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BIOFLOC TECHNOLOGY

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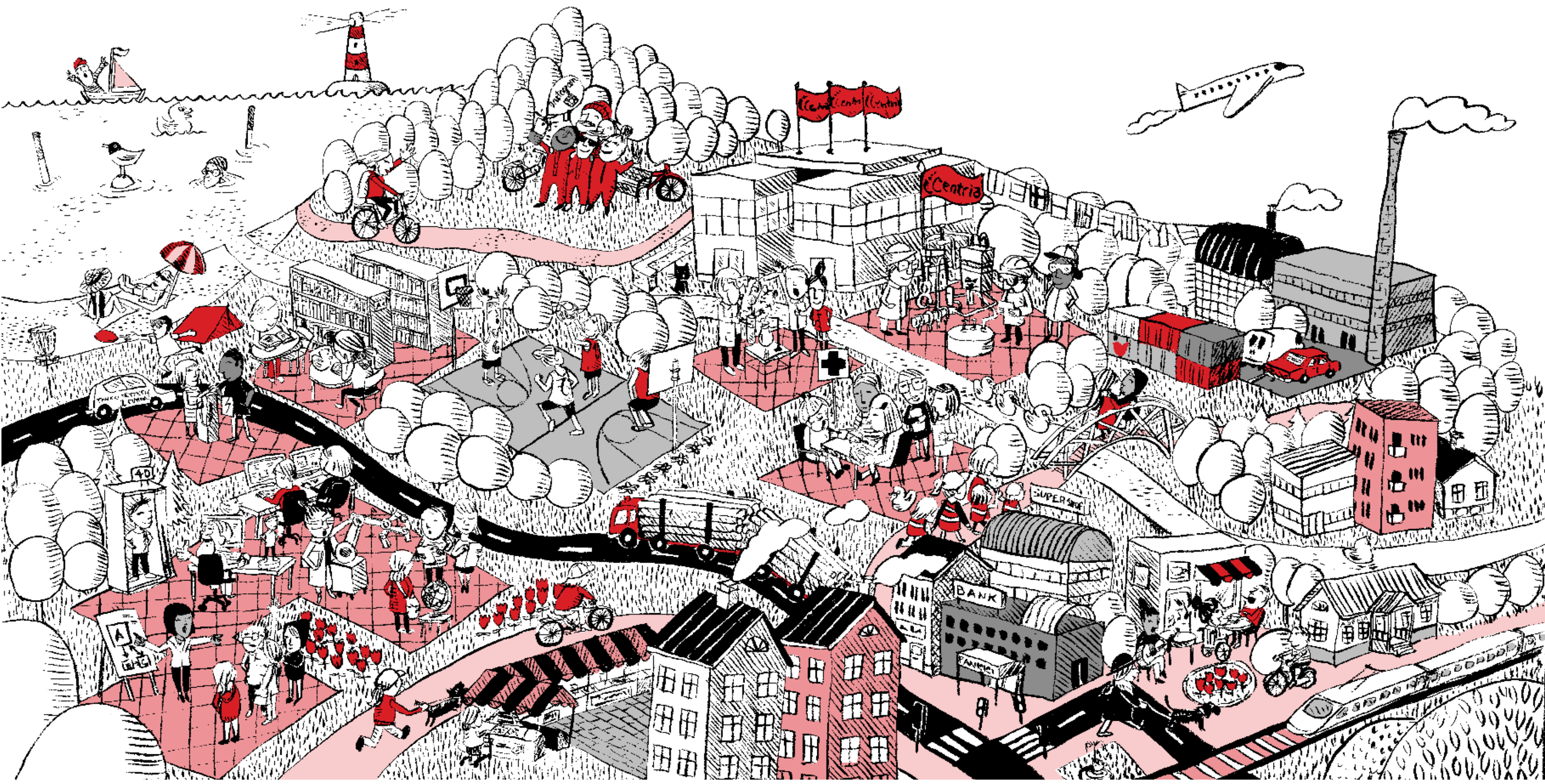

ABSTRACT

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The aim of this thesis was to research the theory on the Biofloc technology. The thesis provides information about the Biofloc system, the use of the system, and the advantages and disadvantages of using Biofloc system. Additionally, this thesis also provides information about the history of fishery and aquaculture along with the differences of them.

In the thesis, several resources were used to gain the knowledge about Biofloc system, the steps involved to set-up the Biofloc system for the growth of shrimp and tilapia as species. The author has written in a depth about the information of fishery and their history as well as about the aquaculture. The advantages and disadvantages of Biofloc systems are described in Chapter 2.2 that gives the idea about Biofloc and whether it is suitable for fish farming for certain fish or aquatic species.

As a result, the information provided in this thesis is for fish farmers to set-up their Biofloc system. The farmers also gain information about the food waste that can be recycled and reused.

