

Proper management of fish farms for the most appropriate productivity

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Abstract

Fish welfare necessitates a well-managed program with constant attention to detail. The best way to ensure optimum fish health is to raise them in a healthy environment with good nutrition and qualified high water, isolation from infectious agents, and new intelligent fish farming methods. In this study, we reviewed vita vaccines to prevent infectious diseases. There are numerous industrial vaccines against infectious bacterial and viral diseases of fish to be used in aquaculture, which we discussed importance once. Water quality parameters are the critical subject in danger identification for the welfare risk assessment of numerous aquaculture operations; thus, aquaponic structures are not distinct from aquaculture. Fish raised in aquaponic systems require appropriate water-high-quality conditions, suggesting that parameters including dissolved oxygen, carbon dioxide, ammonia, nitrate, nitrite, and pH have to be inside desirable species-specific limits considered best value of these parameters. Appropriate nutrition in animal manufacturing systems is vital to the economical manufacturing of a healthy, best-quality product. In fish farming (aquaculture), nutrients are crucial because feed usually represents 50 percent of the variable production cost, so in this study, we discussed the most important ingredients such as proteins, lipids, carbohydrates, vitamins, and minerals. Smart fish farming is a new scientific field to optimize resource efficiency and promote sustainable development in aquaculture. We revise how to use this field in fish farming to estimate fish size or biomass, feeding decision-making, and predicting water quality.

Keywords: Fish farming, Fish disease, Fish nutrition, Smart agriculture, Fish water quality, Fish vaccination

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Introduction

Aquaculture has grown in importance in recent decades as a viable industry capable of meeting global demand for fish. Due to the wide range of internal and external factors that affect aquaculture and the complex interactions of technological, biological, environmental, and economic aspects during the culturing process, fish farming management is complex, similar to other animal breeding industries. (Cobo *et al.*, 2019). Fish welfare necessitates a well-managed program with constant attention to detail. The disease is characterized as a departure from a standard or healthy state of the body, and infectious or noninfectious agents may cause disease in fish. As a result, the best way to ensure optimum fish health is to raise them in a healthy environment with good nutrition, minimal stress, and isolation from infectious agents. Avoiding interaction between the host fish and a pathogen should be a priority wherever possible to avoid infectious disease. A pathogen-free water supply certified pathogen-free stocks and meticulous sanitation are the best ways to accomplish this (Winton, 2001).

In this study, we reviewed the most critical factors in improving yield and reducing mortality in fish farms, including vaccination, water quality, nutrition, and a survey on smart fish farming.

Prevention of infectious diseases by vaccination

Fish vaccination was commenced in 1942 by vaccinating Cutthroat against *Aeromonas salmonicida* infection (Assefa and Abunna, 2018). Advancing vaccination is the most essential and possibly the previous process for preventing and managing fish's infectious diseases (Dadar *et al.*, 2017). There are enhancements in fish vaccination currently. A number of the upgrades consist of immunization of enormous stock and the development of multivalent vaccines. Safety at the stock stage may be executed via vaccination (Plant and LaPatra, 2011). The licensing and registration of recent vaccines are lots simpler than antibiotics. (Assefa and Abunna, 2018) There are numerous industrial vaccines available against infectious bacterial and viral diseases of fish to be used in aquaculture. The primary commercialized fish vaccines were the bacterial vaccine, delivered within the United States in the past due 1970s towards enteric Redmouth sickness and vibriosis (Dadar *et al.*, 2017). these vaccines were inactivated whole-cellular immersion vaccines, which have helped prevent many bacterial diseases (Sommerset *et al.*, 2005). Advances in biotechnology and immunology have improved and commercialized many different fish vaccines like DNA, subunit and Nano vaccines, genetically modified vaccines, and polyvalent vaccines (Dadar *et al.*, 2017). The changed live *Edwardsiella ictaluri* vaccine has been

produced since 2000, by Intervet Inc., underneath the alternate name AQUAVACESCO, and constitutes the primary certified bacterial live vaccine in aquaculture formulated with attenuated pathogenic stress. A few inactivated bacterin vaccines and live attenuated vaccines were proved efficient by using immersion of fish, and a few others are of relatively lower efficiency (Sommerset *et al.*, 2005). Simple inactivated bacterin vaccines work properly against bacterial disease vibriosis; however other bacteria are harder to control utilizing vaccination (Assefa and Abunna, 2018). For Salmonids incorporating unique *Vibrio* species and *Aeromonas salmonicida* as antigens, polyvalent vaccines also are to be had. DNA vaccines were also hired experimentally as certain live vaccines with an excessive level of achievement against Furunculosis; however, their acclaim for use in the area has no longer been drawing close (Sommerset *et al.*, 2005; Muktar *et al.*, 2016). distinct polyvalent oil-adjuvanted vaccines, inclusive of mixtures of *Vibrio anguillarum* with different pathogens, including *Vibrio ordalii*, *Vibrio salmonicida*, *Aeromonas salmonicida*, *Moritella viscosa*, and infectious pancreatic necrosis virus, are also available for use for Salmonids through the intraperitoneal direction (Sommerset *et al.*, 2005; Dadar *et al.*, 2017).

