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Review Article

Effects of Vitamin E Supplemented Feed on Growth Performance of Fish: A Review

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Abstract

Vitamin E (VE), an important lipid-soluble antioxidant, has great influence on growth and maintenance in animal. Vitamin E is a generic term for all naturally occurring tocopherols and tocotrienol as well as their derivatives. VE has a strong reducibility, which protects important substances from oxidation in vivo and has an important role in the maintenance of normal metabolic processes and physiological function. Vitamin E is required to protect the cell membrane from peroxide damage, maintain immunity and enhance resistance to disease, whilst it is tightly associated with embryonic development, nucleic acid metabolism, ascorbic acid biosynthesis as well as maintenance of tissue quality. Vitamin E has become one of the most important vitamins in aquatic animal breeding. Nutrition in the diet of broodfish is known to have a profound effect on gonad development, fecundity, quality of eggs and larvae. Although precise information on the nutritional requirements of broodstock for gonad maturation is scanty, it has been found that quantity and quality of feed as well as the feeding regime is important for maintenance of egg quality and successful spawning. Vitamins are one of the most effective additives to nutritionally complete diets for fish production. As a fat-soluble vitamin, it is the most effective chain-breaking, lipid-soluble antioxidant in biological membranes, where it contributes to membrane stability. It protects critical cellular structures against damage from oxygen free radicals and reactive products of lipid peroxidation. Aquatic animals have high levels of unsaturated fatty acids to maintain cell membrane fluidity especially at low temperatures; it is assumed that vitamin E plays an important role in this context. This study provides a concise summary of the current body of evidence concerning the physiological roles of VE in farmed fish, as well as the impacts of supplemental VE on fish growth performance and reproduction.

Keywords: Antioxidant; Fish; Vitamin E; Vitamin E/vitamin C interaction

Introduction

The provision of high-quality and cost-effective feed is considered a fundamental requirement for achieving profitability and success in the field of aquaculture [1]. The quality of feed not only affects the overall production, but also has a close connection with the water quality connected with it, hence exerting a substantial influence on the welfare of the species being farmed [2,3]. The effectiveness of feed quality is primarily determined by the proper balance of vital nutrients within the feed. Consequently, feed manufacturers must prioritize this aspect by giving the specific consideration [4].

Micronutrients are defined as the indispensable constituents of feed that are necessitated in minute quantities. Micronutrients have a significant impact on several biochemical, metabolic, and physiological processes in animals, leading to enhanced growth, production, and immunity [5]. The significance of micro-nutrients in the production of farmed aquatic species has been found to be of considerable importance [6,7]. Vitamins and minerals are essential micronutrients that must be obtained from the diet, as animals are unable to synthesize them endogenously. Multiple studies have shown evidence for the beneficial impacts of various micronutrients, such as vitamins and minerals, on the growth, reproductive functions, and immune responses of animals [8]. Vitamin E, functions as an antioxidant, thereby inhibiting the oxidation of crucial fatty acids [9,10]. The researchers noted that the addition of dietary VE supplementation had a substantial positive impact on the production of many species, such as the Indian main carp Rohu (*Labeo rohita*) [11], Yellow catfish (*Pelteobagrus fulvidraco*) [12], and Black Sea bream (*Acanthopagrus schlegeli*) [13]. In a similar vein, the introduction of dietary VE demonstrated a notable enhancement in both the immune response and disease resistance of Japanese flounder (*Paralichthys olivaceus*) [14]. Vitamin E plays a crucial role in the regulation of normal physiological processes and metabolism in fish. Multiple studies have provided confirmation that the administration of VE has been shown to boost the growth, immunity, and illness tolerance of fish [15,16].

This review presents an analysis and discussion of the published studies that examine the importance of undertaking in the context of farmed finfish. The published article has received significant attention.

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Functional Role of VE

The dietary levels of other antioxidants or pro-oxidants, such as vitamin C (VC) or selenium (Se), may also influence VE requirements. In addition, the degree of lipid oxidation may influence the fish's ability to absorb these lipids and modulate their VE antioxidant response [17]. It has been reported that secondary lipid oxidation products influence the sensory properties of oil, whereas primary lipid oxidation products (hydroperoxides) are odorless and tasteless. Consequently, some fish can consume oxidized lipids while others cannot [18]. The modulation of antioxidant enzymes by MCs results in the formation of reactive oxygen species, which can contribute to oxidative damage in animal tissues. When fish were exposed to MCs, lipid peroxidation increased [19], whereas VE supplementation protected the fish from MC-induced oxidative damage in a dose-dependent manner. Consequently, VE administration increases the activities of antioxidant enzymes such as catalase, superoxide dismutase, glutathione peroxidase, and glutathione reductase [20].