Key words
Aquaculture, Biofloc, Biofloc system, Fishery, Fish Farm, Technology

CONCEPT DEFINITIONS

BFT
Biofloc Technology

CH
Carbon-hydrogen

Cm
Centimeter

C/N
Carbon-to-Nitrogen

CO2
Carbon dioxide

FAO
Food and Agriculture Organization

FCR
Feed Conversion Ratio

GoT
Gulf of Thailand

MCCI
Microbial Community Color Index

Mg
Milligram

NOAA
National Oceanic and Atmospheric Administration

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1 INTRODUCTION

Biofloc technology (BFT) is productive system in aquaculture and is an alternative way to fish farming. In this system, waste nutrients or toxic materials, such as nitrate and ammonia are recycled and reused to produce protein feed for aquatic species, such as fish or shellfish. Biofloc Technology is also said to be cost-effective, safe, environment-friendly, and an innovative way to fish farming. (Farming Pedia 2020.)

While there are advantages of using Biofloc system for fish farming, there are disadvantages as well. Firstly, the Biofloc system requires more amount of energy for mixing and aeration and also requires supplementation of Alkalinity. As far as performance is concerned, the Biofloc system gives seasonal and inconsistent performance due to sunlight-exposed systems. The use of nitrate in large amount can cause pollution. (Farming Pedia 2020.)

The objective of this thesis was to do theoretical research about the Biofloc technology and other areas that are associated with the Biofloc system. Researching and learning about fishery, aquaculture, and the working method of Biofloc technology were also done, by the author, during the thesis. The main of this thesis was to learn different aspects of Biofloc system, the use of Biofloc system and the advantages and disadvantages of using Biofloc system for particular aquatic species which are explained in Chapter 2.2.

The author has used several resources to research about the working of Biofloc system, the use of Biofloc system, the advantages and disadvantages of Biofloc system, and how the Biofloc technology can be implemented. The author also researched aquaculture and fishery along with their different types, benefits, and their history.

2 BIOFLOC TECHNOLOGY

In the 1970s, a method was developed which is known as Biofloc. Various species of shrimp and tilapia were first used for the Biofloc method. The method was originated from France. Nowadays, Biofloc is used in shrimp and fish farming in Asian countries, the United States, Central and South America, Brazil, China, South Korea, and Italy. The municipal wastewater treatment business provided the inspiration for this strategy. (Abesta 2020.)

To convert toxic waste into less or non-toxic organic products, in municipal wastewater treatment plants, micro-organisms that occurs naturally in animal and human waste are enhanced with food sources, oxygen, and other microbes. The organic products that are extracted from the treatment plants can be returned safely to the environment. (Abesta 2020.)

As we know nutrients can be continuously recycled and reused, the environmentally friendly aquaculture known as Biofloc Technology (BFT) is considered an efficient alternative technique. The long-term viability of such a system is reliant on the development of micro-organisms in the culture medium, which is aided by minimal or no water exchange. (Abesta 2020.) These bacteria, also called Biofloc, serves two purposes:

1. Maintaining water quality by absorbing nitrogen compounds and producing “in situ” microbial protein;
2. Boosting culture feasibility by lowering feed conversion ratios and lowering feed costs.

BFT (Biofloc Technology) is a method or technique that is used to improve the quality of the water. An external sourced carbon or the carbon found by the increment of carbon content of the feed can be added to improve the water quality. Commercially, in aquaculture, less amount of types of Biofloc systems have been employed. The two primary types of Biofloc systems are categorized by the exposure and non-exposure of the system to the natural light. (Harvest 2018.) The types are listed below.

1. Tanks, lined ponds, or lined raceways are Biofloc systems with an exposure to natural light. In outdoor, tanks, or lined ponds are used for shrimp or tilapia species. In greenhouse, lined raceways are used for shrimp species. Algal and bacterial processes are combined with complexity

to control the quality of water in greenwater Biofloc systems. Most of the commercial Biofloc system uses greenwater Biofloc systems. (Harvest 2018.)

2. Tanks and raceways are the Biofloc systems that has been assembled in enclosed structures that do not receive natural light. The water quality is controlled solely by bacterial processes in these systems, which are known as brown-water Biofloc systems. (Harvest 2018.)

2.1 How does Biofloc work?

The working mechanism, such as process of photosynthesis, conditions for bacteria, and other nutritional compositions involved in the development of Biofloc system is explained below in the Chapter 2.1.1, Chapter 2.1.2, and Chapter 2.1.3.

2.1.1 Photosynthesis

Photosynthesis is used to convert uneaten feed, faeces and remaining nutrients into the food. Both autotrophic and heterotrophic bacteria are primarily-produced while breaking down harmful ammonia and nitrates, which accumulates to attract a host of species. Algae, fungus, diatoms, protozoans, and other types of plankton are the host of species that are attracted by the autotrophic and heterotrophic bacteria. Larger aggregations, which resemble brown or green sludge, are visible to the naked eye. Flocs are not quite captivating to human beings; however, it is delicious for shrimp and fish. Concerns related with high animal-stocking densities and inadequate filtering capacity, such as decreasing water quality and an increased risk of disease outbreaks are eliminated by Biofloc systems by recycling proteins. (Beijnen and Yan 2019.)

2.1.2 Bacteria

Bacteria are protein-based organisms that require nitrogen to survive. They absorb oxygen while using chemical energy from organic substrates (though there are anaerobic bacteria). The development of heterotrophic bacteria is then promoted, and nitrogen is taken up via the creation of microbial proteins.

Ammonium, as well as organic nitrogenous waste, will be transformed into bacterial biomass if the carbon and nitrogen levels in the solution are well balanced. (Harvest 2018.)