Viral diseases are extra demanding than bacterial infectious sicknesses to govern because of the dearth of anti-viral therapeutics, demanding situations

in growing effective viral vaccines, and absence of records at the mechanisms of viral disease resistance in fish (Muktar *et al.*, 2016, Dadar *et al.*, 2017). the arena organization for Animal health has indexed positive viral diseases as a catastrophe for large-scale aquaculture industry along with DNA and RNA virus diseases which include Epizootic Hematopoietic Necrosis (EHN), Koi Herpes Virus disorder (KHVD), Infectious Hematopoietic Necrosis Virus, Spring Viremia of Carp (SVC) and Viral Hemorrhagic Septicemia (VHS) (Crane and Hyatt, 2011; Dadar *et al.*, 2017). A massive range of studies trials was carried out for developing effective viral vaccines by groups and educational organizations; however, only some viral vaccines are certified (Sommerset *et al.*, 2005). Presently to be had industrial viral vaccines for aquaculture are inactivated virus vaccines or recombinant protein vaccines. No live attenuated vaccines are presently certified to be used in aquaculture; only one DNA vaccine towards IHN (Infectious hematopoietic necrosis) disease is available (Muktar *et al.*, 2016; Shefat, 2018). Inactivated viral vaccines are potent at excessive doses if introduced via injection; however, value-effective inactivated viral vaccines are tough to broaden in which live viral vaccines confirmed appropriate outcomes in fish. The shortage of effective viral vaccines is one of the most critical troubles dealing with fish vaccinology (Sommerset *et al.*, 2005) (Table 1).

Table 1: Commercially available vaccines against the most critical infectious viral diseases of fish (Midtlyng 1997; Leung 2004; Sommerset *et al.*, 2005; Muktar *et al.*, 2016, Assefa and Abunna, 2018; Shefat 2018).

Name of vaccine	Species vaccinated	Diseases prevented
IHN Virus Vaccine	Salmonids	IHN Disease
IPN Virus Vaccine	Salmonids	IPN Disease
ISA Vaccine	Salmonids	ISA Disease
Iridoviral disease Vaccine	Red sea bream	Iridoviral Disease
SVC Vaccine	Common carp	SVC Disease
KHV Vaccine	Koi Carp	KHV Disease
Betanodavirus	Grouper	Betanodavirus Disease
Carp Erythrodermatitis	Carp	Erythrodermatitis
Grass Carp Hemorrhage Disease Vaccine	Grass carp	Grass carp hemorrhage disease
aemiaGa Vaccine	Lobsters	aemiaGa
Nodavirus Vaccine	Seabass	Viral Nervous Necrosis (VNN)
Pancreas Disease Virus Vaccine	Salmonids	Pancreas disease

In addition, enteric red mouth disease (also known as Yersiniosis) is one of the most common bacterial illnesses in coldwater fish farms, causing considerable mortalities and financial losses in salmonid fish farms, particularly in rainbow trout (*Oncorhynchus mykiss*). Vaccines against ERM are among the most successful disease-control strategies in aquaculture, with the first commercial product launching in 2003 (Zorriehzahra *et al.*, 2017).

Furthermore, given the importance of these diseases and the consequent economic losses, it is critical to developing laboratories that take samples regularly and monitor the genotypes of viruses circulating in this portion of the country (Khosravi *et al.*, 2019). New rapid diagnostic technologies for detecting virus carriers or health, monitoring and surveillance programs, effective immunizations, control, prevention, and eradication should be explored as part of a

complete approach (Zorriehzahra *et al.*, 2019).

Water quality management

Water quality parameters are the critical subject in danger identification for the welfare risk assessment of numerous aquaculture operations; thus, aquaponic structures are not distinct from aquaculture. Fish raised in aquaponic systems require appropriate water high-quality conditions, suggesting that parameters including dissolved oxygen, carbon dioxide, ammonia, nitrate, nitrite, and pH have to be inside desirable species-specific limits. The deterioration of water quality parameters influences fish physiology, increase rate, and feed performance, leading to pathological adjustments or even mortality below extreme situations (MacIntyre *et al.*, 2008; Person-Le Ruyet *et al.*, 2008). In terms of aquaponic structures and considering the fish welfare troubles, carrying potential is foremost for preserving the

balance among plant and fish necessities in a co-culture medium. Carrying potential expresses the maximum biomass of fish in the system with ideal water best limits. The carrying potential of a given amount of water is decided with the aid of the fish's oxygen intake rate and their responses to Ammonia, CO₂, and various doubtlessly poisonous metabolic wastes that might be produced. Pressure includes a sequence of physiological and behavioral reactions that help fish withstand death or adapt to converting situations. While pressure is extreme or extended, the fish's potential to re-establish homeostatic norms can be insufficient (Person-Le Ruyet *et al.*, 2008).

Stress includes a sequence of physiological and behavioral reactions that help fish withstand death or adapt to converting situations. While stress is intense or extended, the fish's potential to re-establish homeostatic norms can be insufficient (Thune *et al.*, 1993). Water presents fish with the oxygen required to survive, dilutes and eliminates doubtlessly poisonous metabolites, and gives gravity assistance. Irrelevant ranges of high-quality water parameters affect physiology, increase rate, and feed performance (biomass increase/feed fed) and may reason terrible stimuli. From the aquaponics' attitude, the stabilization of water's chemical composition generally requires some time, relying on the temperature and various elements together with stocking

density. A production format for aquatic organisms and plant life) impairing the fish's biological potential can be resulting from risky water situations, which affect the welfare situations thru complicated interactions among water quality parameters (Yavuzcan Yildiz *et al.*, 2017).