Dietary VE supplementation had no effect on liver antioxidant enzyme activities, liver glutathione content, total mercapthans, or phagocytic chemiluminescent response and subjected to normoxic and moderate oxidative stress [21,22]. This moderate protective effect of VE against lipid peroxidation in salmonids may be attributable to the presence of an additional antioxidant, astaxanthin. Astaxanthin can prevent vitamin E from oxidizing, thereby sparing the vitamin E [23,24]. This suggests that it would not be necessary to supplement VE in salmonid diets in order to promote antioxidant defences, overall health, and growth if sufficient quantities of astaxanthin and VE are already present in the feed formulation's raw materials. Vitamin E is essential for fish and prawns because they are rich in polyunsaturated fatty acids (PUFA), which are highly prone to oxidation. Oxidation of PUFA results in the formation of a number of primary and secondary toxic products that can cause a wide range of problems in fish and prawns, such as oxidative stress, a decrease in growth rates, a decrease in immune response, a loss of nutritional value, an unpleasant flavor, or a decrease in quality and shelf life [25,26]. The peroxidation of fatty acid reduces membrane fluidity, increases membrane permeability, and inactivates enzymes bound to the membrane. The antioxidant effectiveness of VE supplementation may also depend on the dietary lipid content or the size and developmental stage of the fish. Therefore, fish that require low levels of dietary lipids require low levels of VE in comparison to fish that require high levels of dietary lipids [27]. In addition, the increase in dietary PUFA increases the VE requirements for antioxidant protection, especially in rapidly growing species and juvenile fish [28-30].

However, excessive production of unsaturated lipid renders membranes more susceptible to oxidative damage, which can impair cellular function. Therefore, antioxidant supplements such as VE can play a significant role in preventing cellular injury in fish. This suggests that the VE requirement for fish increases with decreasing water temperature. In comparison to VE-deficient fish, VE supplementation improved blood parameters and survival of fish species [31]. In addition, dietary lipid levels and sources modulate the response to cold stress [32,33], supporting the adaptive function of VE in aquatic organisms against cold stress.

Vitamin E/Vitamin C ratio for Growth Performance of Fish

Vitamin C is widely recognized as a reducing agent, functioning as an electron donor. It serves as an important antioxidant, effectively scavenging free radicals and reactive oxygen species. Consequently, VC plays a crucial role in preventing cellular damage caused by radicals, safeguarding cell membrane integrity, preserving cytosol components, and facilitating the regeneration of vitamin E when both vitamins are present. The antioxidant action of VC relies on its capacity to replenish or preserve VE from membrane α-tocopherol radicals [34]. This implies that both VC and VE exhibit a synergistic effect in their roles as significant antioxidants, growth promoters, and stimulators of the immunological response. In addition, they fulfil many physiological roles in aquatic creatures that are raised in captivity [35]. Nevertheless, the synthesis of VC within living organisms is not possible due to the absence of the L-gluconolactone oxidase enzyme in fish, which is essential for the biosynthesis of VC [36,37]. Hence, the presence of exogenous vitamin C is crucial for the optimal performance and physiological processes of fish.

Vitamin C, also known as ascorbic acid, is a water-soluble vitamin that possesses antioxidant properties. It has the ability to mitigate oxidative stress in animals by neutralizing the oxidative free radicals generated through cellular processes or external stress-inducing factors [38]. The majority of these radicals are classified as reactive oxygen species, encompassing hydrogen peroxide, hydroxyl radical, and superoxide anion. These species have the potential to inflict harm onto cellular membrane constituents, including lipids, carbohydrates, proteins, and DNA [39].

Inhibition of the fat peroxidation

The vitamin C has the potential to inhibit lipid peroxidation and provide cellular protection against oxidative stress. Comparable findings were also documented in studies conducted on Atlantic salmon [40], Channel catfish [41], and European seabass [42]. These investigations revealed that the inclusion of vitamin C in the diet of these fish species provided protection against vitamin E insufficiency and led to elevated levels of α-tocopherol in their tissues. VC is capable of protecting VE against membrane α-tocopherol radicals, thereby exerting an antioxidant effect [43]. Therefore, the interaction between VC and lipids has an impact on lipid metabolism by promoting the retention of VE (vitamin E) and/or inhibiting the oxidation of VE. This suggests that VC possesses a potent lipid antioxidant effect, which works in conjunction with VE to enhance the overall health and vitality of fish. The VC-VE interaction mechanism has been associated with the differential susceptibility to VE deficiency observed in various species of farmed fish [44,45].