The bacteria now extract nitrogen from the water and regulate the quality of the water. The waste is degraded by microbial action, which converts some of it to Carbon dioxide (CO_2) and around 59 percent to microbial biomass. In most ponds, there is not enough nitrogen to support the growth of new cells. However, carbon-rich and protein-deficient materials (carbohydrate, Carbon-hydrogen (CH) molecule) such as starch or cellulose can be added (flour, molasses, and cassava). Another reason to keep the Carbon-to-Nitrogen (C/N) ratio above 10 is to save money. Bacteria play a crucial role in the food chain. We can control nitrogen levels in the pond by manipulating microbial activity. They appear to boost disease resistance. (Harvest 2018.)

2.1.3 Nutritional Composition

Biofloc has good nutritional value. The dry weight protein ranges from 25% - 50% and fat ranges from 0.5% - 15%. Biofloc is also a good source of vitamins and minerals, especially phosphorous. It has a similar effect on probiotics (microorganisms introduced to the body with a purpose to gain health benefits from them; Lactobacillus, Lactococcus). Fishmeal or soybean in the feed are exchanged with the dried Biofloc. (Wasave, Chavan, Pawase, Shirdhankar, Mohite, and Pai 2020.)

Molasses as a carbon source, 28.7% - 43.1% of protein and 2.11 and 3.625% of lipids are in Biofloc used to culture Litopenaeus vannamei whereas cultured tilapia with wheat flour, was obtained protein level of 38%, and for lipids of 3.16% and 3.23% (Wasave et al. 2020). Rotifers, ciliates, protozoa, nematodes, copepods, bacteria, microalgae and yeast form diversified Biofloc taking into consideration their nutritional contribution and ecological importance, such as microalgae, protein content may vary from 30% - 65% of dry weight. In chlorophytes and diatoms, saturated fatty acids can constitute 15% - 40% of total fatty acids, while green microalgae show a low concentration of monosaturated fatty acids and high polyunsaturated concentrations. Proximal composition of some planktonic species that are found in Biofloc shows that rotifers can contain 54% - 60% of crude proteins whereas Cladocerans 50% - 68% and copepods 70% - 71% (Wasave et al. 2020).

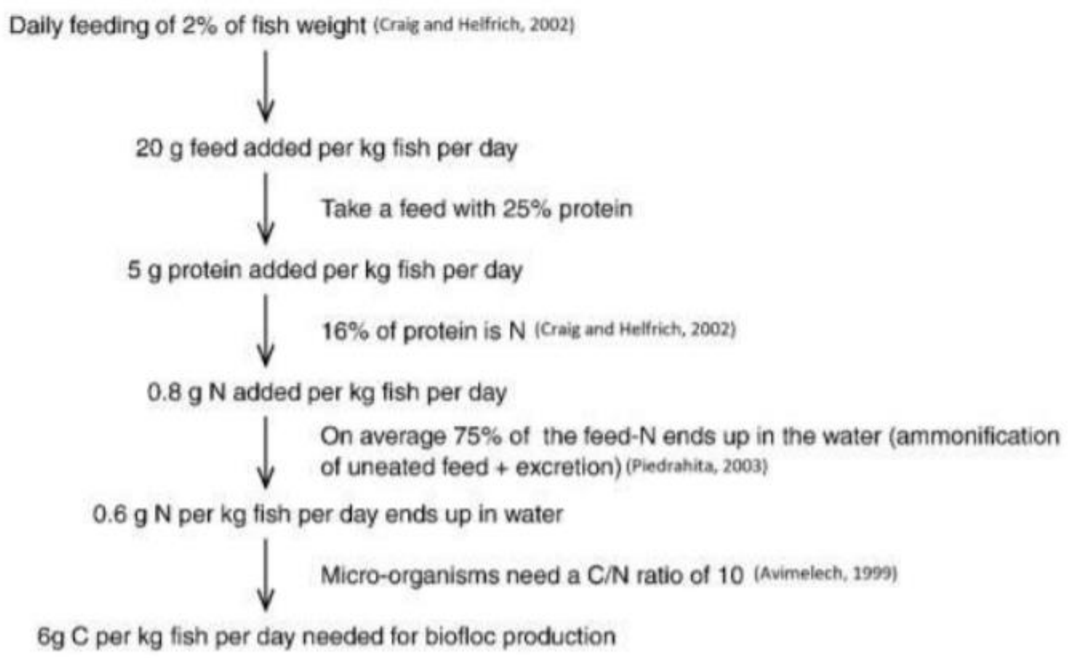

FIGURE 1. Simple calculation of the amount of carbon required to remove nitrogen waste (Wasave et al. 2020)

In figure 1 there is the image that shows the simplified calculation of the daily amount of carbon required to remove the nitrogen wasted from uneaten food and excretion from the animals by Biofloc.

2.2 Pros and Cons of Biofloc Technology

The use of Biofloc technology can be advantageous as well as disadvantageous. Both the advantages and disadvantages of using the Biofloc technology are explained below in the Chapter 2.2.1 and Chapter

2.2.1 Pros of Biofloc Technology

Biofloc Technology is an environment friendly system for fish farming which reduces the environmental impact and improves the efficiency of the land and water and their use. The water exchange is zero or limited in BFT which reduces the risk of water pollution as well as the spread of harmful pathogens.