Dissolved oxygen (DO) is the number one water quality attention for aquaponic systems in different aquaculture gadgets. Fish extract oxygen from the water with the aid of passive diffusion via the gills. A good sufficient DO awareness in the water is needed to facilitate passive diffusion down an awareness gradient from the water into the blood (Colt and Tomasso, 2001). If DO concentrations fall under the fish's necessities, fish cannot convert power as effectively right into a usable form, resulting in decreased growth fee, feed performance, and swimming ability (JONES, 1971). The instantaneous response of fish to reduced DO concentrations is to grow the opercular ventilation rate and display a gasping reaction (Wedemeyer, 1996). In aquaponics, the minimum oxygen degrees to promote appropriate health and physiological situations in the fish inventory can change based on fish species and fish size. The solubility of oxygen in water decreases because the temperature will increase. Colt and Tomasso (Colt and Tomasso, 2001) contributed the primary points in aquaculture preparation which can be of importance in aquaponic systems while

considering the allowable DO ranges, i.e.,

- The extended temperature will increase the metabolism, breathing, and oxygen demand of fish;
- Fish increase their oxygen uptake after feeding because of the oxygen demand required for feed processing, called particular dynamic movement;
- Oxygen consumption is proportional to the dimensions and quantity of fish in a given system;
- Larger fish use less oxygen per unit weight than smaller fish;
- Stressful situations, which include impaired gill function, exposure to stressors, and reduction in oxygen-carrying potential, cause the increase in the oxygen demand of fish.

In general, the endorsed restriction for DO ranges in fish culture is six ppm for coldwater fish and four ppm for warm water fish to defend their health. In aquaponics, the nitrogen cycle is an essential issue. The cycle starts with the creation of protein in fish feed, which is ingested through fish after which excreted to the aqueous phase in the form of available ammonia nitrogen (TAN, i.e., NH_3 and NH_4). Ammonia is first oxidized to nitrite (NO_2) through ammonia-oxidizing bacteria (especially *Nitrosomonas* spp.) in a biofilter and then transformed to nitrate (NO_3) by using nitrite-oxidizing bacteria (especially *Nitrobacter* spp.). In the aquatic environment, ammonia exists in 2 forms in equilibrium: un-ionized

ammonia and ionized ammonium. Therefore, the overall ammonia concentration is the sum of the concentrations of un-ionized ammonia and ionized ammonium. The equilibrium between NH_3 and NH_4^+ varies regarding the different factors, most notably the concentration of hydrogen ions and temperature (Yavuzcan Yildiz *et al.*, 2017).

Most of the Ammonia discovered in a fish farm is produced via the fish in aquaculture systems. Ammonia is the primary waste metabolite produced through fish from the catabolism of protein contained within the feed. Most biological membranes are permeable to un-ionized ammonia and comparatively impermeable to ionized ammonium. Consequently, in fish, ammonia in the outside environment either induces retention of endogenous ammonia within the fish or enters via the gills through passive diffusion down a concentration gradient. Ammonia is excreted from the fish through the gills (Evans *et al.*, 2005). Ammonia toxicity depends basically on the concentration of ammonia and the pH of the environment. Randall and Tsui (2002) mentioned that acute ammonia toxicity impacts the central nervous system of fish and manifests as a neurological disease. Ammonia interferes with physiological techniques that subsequently bring about cells' death within the brain; however, ammonia toxicity and its specific nature are not understood in fish. Excessive concentrations of ammonia decrease

survival inhibit increase and cause a variety of physiological dysfunctions. The immoderate level of ammonia in water acts as a stressor in that it stimulates the discharge of corticosteroid hormones into a move, affecting the welfare of the fish (Masser *et al.*, 1999) stated that un-ionized ammonia nitrogen concentrations as low as 0.02–0.07 ppm had been shown to slow growth and cause tissue damage in numerous warm-water fish species. Tilapia tolerate high un-ionized ammonia concentrations and infrequently show poisonous results in well-buffered recirculating structures. However, insensitive species consisting of rainbow trout (*Oncorhynchus mykiss*), the endorsed degree of un-ionized ammonia is $<0.02 \text{ mg.L}^{-1}$ (Wedemeyer, 1996). In the control of recirculating systems, ammonia needs to be monitored each day. If the overall ammonia concentrations begin to grow, the biofilter might not be working well. Nitrite turns poisonous even at low concentrations for plenty of fish species (Thangam, 2014). The level of toxicity to nitrite varies with species. In freshwater fish, nitrite enters via the gills. Nitrite ions are actively taken up thru the chloride cells, and they can be pumped in towards a concentration gradient (Jensen, 2003). Blood plasma concentrations of nitrite can collect up to 10 times more than the ambient water concentration (Eddy *et al.*, 1983). Nitrite spreads from the blood plasma into red blood cells, in which it oxidizes the Fe^{2+} in hemoglobin (Hb) to the

Fe^{3+} oxidation state, changing hemoglobin into methemoglobin (metHb). MetHb reduces the entire oxygen-carrying potential of the blood (Kroupova *et al.*, 2005). Nitrite exposure reduced hemoglobin and hematocrit in tilapia (*Oreochromis niloticus*) with mild methemoglobinemia following publicity to 0.50 and 1.38 $\text{mg L}^{-1} \text{NO}_2\text{-N}$ for 48-h static tests (Yildiz *et al.*, 2006). Nitrite exposure within the variety of 0.50 and 1.38 $\text{mg L}^{-1} \text{NO}_2\text{-N}$ brought on growth in methemoglobin ranges. Methemoglobin concentrations in an extra 50% are considered threatening to fish (Bowser *et al.*, 1983).

