aquaculture and ensure long-term profitability. sustainable methods for *Artemia* culture are crucial for reducing the environmental impact of aquaculture and ensuring long-term profitability. Sustainable methods include the use of renewable energy sources, minimizing water usage, reducing waste generation, and optimizing feed management. These methods not only reduce the environmental impact of *Artemia* culture but can also increase the productivity and efficiency of the operation and increased production. The culture of *Artemia* typically involves the hatching of cysts, which are harvested from the female *Artemia,* in saltwater tanks or ponds. The hatched nauplii are then fed with different diets (algae, yeast, rice bran, wheat bran, chicken manure, etc. and grown until they reach maturity, at which point they can be harvested and used as a live feed. Some commonly used culture methods include bio floc, green water, and commercial feed culture methods. Each method has its own advantages and disadvantages, and the choice of method depends on the specific requirements and resources available to the culturist. The choice of method depends on factors such as water quality, salinity, temperature, feed quality, and lighting conditions. Over the past few years, there has been an increasing focus on sustainable *Artemia* culture, which involves adopting practices that promote the use of renewable energy sources, reduce water usage, minimize waste production, and optimize feed management. These factors are of critical importance in ensuring that *Artemia* culture is carried out in an environmentally responsible manner, which maximizes its long-term viability.

In terms of yield, the production of *Artemia* can vary depending on the culture method used. Bio floc culture, for example, can produce higher yields of *Artemia* with the optimization of wastewater. In algae-limited conditions, the production increased due to the mechanism of the cultured species toward each other. For better growth, yield, and reproduction, *Artemia* in bio floc culture, in algae limited condition, or with different diets in a single unit or mixed culture with two of them can be used. Each of these techniques requires specialized equipment and careful attention to detail to ensure optimal growth and survival rates.

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