BFT is cost-effective and efficient; it produces standard feed with higher productivity rate and also encourages higher biosecurity in the system. For fish feed formulation, the cheaper food fish and trash fish are used which can reduce the pressure to catch fish. (Krishnapriya 2016.)

2.2.2 Cons of Biofloc Technology

To mix and circulate the air through or dissolve in a liquid, BFT requires more energy. The response time is decreased because the rates of water respiration are elevated. Along with more energy, BFT requires a start-up period and also supplementation of alkalinity. Accumulation of nitrate in a large amount can increase the pollution that is harmful. Performance given by the Biofloc technology is seasonal and inconsistent due to exposure of the system to the sunlight. (Krishnapriya 2016.)

2.3 Implementation of Biofloc Technology for Fish farming

The Biofloc fish farming can be done both; indoors and outdoors. When setting up an indoor fish farm, we can use the container or tub along with the barrels to grow the fish. After that, the water from a reliable source, such as local water can be used to put the fish in the tank.

The process and the equipment that are used to set up an outdoor fish farm are listed and explained below.

1. Water preparation or Tank set-up:
   It is the vital step to prepare water for fish farming. To prepare water, we should make a pond or enclosed tank with cement so that the soil does not change the water condition or Biofloc systems. In case of water preparation, most of the tropical countries have a significant advantage. However, due to the heavy rainfall alkalinity and pH of water in outdoor tanks are affected. Because of the effect caused by heavy rainfall, the indoor water tank is better than outdoor water tank. (Farming Pedia 2020.)

PICTURE 1. Covered and lined pond system (Beijnen and Yan 2019)

In picture 1 there is the image that shows the covered and lined pond system which is best suitable for Biofloc systems (Beijnen and Yan 2019).

2. Aeration:
   After setting up the tank or choosing the right pond, aeration is the next step that needs to be done. The process that circulates the air, mix or dissolve in a liquid is known as aeration (Tuser 2020). The movements of all the systems should be constant for maintaining high oxygen levels and preventing solids from lodging. Oxygen is lost in the areas that are inactive and the area becomes an anaerobic area. Ammonia and methane are emitted in large amounts by the anaerobic area which can be prevented or avoided by preparing a well-planned aerator configuration. Paddlewheel aerators are used in wetlands and should be strategically installed for a current to be generated in the pond. (Farming Pedia 2020.)

3. Pre-seeding microbes:
   For Biofloc to improve the growth of Bioflocorder, pre-seeding is useful. Pre-seeding also helps Biofloc to maintain and stabilise the pond quickly. Several commercial or homemade ingredients are added to the cultural water that can be used to pre-seed the farm water. (Farming Pedia 2020.)

   Starter cultures for various probiotic microbes are provided by the two most renowned companies, INVE and VINNBIO. Several brands that are locally produced are available in Asia. Probiotic and prebiotic microbes are produced by using Red Cap 48 and wheat pollard and mixing them in a closed drum and leaving the mixture to stir for 48 hours after which it is ready to be used and added to the pond or tank. (Beijnen and Yan 2019.)

PICTURE 2. Conical beaker used to measure the growth of Biofloc (Beijnen and Yan 2019)

In picture 2 there is the image that shows the measurement of the growth of Biofloc using a conical beaker (Beijnen and Yan 2019).

4. Species selection and stocking densities:
   Biofloc systems has an enhanced water quality that can be profited by most species while feeding and digesting the Biofloc. However, we need to select species that profit from extra protein produced by the system. Tilapia and shrimp are the filter feeders to engulf Biofloc that can significantly improve the feeding performance. (Farming Pedia 2020.)

   Culture water has the capacity to self-filter and the aeration is strong because of which high stocking densities are possible. Shrimp are commonly stocked at densities of 150 to 250 post-larvae per square metre. Similarly, tilapia can be safely stocked at the densities of 200 to 300 fry per cubic metre. The risk of diseases increases significantly due to the use of higher stocking densities which compromises the health and welfare of the animals. (Beijnen and Yan 2019.)

PICTURE 3. Shrimp species (Navarro 2018)

In picture 3 there is the image of shrimp that are suitable species for the Biofloc systems.

5. Adjusting carbon source input:
   Growth and development of Biofloc in the pond or raceway are jump-started to prevent high level of ammonia, that are generated from the nitrogen present in the feed, at the beginning of

the farming cycle. The jump-start is done when there is enough amount of carbohydrates available in the pond or raceway system. In the carbohydrates, carbon is present through which ammonia are accumulated and synthesized by enabling heterotrophic bacteria. The synthesized ammonia helps to maintain the quality of the water. (Beijnen and Yan 2019.)

Farmers should choose only sources of carbon and mixture of feed with a carbon-to-nitrogen (C/N) proportion above 10 because it supports the growth of the heterotrophic micro-organism. Generally, shrimp and fish feeds have a carbon-to-nitrogen proportion of 9:1 or 10:1. To increase the proportion of carbon-to-nitrogen (C/N) to between 12:1 and 15:1, additional inputs are required. Materials, such as cassava, sugarcane, hay, molasses, or starch, contains single sugars and breaks down rapidly and can be used to increase the proportion of carbon-to-nitrogen. Reducing the protein content of the used feeds can also be used for the increment of the proportion of C/N. Carbon source should be adjusted repeatedly for preventing the high level of ammonia during the advanced stages of the production process, especially when high stocking densities is used in combination with huge amount of artificial feeds. For successful implementation of Biofloc system, controlling the ammonia peaks is one of the most difficult step in the whole process. (Beijnen and Yan 2019.)