The physiological disturbances can be frequently rooted in hypoxia due to methemoglobin accumulation. Therefore, it is predictable that oxygen starvation induces hyperventilation. Because the gills are directly in touch with the aquatic habitat, the morphological and physiological changes in the gill tissue are essential. Svobodova *et al.* (2005) reported that hyperplasia, vacuolization, and increased numbers of chloride cells were the primary histological lesions in the gill's nitrite-treated carp (*Cyprinus carpio*). Nitrite can attain high concentrations in recirculating aquaculture structures wherein excessive densities of fish are stored. Scaled fish species are commonly more tolerant to high nitrite concentrations than species inclusive of catfish, which might be very touchy to nitrite (Masser

et al., 1999). Low concentrations of dissolved oxygen affect the toxicity of nitrite. Because nitrite affects blood's potential to move oxygen, a discount in ambient water DO concentrations increases toxicity. Although there is considerable research about acute and sublethal consequences of nitrite on fish in the literature (Tucker and Schwedler, 1983; Jensen, 2003; Kroupova *et al.*, 2005; Luo *et al.*, 2016), complete research on the persistent effects of nitrite on exclusive fish species below aquaponic conditions can be essential considering the interplay of plant roots and the efficiency of associated bacteria in the system. In brief, the associated bacteria that can be involved in aquaponic systems are the subsequent: ammonia-oxidizing bacteria (AOB), such as bacteria of the genera *Nitrosomonas*, *Nitrosococcus*, *Nitrosospira*, *Nitrosolobus*, and *Nitrosovibrio*, and nitrite-oxidizing bacteria (NOB), which includes bacteria of the genera *Nitrobacter*, *Nitrococcus*, *Nitrospira*, and *Nitrospina* (Ebeling *et al.*, 2006).

In general, data on persistent nitrate toxicity in cultured fish species throughout numerous life degrees is confined. Nitrate, the end manufactured from nitrification, is quite non-poisonous besides at very excessive concentrations (over 300 ppm (Masser, Rakocy *et al.*, 1999). However, Davidson *et al.* (2014) suggested that when Water 2017, 9, 13 five of 17 recirculating aquaculture systems (RAS) have been operated with shallow

water alternate nitrate brought on chronic toxicity to numerous fish species. As a result, the take a look of Davidson *et al.* (2014) underlines how deficient nitrate levels (80–100 mg.L⁻¹ NO₃-N) have been associated with chronic health troubles in and welfare effects to juvenile rainbow trout below RAS conditions. Modifications in swimming behavior barely reduced survival and decreased available biomass were the principal findings of impaired welfare situations in a RAS system with rainbow trout. Even though, in the case of aquaponics, nitrogen compounds must always be evaluated with the plant life aspect. Nitrate and ammonium are the most not distinctive sorts of nitrogen taken up utilizing the flora. The removal of vitamins is stricken by the plant species and cropping approach, as Buzby and Lin suggested (Buzby and Lin, 2014). The unfavorable capability outcomes of ammonium or nitrate on the fish properly-being are predicted to be relieved by eliminating those compounds through plant uptake inside the aquaponic system. Nevertheless, the designing of aquaponic systems and the strategies used are the elements affecting nitrogen compounds concentrations inside the system and their possible stress consequences on fish in addition to stress type.

The management of pH is also vital in aquaponic systems because pH will gradually decline because of the nitrification procedure, which increases H⁺ and NO₃⁻ ions within the system.

An essential item in aquaponic systems is pH stabilization because it is essential to all living organisms inside a cycling system that consists of fish, vegetation, and bacteria. Most plants need a pH value between 5.5 and 6.5 to improve the uptake of nutrients. The optimum pH of 3 important bacteria has been stated as Nitrobacter: 7.5; Nitrosomonas: 7.0–7.5; and Nitrospira: 8.0–8.3. In terms of fish tolerance to pH modifications based totally on fish species and size, the endorsed pH for aquaculture is 6.5–8.5 (Ebeling and Timmons, 2010). In combining the hydroponic systems with aquaculture, the pH value seems to be the drastic issue to the concurrent renovation of nutrient uptake via the plant and the most efficient pH value for fish and the biofilter bacteria. pH values are higher than 7.0 because of the decreased micronutrient and phosphorus solubility, and plant uptake of certain nutrients is limited in the aquaponic environment (Tyson *et al.*, 2004). However, as acidic water is one of the stressors in aquaculture environments, low water pH ranges in aquaponic systems can negatively affect fish's welfare. Another issue associated with pH degrees is the interaction between pH and phosphorus (P) availability and speciation. Cerozi and Fitzsimmons (da Silva Cerozi and Fitzsimmons, 2016) suggested that P availability reduced with the excessive pH value of aquaponic

nutrient answers and insoluble calcium phosphate species formed.

Consequently, the high pH stage appears to be precluded inside the plant uptake of P in aquaponics. In terms of fish welfare, P in aquaculture is not always categorized as a water quality parameter that can affect fish health/welfare. It is far recognized that phosphorus can be poisonous; however, toxicity takes place hardly ever in nature and is usually no longer an issue except phosphorus's oblique consequences. It is essential to consider that sustainable aquaponic production calls for balancing nutrient concentrations and pH for the most significant increase of 3 organisms: vegetation, fish, and nitrifying bacteria. The primary supply of carbon dioxide is fish metabolism in aquaculture. It is recognized that loose carbon dioxide is poisonous to fish. Fish cannot release endogenous carbon dioxide into the water while ambient CO₂ concentrations are excessive, ensuing in CO₂ increases inside the blood, a situation defined as hypercarbia. Because of decreased blood pH alongside acidosis in hypercarbia, the blood declines oxygen-carrying potential (the Bohr Effect). Carbon dioxide toxicity can be characterized through moribund fish, gaping mouths, and shiny red gill lamellae (Yavuzcan Yildiz *et al.*, 2017). The link between CO₂ and water hardness was reported because of the purpose of nephrocalcinosis in rainbow trout, with the signs of the

calcifying material manifesting within the ureters and kidney and as impaired food conversion overall performance (Fikri *et al.*, 2000). Land-based totally, recirculating aquaculture systems in addition to aquaponic systems can reveal fish to higher-than-natural degrees of aquatic hypercarbia. Oxygen is artificially provided to those systems to grow fish manufacturing, but biomass growth generally increases CO₂ production. In general, the tolerable water quality parameters for

fish are in equal variety with the vegetation except for water temperature and pH within the aquaponic system. While considering fish species' wellbeing in aquaponic systems, fish species with a high tolerance to pH and water temperature must be considered. PH and temperature are the parameters that affect the optimization of aquaponic production, each for fish welfare/health problems and plant desires (Table 2).

Table 2: Standard water quality tolerances for fish (warm or coldwater), hydroponic vegetation, and nitrifying bacteria (Lichtenstein 1959).

Organism type	Temperature (°C)	pH	Ammonia (ppm)	Nitrite (ppm)	Nitrate (ppm)	Dissolved Oxygen(ppm)
Warmwater fishes	22-32	6-8.5	<3	<1	<400	4-6
Coldwater fishes	10-18	6-8.5	<1	<0.1	<400	6-8
Plants	16-30	5.5-7.5	<30	<1	-	>3
Bacteria	14-34	6-8.5	<3	<1	-	4-8

Fish nutrition management

Appropriate nutrition in animal manufacturing systems is vital to the economical manufacturing of a healthy, best-quality product. In fish farming (aquaculture), nutrients are crucial because feed usually represents 50 percent of the variable production cost. Fish nutrition has superior dramatically in current years with the improvement of new, balanced industrial diets that promote the ideal fish increase and health. The development of recent species-specific diet formulations helps the aquaculture industry expand to increase demand for less expensive, safe fish and seafood products (Craig *et al.*, 2017).

Commercially produced feeds

Prepared or synthetic feeds can be either complete or supplemental. Complete diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) essential for the fish's ideal growth and health. Most fish farmers use complete diets, generally made from the following components and percentage degrees: protein, 18-50 percentage; lipids, 10-25 percentage; carbohydrate, 15-20 percentage; ash, <8.5 percentage; phosphorus, <1.5 percentages; water, <10 percentages; and trace quantities of nutrients and minerals. The feed's dietary content material relies upon what fish species are being cultured and

at what life stage. While fish are reared in high-density indoor systems or restrained in cages and cannot forage freely on natural meals (e.g., algae, aquatic vegetation, aquatic invertebrates, etc.), they need to be supplied a complete diet.

Supplemental (i.e., incomplete or partial) diets, on the other hand, are only meant to complement the natural food available to fish in ponds or outdoor raceways. Supplemental diets do not contain a complete set of vitamins and minerals, but they are commonly used to supplement a natural diet with additional protein, carbohydrates, and lipids (Craig *et al.*, 2017).

Proteins

Since protein is the most costly fish feed component, it is essential to know precisely how much protein each species and life stage needs. There are more than 200 amino acids in nature, and only about 20 are commonly used. Ten of these are essential (non-replaceable) amino acids that fish cannot produce. Methionine, arginine, threonine, tryptophan, histidine, isoleucine, lysine, leucine, valine, and phenylalanine are the ten essential amino acids that must be obtained from food. The amino acids lysine and methionine are often the first to become depleted.

Methionine levels are generally low in fish feeds made with plant protein (e.g., soybean meal). Meanwhile, methionine and lysine deficiency is

common in fish feeds made with bacterial or yeast proteins. As a result, when these protein forms are used to replace fishmeal, these amino acids must be returned to the diet. It is critical to understand and meet each fish species' dietary protein and precise amino acid requirements to promote optimal growth and health. Protein ranges in aquaculture feed range from 30 to 35 percent for shrimp, 28-32% for catfish, 35-40% for tilapia, 38-42% for hybrid striped bass 40-45 percent for trout and other marine finfish. Herbivorous (plant-eating) and omnivorous (plant and animal eaters) fish have lower protein requirements than carnivorous (flesh-eating) fish. Fish raised in high-density systems (e.g., recirculating aquaculture) have higher protein requirements than fish presented in low-density systems (e.g., ponds).

Smaller fish, as well as those in their early stages of life, have higher protein requirements. Fish's protein needs usually decrease as they become more extensive. Protein requirements are also affected by the fish's genetic composition and feeding rates and the rearing environment, water temperature, and water quality. If the diet contains enough fats and carbohydrates (energy), protein helps the fish develop. If this is not the issue, the more expensive protein can be used for energy and survival rather than development. Carbon (50%) is the most abundant element in proteins, followed by nitrogen (16%), oxygen (21.5%),

hydrogen (6.5%), and other components (6.0 percent). Fish can eat a high-protein diet, but up to 65 percent of the protein they consume can be lost to the environment. The majority of nitrogen is excreted as ammonia (NH₃) by fish gills, with just 10% being excreted as solid waste. Excess nitrogen from fish farm effluents can cause eutrophication (nutrient enrichment) of surface waters, a significant water quality problem for fish farmers. Protect downstream water quality, appropriate feeds, feeding strategies, and waste management practices are required (Craig *et al.*, 2017).

Lipids

Lipids (fats) are high-energy carbohydrates used in aquaculture feeds to partly spare (substitute for) protein. Proteins and carbohydrates have about half the energy density of lipids. Lipids make up about 7-15 percent of fish diets, include essential fatty acids and function as fat-soluble vitamin transporters. Higher levels of lipids in the diet have become common in fish feeds recently. Although increasing dietary lipids can help reduce feed costs by partially sparing protein in the feed, issues like an excessive fat deposition in the liver can negatively impact fish health, efficiency, and shelf life.

Fatty acids and triacylglycerols are examples of simple lipids. Fish typically require omega-3 and omega-6 (n-3 and n-6) fatty acids. Saturated fatty acids (no double bonds), polyunsaturated fatty acids (>2 double

bonds), and strongly unsaturated fatty acids (>4 double bonds) are the three forms of fatty acids. Marine fish and algal oils are naturally rich in omega-3 highly unsaturated fatty acids (>30%) and are excellent lipid sources for fish diet production. These lipids can be deposited in the muscle of fish. People who eat these fillets can reap the health benefits of omega-3 fatty acid-rich foods, such as reduced depression symptoms and improved cardiovascular health. For optimum growth and wellbeing, marine fish need omega-3 fatty acids in amounts ranging from 0.5 to 2.0 percent of their dry diet.