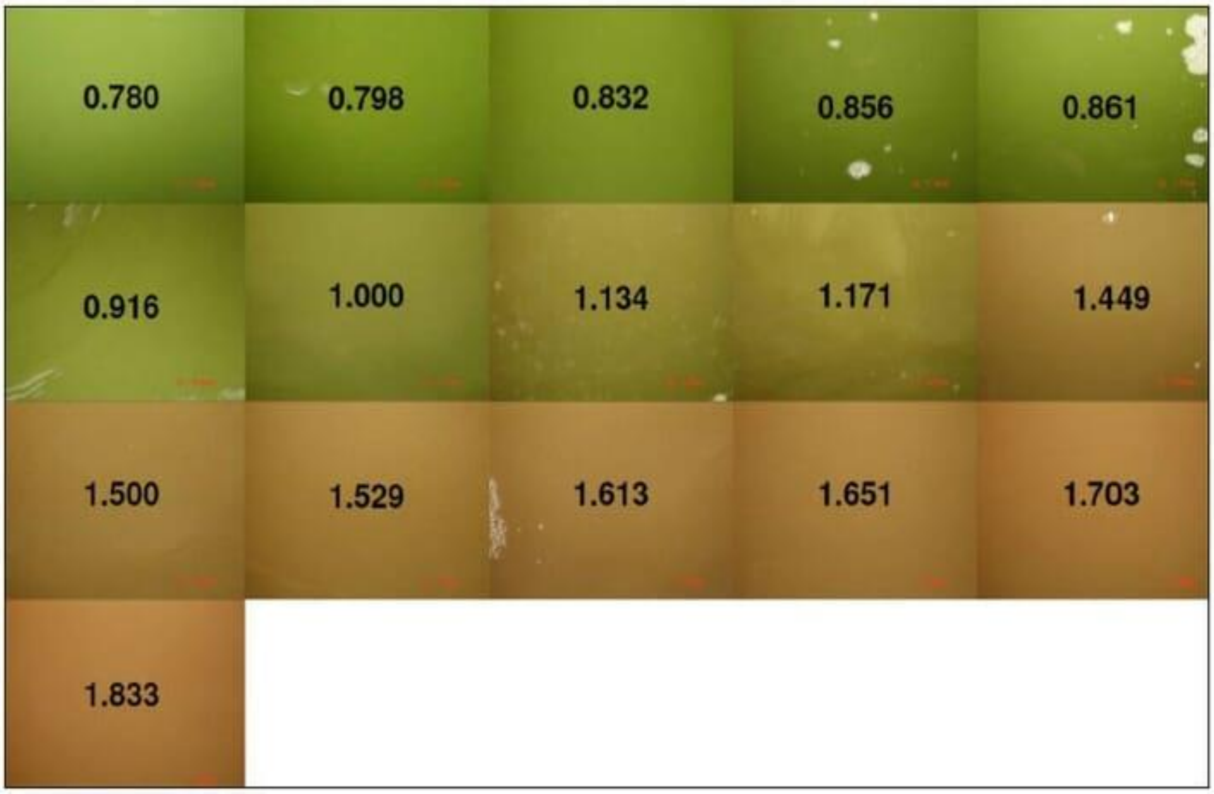

FIGURE 2. The Microbial Community Color Index (MCCI) (Beijnen and Yan 2019)

In figure 2 there is the image of the microbial community color index is the index that shows the transition from an algal-dominated system to a bacterial-dominated system.

6. Biofloc growth:
   Biofloc number starts to increase rapidly with the help of aeration, natural light, and pre-available source of carbon. The increment of number of flocs from zero to around four to five units per milliliter in few weeks depends on various factors, such as temperature of water, availability of nutrients and sunlight, and the amount of seeded Bioflocs at the beginning of the process. As the process continues, the expectation of the density can be up to 10 billion bacteria per cubic centimeter. The increased density maintains the good quality of the water by minimizing the ammonia content in the water section. (Beijnen and Yan 2019.)

   The water samples are collected, late in the morning, at a depth of 15 to 25 centimeter to observe the growth of Bioflocs by using a cone-shaped beaker. The solid particles that sticks on the side of the cone-shaped beaker should be left for 20 minutes to settle; they make it easy to count them. To perform larger operations, the Mil Kin bacterial counter can be a useful tool. (Beijnen and Yan 2019.)

7. Observing and control of Biofloc development:
   From step 7 onward, the pond water is observed and the activity of the two Biofloc types along with their respective densities are determined by regularly taking a sample of a water. Green algae and brown bacteria are present outdoors. The green algae utilize the sunlight for their development, and brown bacteria consumes remaining feeds, their byproducts, and other related wastes. At first, the pond looks green because of the tendency of algae to multiply faster. However, after a few weeks the bacterial colonies start to dominate turning the pond brown. The color of the pond remains brown even after it reaches the critical point due to the growth of stock and increasing volumes of feed. According to Nyan Taw, the brown color is reached quickly with tilapia because they are fed with more feeds, while it takes more time with shrimp. (Beijnen and Yan 2019.)