Eicosatetraenoic acid (EPA: 20:5n-3) and docosahexaenoic acid are the two prominent essential fatty acids in this category (DHA: 22:6n-3). Freshwater fish do not need long-chain, highly unsaturated fatty acids; however, they do need linolenic acid (18:3-n-3), an 18-carbon n-3 fatty acid, in amounts ranging from 0.5 to 1.5 percent of the dry diet. Freshwater fish cannot produce this fatty acid, so it must be obtained via the diet. Much freshwater fish may use enzyme systems to elongate and desaturate linolenic acid, making the longer-chain omega-3 fatty acids EPA and DHA required for other metabolic functions and cellular membrane components. Since marine fish lack these elongation and desaturation enzyme systems, they must consume long-chain omega-3 fatty acids. Other fish species, such as tilapia, need n-6 fatty acids, while others, including catfish, need a mixture

of n-3 and n-6 fatty acids (Craig *et al.*, 2017).

Carbohydrates

Carbohydrates (starches and sugars) are the most cost-effective energy sources for fish. Carbohydrates are included in aquaculture diets to reduce feed costs and for their binding activity during feed manufacturing, even though they are not needed. Dietary starches are helpful in the production of floating feeds by extrusion. Cooking starch makes it more biologically accessible to fish during the extrusion phase.

Carbohydrates are processed as glycogen in fish, which can be mobilized to meet energy demands. They are a significant source of energy for mammals, but fish do not use them effectively. Mammals, for example, can get around four calories from 1 gram of carbohydrate, while fish only get around 1.6 calories from the same amount of carbohydrate. Fish will consume up to 20% of the carbohydrates in their diet (Craig *et al.*, 2017).

Vitamins

Vitamins are organic compounds that are needed in the diet for fish to develop and stay healthy. They are frequently not synthesized by fish and must be consumed. Water-soluble and fat-soluble vitamins are the two types of vitamins. B vitamins (thiamine, riboflavin, niacin, pantothenic acid, pyridoxine, biotin, folic acid, and cobalamins), inositol, choline, and

vitamin C are all water-soluble vitamins (ascorbic acid). Vitamin C is perhaps the most essential of these since it is a potent antioxidant that helps fish and shrimp's immune systems.

Vitamins A (retinol, beta-carotene), D (cholecalciferol), E (tocopherols), and K are fat-soluble vitamins (phyloquinone). Vitamin E is the one that gets the most attention because of its essential antioxidant role. When used as a feed component, vitamins E and C help prevent dietary lipid oxidation, extending shelf life. Each vitamin deficiency has its own set of symptoms, but the most common sign of any vitamin deficiency is stunted development. Ascorbic acid and folic acid deficiencies can cause scoliosis (bent backbone symptom) and dark coloration, respectively (Craig *et al.*, 2017).

Minerals

Minerals are inorganic elements that must be consumed for the body to function normally. Based on the amount needed in the diet and the amount present in fish, they could be divided into two parts: macro-minerals and microminerals. Many minerals can be absorbed directly from the water by fish through their gills and skin, allowing them to compensate for mineral shortages in their diet to some degree. Calcium, sodium, chloride, potassium, chlorine, Sulphur, phosphorous, and magnesium are common dietary macro-minerals. These minerals help with bone formation and integrity by

regulating osmotic equilibrium. Iron, copper, chromium, iodine, manganese, zinc, and selenium are common microminerals. Small amounts of these trace minerals are needed as components in enzyme and hormone systems (Craig *et al.*, 2017).

Probiotics

Probiotics are an effective alternative sustainable source of beneficial organisms with bactericidal or bacteriostatic action on pathogenic bacteria, antibacterial, antiviral, and antifungal activity, immunomodulatory characteristics of promoting health and welfare to promote growth performance, augment the immune system, disrupt QS as a new anti-infective strategy, and alleviate suffering. Academicians, scientists, producers, and fish sector owners must collaborate to focus and explore the specific aspects of bacteria-host interactions that confer possible favorable changes in diverse immune responses elicited by different bacterial strains to propose clinically effective, bacteria-based strategies to promote the health, production, and economic growth of the fish industry. The formulation of probiotics should be feasible on a wide scale with low operational costs. They should not be seen as an "elixir of life," but rather as an addition to a balanced diet to achieve and maintain good health free of infections and disease-causing microorganisms (Zorriehzahra *et al.*, 2016)

Smart fish farming

Smart fish farming is a new scientific field to optimize resource efficiency and promote sustainable development in aquaculture by integrating the Internet of Things (IoT), big data, and artificial intelligence. Artificial intelligence, cloud computing, and other modern information technologies, Also, real-time data collection, quantitative decision-making, intelligent control, precise investment, and personalized service have all been accomplished, resulting in the formation of a new fishery production mode. Data and information are essential components of smart fish farming. The ability to make scientifically-based decisions will be enabled by the aggregation and advanced analytics of all or part of the data. However, the enormous sum of multiple sources, multiple formats, and complex data presents several challenges in smart fish farming. Information on the equipment, the fish, the environment, the breeding process, and the people comes from various sources. Text, image, and audio are among the formats available. Different cultured species, modes, and stages cause data complexities.

The task of dealing with the above high-dimensional, nonlinear, and massive data is challenging. In today's fish farming, more emphasis is being placed on data and intelligence than ever before. Data-driven intelligence approaches, such as artificial intelligence and big data, have started

to change these industries (Yang *et al.*, 2021).