   In table 1 below there is the table of the development of Biofloc system that is being monitored in the relation to feed rates. The water color, dominant pathway, aerator power, water respiration, and net photosynthesis is presented in the table.

TABLE 1. Development of Biofloc system (Beijnen and Yan 2019)

Feeding rate (kg/ha per d)	Water color	Dominant pathway	Aerator power (hp/ha)	Water respiration (mg/L per hr)	Net photosynthesis (mg/L per hr)
100	green	algae	30	−0.5	+4.2
200	green	algae	30	−1.0	+8.3
300	green	algae+bacteria	150	−5.8	+1.2
400	green	algae+bacteria	150	−5.8	−2.0
500	green-brown	algae+bacteria	150	−4.0	−1.0
600	brown-green	bacteria+algae	150	−4.0	−3.5
700	brown	bacteria	175	−4.0	−4.0
800	brown	bacteria	200	−5.0	−5.0
900	brown	bacteria	200	−6.0	−6.0

8. Water parameter monitoring and control, as well as associated agricultural infrastructure:
   The increment of aeration must be high when the Biofloc system turns brown so that the high respiration rate of the system can be maintained. Figure 2 shows that respiration rates can approach 6mg per liter per hour at this stage of the process. The respiration rate needs at least six times more energy per hectacre than it is needed at the beginning of operations. (Beijnen and Yan 2019.)

   The aeration system should be functional all the time. When the system is not functional, there is a power outage that causes a lack of oxygen which results in crop failure. Crop failure is also the result caused by the ammonia generated in a low-oxygen environment by many heterotrophic bacteria. (Beijnen and Yan 2019.)

   Aerators along with the power system that generates energy to run the system should be maintained and observed, regularly and properly. In many Asian countries the power system is not reliable, especially in the rural areas where most of the farming operations are situated, and thus investment in an off-grid solution is recommended to the farmers. Several manufacturers sell solar-powered paddlewheel aerators which are more expensive and not as a diesel generator. The best option for most of the large-farm operations is a diesel generator that is large along with a backup generator. (Beijnen and Yan 2019.)

9. Observing and control of farm stock:

   While the first goal of a Biofloc system is to maintain and improve the quality of the water at a low cost and also without exchanging the water, the second goal is to bring improvement in the growth rates of flocs and to bring efficiency in the feeding process which, at the end, improves the profit and sustains the farming operations. Activities, such as the performance of the farm stock, appearance of the farm, calculating and recording growth rates, FCR (Feed Conversion Ratio), and stock survival need to be observed and controlled to check the wellness of the farm. Additional 0.25 units to 0.5 units of growth, for each unit of growth in the stock feed, can be expected to come from the Biofloc in the system. An enormous bounce can be noticed when the current farm records and previous non-biofloc farm activities are compared. (Beijnen and Yan 2019.)

10. Harvest and clean-up:

    Shrimp can be harvested for up to 20 to 25 tons per hectare. Better growth rates and survival can be expected if all the steps mentioned above are followed accordingly. The increased growth rate lowers the overhead expenses and increases the profitability. (Beijnen and Yan 2019.)

    After harvest, it is important to prepare and clean the pond set-up or raceway. The preparation and cleaning are sometimes overlooked and undervalued. It is not a good idea or advisable to reuse the culture water just because it seems appealing since it took much effort to build up the microbe populations. Pathogens may have established a culture, posing a major biosecurity danger. According to the research, heavy metals can build up in culture water over time, accumulating in the supply and rendering it unfit for human consumption. It is advisable to clean the tank before starting the next batch of farming. (Beijnen and Yan 2019.)

3 AQUACULTURE

There has been much discussion lately about Aquaculture, but if we look closely at history, we know it has been here for thousands of years (approximately 4000 years.). In 473 B.C. Chinese author known as Fan Lai wrote a book called “The classic culture of fist” to teach others to raise fish for food. In 1733 modern method of aquaculture started in Germany, they successfully fertilized egg to raise fish for food. (Rabanal 2021.)

3.1 What is Aquaculture?

As the interest for fish has expanded, innovation has made it conceivable to develop food in coastal marine waters and the open ocean. Aquaculture is a strategy used to produce food and other commercial products, restore habitat and replenish wild stocks, and rebuild populations of threatened and endangered species. (Rabanal 2021.)

There are two main kinds of Aquaculture, marine and freshwater. NOAA (National Oceanic and Atmospheric Administration) endeavours basically centre around marine aquaculture, which alludes to cultivating species that live in the sea and estuaries. (Rabanal 2021.)

The practice of producing aquatic organisms in a controlled environment for human consumption is known as aquaculture. Aquaculture is very similar to agriculture. In agriculture plants or livestock are used whereas in aquaculture fish is used for farming. Fish farming is another term for aquaculture. Farmed fish is most typically labelled on the seafood that are sold at local grocery shop. Aquaculture can and does take place anywhere on the planet, such as coastal ocean waters, ponds or rivers with freshwater. Aquaculture is also possible on land with the help of tanks. (Global Seafood Alliance 2019.)

3.2 Types of Aquaculture

Aquaculture systems range in size from very large to semi-intensive to highly intensive to hyper-intensive. Because there are no apparent divisions and levels of intensification constitute a continuum, individual characterization of each system must be stated when utilizing this word. (Princy 2020.)

There are many different farming systems, for example:

1. Water-based systems (cages and pens, inshore/offshore).
2. Land-based systems (rained ponds, irrigated or flow-through systems, tanks and raceways).
3. Recycling systems (high control enclosed systems, more open pond based recirculation).
4. Integrated farming systems (such as, livestock-fish, agriculture and fish dual use aquaculture and irrigation ponds). (Princy 2020.)

3.3 Benefits of Aquaculture

Studies proved that aquaculture has brought immense positive impact on the global food production industry. Some of the amazing benefits of aquaculture are mentioned below:

1. Rich source of micronutrients and animal protein:
   Aquaculture or fish farming is considered as a great source of protein because they produce fish. Fish, which is a product of aquaculture, satisfies the current need for animal protein for more than 1 billion people worldwide with limited resources. (Princy 2020.)

   Micronutrients contained in fish are also necessary for appropriate cognitive and physical development of children. As a result, aquaculture contributes to general development of people around the world. (Princy 2020.)

2. It conserves the aquatic population:
   Aquaculture helps in saving the number of inhabitants in wild sea-going plants and different organic entities by turning away the elimination of such species which is caused by unrestrained mistreatment. (Princy 2020.)

3. A Nurturer of biodiversity and ecosystem:
   It is yet another significant advantage of aquaculture. Aquaculture techniques have led to the discovery of natural ways for varied aquatic species and plants to cohabit. As a result, aquaculture contributes to the reduction of environmental waste and the enhancement of ecosystem function. (Princy 2020.)

4. Employment opportunities:
   Aquaculture offers a variety of job options. Aqua farming, as a new field, will provide many job prospects. (Princy 2020.)

4 FISHERY

Fishing can mean the raising or catching of fish and other forms of aquatic life or, more generally, the place where such an undertaking is carried out also known as a fishing ground. Commercial fishing includes wild fishing and fish farming both in freshwater bodies (approximately 10% of all catches) and in the oceans (approximately 90%). Around 500 million people around the world are economically dependent on fishing. In 2016, 171 million tonnes of fish were produced, but overfishing is a growing problem and is causing some stocks to decline. (Kumar 2021.)

4.1 History of Fishery

Angling is the process of catching fish. It has a history of more than 35,000 years and can be an individual need or a collective enterprise that involves large groups of men. Since the 16th century, fishing boats have been able to cross the oceans in search of fish, and since the 19th century it has been possible to use large boats and in some cases fish on board. (Kumar 2021.)

Fishing is a term that can be applied to the capture of other aquatic animals such as cephalopods, shellfish, crustaceans and echinoderms. The term is not generally used to refer to the capture of aquatic mammals such as whales. (Kumar 2021.) Ancient history and Pre-history of fishery are presented with more detail in Chapter 4.1.1 and Chapter 4.1.2, respectively.

4.1.1 Ancient history of Fishery

The old Nile was full of fish; Fresh and dried fish was a staple food for a large part of the population. The Egyptians invented various fishing devices and methods and these are vividly illustrated in tomb scenes, drawings, and papyrus documents. Simple reed boats were used for fishing. Braided nets, baskets made of willow branches, harpoons and hooks and lines were used (the hooks are between eight millimetres and eighteen centimetres long). The use of metal barbed hooks was started in the 12th Dynasty. (Kumar 2021.)

4.1.2 Pre-history of Fishery

Fishing is an ancient practice dating back at least to the Upper Paleolithic, which began around 40,000 years ago. Isotope analysis of the skeletal remains of Tianyuan Man, a 40,000-year-old modern human from East Asia, has shown that he regularly consumed freshwater fish. Archaeological features such as clam piles, discarded herring spines, and cave paintings show that shellfish were important for survival and were consumed in significant quantities. During this time, most people lived a hunter-gatherer life and were inevitably on the move. However, there were people with permanent settlements, though not necessarily permanently inhabited, such as Lepenski Vir. Lepenski Vir are almost always associated with fishing as the main source of food. (Kumar 2021.)

4.2 Types of Fishery

Inland fisheries and Marine fisheries are the main types of fisheries. While fishing, several gears are required. The list of those gear used for large-scale and small-scale fisheries is shown in the table 2 below.

TABLE 2. Division between small-scale and large-scale fisheries based on gears used in them (FAO Organization, 2021)

Large-scale fisheries (Marine Fisheries)	Small-scale fisheries (Inland Fisheries)
1. Types of trawl, such as otter board, beam, and pair 2. Types of seine, such as purse and anchovy purse 3. Types of gill net, such as mackerel encircling and king mackerel drifting 4. Deep water set net 5. Push net	1. Types of gill net, such as pomfret, mackerel, crab, mullet, and other 2. Squid trammel net 3. Shrimp trammel net 4. Squid falling net 5. Other cast nets 6. Long line 7. Hand push net 8. Hand line and pole and line 9. Set bag net 10. Shallow water set net 11. Types of trap, such as crab, squid, and fish 12. Other stationary gears

4.2.1 Inland Fisheries

Any activities that are performed for the extraction of fish or other aquatic species from inland waters are said to be inland fisheries. Inland waters are required for inland fishery. Inland waters are referred to lakes, brooks, rivers, ponds, streams, inland canals, dams, and other land-locked water; usually freshwater, such as the Caspian Sea and Aral Sea. Freshwater means zero salinity and while inland waters are freshwater, there are areas, such as estuaries, deltas, and coastal lagoons which have fluctuations in salinity but still are nationally classified as inland waters. (Food and Agriculture Organization 2021.)