For smart fish farming, data must be transformed into actionable knowledge (Shahriar and McCulluch, 2014). Artificial intelligence, such as machine learning and computer vision applications, is the next generation of fisheries data systems technology (Bradley *et al.*, 2019). The traditional computer, on the other hand, learning algorithms depend heavily on features created by humans (Goodfellow *et al.*, 2016), and it is still difficult to figure out which features are best for a given mission (Min *et al.*, 2017).

Deep learning (DL) has overcome previous limitations in artificial intelligence (AI) as a breakthrough. Agriculture, natural language processing, medicine, meteorology, bioinformatics, and security monitoring are just a few of the fields where deep learning methods have shown outstanding results (Dhiman and Vishwakarma, 2019). DL is a term used to describe a group of people who work in the field of digital. Instead of requiring handcrafted optimal feature representations for a specific type of data based on domain knowledge; machine learning improves data processing by extracting highly nonlinear and complex features via sequences of multiple layers automatically (LeCun *et al.*, 2015). DL provides advanced analytical tools for revealing and understanding the massive amounts of data in big data to support smart fish farming, thanks to its

automatic feature learning and high-volume modelling capabilities (Liu *et al.*, 2019). In analyzing massive and heterogeneous big data in aquaculture, DL techniques can solve the problems of limited intelligence and poor performance. Intelligent data processing and analysis and decision-making control functions in smart fish farming can be achieved by combining the Internet of Things, cloud computing, and other technologies.

Deep learning applications in smart fish farming

In this study, deep learning applications in smart fish farming, 41 papers on DL, and smart fish farming were addressed. Live fish recognition, species classification, behavioral analysis, feeding decisions, size or biomass estimation, and water quality prediction are the six types of specific applications. The number of papers associated with each submission is shown in Figure 5. Live fish identification and species classification are the most popular areas. These papers were released in 2016 or later, with three in 2016, three in 2017, 12 in 2018, 15 in 2019, and eight in 2020 (through May 2020), showing that DL has advanced quickly since 2016. Most papers include image processing in addition to water quality prediction and sound recognition. Furthermore, though most articles are about fish, a few are about lobsters or other marine animals (Yang *et al.*, 2021).

Analytical psychiatry

Fish are responsive to environmental changes and show a series of behavioral responses to environmental factors changes (Mahesh *et al.*, 2008). Furthermore, behavior can be used as a reliable reference measure for fish health and harvesting (Zion, 2012). Relevant behavior monitoring, especially for unusual behaviors, may provide a nondestructive understanding of fish status as well as an early warning (Rillahan *et al.*, 2011). Real-time monitoring of fish behavior is critical for determining their health and making decisions about capture and feeding (Papadakis *et al.*, 2012). Fish display their behavior through a series of behaviors with a degree of consistency and time correlation. For photographs taken before and after the action, methods for distinguishing an action from a single image will lose their utility. It is preferable to use time-series information from previous and subsequent frames in a video to capture action relevance. DL methods' ability to identify visual patterns has been demonstrated (Wang *et al.*, 2017). The specifics of the DL-based behavioral analysis are shown in Table 3. RNNs, in particular, have the potential to effectively address the above problem due to their powerful modelling capabilities for sequential data (Schmidhuber, 2015; Zhao *et al.*, 2018) proposed a novel approach for detecting, localizing, and recognizing a fish school's unusual local behaviors in

intensive aquaculture using a changed motion effect map and an RNN.

Individual tracking in a fish school is difficult due to complex nonrigid deformations, identical appearances, and repeated occlusions. Individual fish heads have fairly consistent shapes and colors that can be used to track them down (Butail and Paley, 2012).

As a result, data associations across frames can be accomplished, allowing behavior trajectory monitoring to be applied without being hampered by repeated occlusions (Wang *et al.*, 2017). Furthermore, data improvement and iterative training approaches may improve the precision of classification tasks for detecting challenging behaviors with the naked eye (Zhiping and Cheng, 2017). Finally, for 2–15 individuals in small groups, idTracker and more advances in identification algorithms for unmarked animals have been successful (Pérez-Escudero *et al.*, 2014). Idtracker.ai, an improved algorithm, has also been proposed. Idtracker.ai can monitor all the individuals in small and large groups (up to 100 individuals) using two separate CNNs, with a recognition accuracy that usually exceeds 99.9% (Romero-Ferrero *et al.*, 2019).

Estimation of size or biomass

When managing a fish farm, it is critical to regularly monitor fish parameters such as abundance, quantity, scale, and weight (Albuquerque *et al.*, 2019). Scientific fishery management and conservation methods for

sustainable fish production are based on quantitative estimation of fish biomass (Zion, 2012; Lorenzen *et al.*, 2016; Melnychuk *et al.*, 2017; Saberioon and Císař, 2018; Li *et al.*, 2020). Fish are responsive and move freely within an atmosphere where visibility, illumination, and stability are generally uncontrollable, making it challenging to estimate fish biomass without human interference (Li *et al.*, 2020).

Recent DL applications in fisheries science suggest that extensive sampling in smart fish farming may be a viable option. Fish morphological characteristics such as length, width, and weight can be more accurately estimated using machine vision and deep learning. The majority of recorded applications (Marini *et al.*, 2018) were semi-supervised or supervised. While this method adds to the workload, it is appropriate for more complex pictures (Tseng *et al.*, 2020). DL models' structural characteristics and computational capabilities can be wholly exploited (Hu *et al.*, 2014).

Furthermore, DL-based methods may reduce the impact of fish overlap on length estimation. The number of fish shoals can also be used as a source of information to create intelligent systems. In the field of animal computing, DL has shown numerous benefits. A fish distribution map can be created using DL to achieve automatic counting of fish groups under high density and frequent occlusion conditions, and then the fish distribution, density, and quantity can

be obtained. These values may indirectly represent fish conditions such as malnutrition, anomalies, and other states, making them a valuable guideline for feeding and harvesting decisions (Zhang *et al.*, 2020).