PICTURE 4. Small-scale inland fisheries (FAO 2021)

In picture 4 there is the image of people throwing a net inside the water for fishing which also represents the technique of small-scale inland fisheries.

Vital sources of food for human being are provided by the fisheries in inland waters. Worldwide number of population is predicted to increase from 7.6 billion to 9.7 billion by the year 2050; the inland fisheries will play a vital role in providing food for the growing population. Since inland fisheries provide important source of nutrition, food security and micronutrients that are an integral part of the agricultural landscape in some countries, they are linked to production of food, management of water and land, biodiversity as well as ecosystems. (Food and Agriculture Organization 2021.)

Because of the development of water and land resources, that are used for agriculture in the country, are having an impact on inland fisheries. Human activities, such as navigation, damming, urbanization, reclamation of wetland for the purpose of agriculture, extraction and transfer of water, and waste disposal are threatening to the aquatic environment. However, the inland fisheries can be managed by creating an ecosystem which takes biological, human, economic, and social factors into consideration. (Food and Agriculture Organization 2021.)

4.2.2 Marine Fisheries

Any activity that is performed for the extraction of fish or other aquatic species in all the oceans and seas of the world, including bays and estuaries is said to be marine fishery. It is a type of fishery that needs salt waters. Marine fisheries can also be referred as large-scale fisheries. The capture and culture of aquatic organisms in salt water accounts for the bulk of the fishery products that reach the world's markets.

PICTURE 5. Large-scale marine fisheries (FAO Organization 2021)

In picture 5 there is the image of the boat used for fishing in salt water in Thailand.

Thailand along with other developing states of the South China Sea region have reported a major development and expansion of marine captured fisheries from the year 1945. Technologies such as the trawl net was introduced to be used for fishing. Marine capture fisheries were expanded with the help of modern techniques. The development of marine fisheries is due to the increasing motorization of boats for fishery and the inflow of capital for the infrastructure. Technical assistance that is provided by FAO (Food and Agriculture Organization) and the uncovering of fishing areas in offshore waters also plays a vital role in the development of marine fisheries. There is a government policy that supports the fisheries sector. In the context of Thailand, marine capture fisheries are the primary subsector of capture fisheries. In 2004, 68.5% of the total marine production was contributed by the marine production from the GoT (Gulf of Thailand) and the remaining 31.5% were contributed by the Andaman Sea. (FAO Organization 2021.)

5 DIFFERENCES BETWEEN AQUACULTURE AND FISHERY

Catching fishes from natural resources, such as rivers and seas is called fishery. Production of fish and other sea-food in fresh water or marine water resources is called aquaculture. (Kumar 2021.)

1. The fishery includes fish or shellfish. Fisheries are mainly engaged in catching, processing, and selling fish. Meanwhile, aquaculture is linked to the cultivation of both aquatic animals and aquatic plants. (Kumar 2021.)
2. While fishing relates solely to catching wild fish or raising and catching fish, aquaculture is a science that encompasses all aspects of marine life. (Kumar 2021.)
3. While the fishery can be freshwater or saltwater, wild or farmed fishery, aquaculture can be mariculture or integrated multitrophic aquaculture. (Kumar 2021.)
4. Pearls are products that are only obtained through aquaculture and not through fishing. (Kumar 2021.)
5. Approximately 90 percent of fish and shellfish are caught in wild fisheries. Since the wild fish population has declined in recent years, aquaculture is seen as a way to conserve this wild fish population. (Kumar 2021.)

6 CONCLUSION

The main aim of this thesis was to learn about the Biofloc and its technology and to learn about the fish species for which Biofloc is most suitable. This thesis also represents the inter-relation between the aquaculture, fishery, and Biofloc system.

In conclusion, Aquaculture will be enabled by Biofloc Technology for the growth towards an eco-friendly and biosecurity approach. In BFT (Biofloc Technology), FCR (Feed Conversion Ratio) is reduced by the consumption of microorganisms. When we convert nitrogen extracted from fish faeces, microbial protein is produced and also the farmer's expenses are reduced due to FCR. It helps in maintaining water quality by continuous recycling, ensures less FCR (Feed Conversion Ratio) through feces and waste recycling in the pond. Thus, it has proven more profitable than conventional fish farming as well as more production is ensured with low feed input. This technique is highly suitable in urban areas where there is scarce land and water but advanced technology. Nepalese farmers with poor economic conditions can also afford Biofloc technology ultimately ameliorating their economic status. Now, it is Nepalese turn to incorporate Biofloc technology in the existing farming system for intensive fish production with low feed, water and land resources to establish a blue revolution in a country, such as Nepal.

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