Another significant input to fishery assessment models is the age structure of a fish school. The current approach for evaluating fish young-age structure is based on manual otolith age assessments, a time-consuming and expertise-required procedure. Instead of using a pretrained CNN to estimate fish ages from otolith pictures, a DL approach can perform target recognition using a pretrained CNN. The precision is comparable to that of human experts, but it is much quicker (Moen *et al.*, 2018). To track fish biomass, optical imaging and sonar are frequently used. A deep learning algorithm is used to automatically learn the conversion relationship between sonar and optical images, allowing a 'daytime' image to be created from a sonar image and a night vision camera image. This method can be used to accurately count fish, among other things (Terayama *et al.*, 2019).

Feeding decision-making

The feeding level of fish can influence the production efficiency and breeding cost in intensive aquaculture (Chen *et al.*, 2020). Feed costs for certain fish varieties account for more than 60% of overall costs in actual production (Wu *et al.*, 2015; Føre *et al.*, 2016; De Verdal *et al.*, 2018). As a result,

excessive feeding reduces production quality, while inadequate feeding impacts fish development. Excessive feeding decreases feed conversion efficiency and pollute the atmosphere with residual bait. As a result, improving the feeding process will result in significant financial gains (Zhou *et al.*, 2018). However, many factors influence fish feeding, including physiological, nutritional, environmental, and husbandry factors, determining the actual needs of fish is difficult (Sun *et al.*, 2016).

Feeding decisions have traditionally been based primarily on simple timing controls and experience. Most current research on using DL to make feeding decisions has primarily focused on image analysis. An improved feeding strategy based on fish behavior can be established using machine vision. This type of device will end the feeding process at more suitable times, eliminating waste and improving fish welfare. Fish feeding strength can also be approximately rated and used as a feeding guide. The use of a combination of CNN and machine vision to determine fish feeding intensity characteristics were found to be successful (Zhou *et al.*, 2019); the qualified model accuracy was found to be high.

Superior to two manually extracted feature indicators: the flocking index of fish feeding behavior (FIFFB) and the snatch intensity of fish feeding behavior (Snatch) (Chen *et al.*, 2017). This approach can be used to detect and

assess fish appetite to help producers make better decisions. It would be essential to explore the use of newer neural network architectures for both spatial and motion feature extraction, given recent advances in CNNs. Such models, when combined with time-series data, can allow for better feeding decisions.

Måløy *et al.* (2019) combined a three-dimensional CNN (3D-CNN) and an RNN to create a new dual deep neural network that considered temporal and spatial flow. The RNN and 3D-CNN were used to capture temporal sequence information, allowing for identifying both feeding and nonfeeding behaviors. According to a comparison, the recognition results obtained with this dual-flow structure were superior to those obtained with individual CNN or RNN models.

Prediction of water quality

It is essential to predict changes in water quality parameters to detect abnormalities, avoid disease, and lower fish risks (Hu *et al.*, 2015). The water environment in real-world aquaculture is characterized by several parameters that interact with one another, causing significant inconvenience in the prediction process (Liu *et al.*, 2014). When applied to big data, conventional machine learning-based prediction models lack robustness, resulting in a general lack of long-term modelling capability, and they are unable to completely represent the data's critical characteristics (Liu *et al.*, 2019). DL, on

the other hand, has nonlinear solid approximation, self-learning, and generalization capabilities. Prediction methods based on DL have become increasingly popular in recent years (Le Roux and Bengio, 2008).

One of the most critical parameters in smart fish farming is dissolved oxygen, crucial for intelligent management and control (Rahman *et al.*, 2020). Because of the time lag between the introduction of dissolved oxygen control measures and their regulation results, it is crucial to forecast possible dissolved oxygen changes to maintain a consistent water quality (Ta and Wei, 2018). The relationships among quantitative water characteristics and water quality variables can be extracted using DL-based models, including a CNN or a deep belief network (DBN) (Lin *et al.*, 2018). Models like these have been used to estimate water quality parameters for intensive fish or shrimp farming. The results show that such models' accuracy and stability are adequate to meet actual production requirements (Ta and Wei, 2018).

However, most existing approaches have only been effective in predicting water quality in the short term. Scholars have been paying more attention to longer-term forecasts in recent years. The ability to extract the spatiotemporal relationships between water quality and external factors is crucial for long-term prediction. As a result, spatiotemporal models like LSTM networks and RNNs have become very common (Hu *et al.*,

2019). For example, an attention-based RNN model can describe time-space relationships clearly and effectively, and its learning capacity is superior to that of other models for both short- and long-term dissolved oxygen predictions (Liu *et al.*, 2019). These models' accuracy can be improved by continuously optimizing them during the prediction process (Deng *et al.*, 2019).

Dissolved oxygen and other water quality parameters are closely linked to time in their prediction. LSTM, DBN, and other DL models with attention can mine time sequence information effectively and produce satisfactory results. Consequently, a significant development path in water quality prediction tasks would be how to use DL models to prevent or reduce the negative effect of uncertainty factors on prediction outcomes.

In conclusion, it is critical to understand the essential factors for excellent fish farm management to achieve optimum production while preserving fish health. Controlling these variables, such as water quality and nutrition, can reduce casualties and the production of healthy fish. The best way to avoid economic losses and ensure our financial capital is to prevent infectious diseases by vaccination. Smart fish farming is a modern technological area that combines the Internet of Things (IoT), big data, and artificial intelligence with the using Best Management Practice (BMP) to improve resource production and foster

sustainable development in aquaculture. High quality level production to reach aquaculture sustainable development could be the main target in this way. So, an attempt to review and address these critical factors were considered in this perspective.

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