The growth performance of channel catfish was found to be impaired when they were fed diets lacking in vitamin VC, irrespective of supplementation with vitamin E. Moreover, the presence of vitamin E deficiency symptoms was not observed in fish that were provided with a diet lacking in VE but supplemented with vitamin C [46,47]. The preventive function of VC in situations where VE is lacking or insufficient has been observed in rainbow trout and Atlantic salmon [48,49]. The assessment of antioxidant enzyme activity, such as superoxide dismutase, catalase, or glutathione peroxidase, can serve as a reliable measure of lipid peroxidation and the resulting cellular harm [50-53]. The heightened release of these enzymes serves to inhibit lipid peroxidation and mitigate cellular harm. The simultaneous presence of vitamin VE and VE in suitable proportions can produce combined antioxidant actions, resulting in the regulation of the oxidative stress indicators discussed earlier, protection against cellular damage caused by free radicals, and inhibition of lipid peroxidation [54]. Moreover, the inclusion of a high concentration of dietary VC resulted in a notable decrease in the levels of secondary lipid oxidation products, specifically thiobarbituric acid reactive substances, in hybrid Tilapia (*Oreochromis niloticus* × *O. aureus*) that were fed a diet lacking in vitamin E [55].

However, an excessive intake of vitamins C and E can lead to their pro-oxidant properties being manifested in living organisms, resulting in the occurrence of oxidative stress. The use of excessive quantities of vitamins can result in a notable decrease and disruption in the VC/VE ratio, hence hindering the ability to restore VE levels with VC supplementation [56].

Growth performance and health condition of VE/VC supplemented diet

The supplementation of dietary VC resulted in an elevation in liver VE concentration, however the administration of supplementary VE did not have any impact on liver VC levels [57-58]. In contrast, the administration of high amounts of dietary VC or VE did not yield any significant enhancement in the immunological response. The addition of supplemental VC at a dosage of 100 mg kg^{-1} feed resulted in enhanced growth, feed efficiency, survival rates, and improvements in haematological parameters. Furthermore, the inclusion of VC in the diets of catfish effectively avoided the occurrence of vertebral deformities [59]. The supplemetation of dietary VC intake resulted in an elevation of liver α-tocopherol levels, so providing evidence to support the hypothesis that VC has a sparing impact on vitamin E [60-62].

The optimal growth, immunological response, and disease resistance of fish are dependent on the ratio between vitamins C and E in their meals. Previous studies have indicated a potential mitigating effect of VC on VE when administering large doses of VC to diets lacking in VE. The phenomenon of VE sparing has been documented in various species, including Atlantic Salmon, hybrid Tilapia, and Channel catfish [63-65]. The inclusion of approximately 100 mg of dietary VC/kg of feed significantly enhanced the development and feed efficiency of Nile Tilapia. On the other hand, the level of vitamin E present in the basal diet was shown to be adequate in supporting the overall performance of the fish [66-69]. However, a dosage of 50 mg of vitamin E/kg of body weight was found to be essential for achieving the highest level of survival in cases when dietary vitamin C was insufficient [70-74].

Lipid interaction with VE

The fish diets and tissues containing significant amounts of highly unsaturated fatty acids (HUFA) are susceptible to lipid oxidation, which releases a number of toxic byproducts and causes a number of animal problems [75-79]. As an antioxidant, the presence of VE in the fish body prevents lipid oxidation, whereas a decrease in VE concentration decreases the VE/PUFA ratio [80]. Through the regulation of the microsomal electron chain, which is a component of the desaturase complex, VE also plays an important role in the desaturation of n-3 and n-6 PUFA [81-82]. This means that as the HUFA content of a fish's diet increases, so does its demand for VE [83,84]. In support, vitamin E requirement of Common carp (*Cyprinus carpio*) [85], Blue tilapia (*Oreochromis aureus*) [86], Grouper (*Epinephelus malabaricus*) [87] increased with in- creasing dietary lipid (PUFA) levels. A high supplementation of VE (200 mg kg^{-1} diet) substantially decreased liver VE when fish oil was added to the diet. These findings support VE's function as an antioxidant that prevents lipid oxidation.

It has also been reported that the use of oxidized oil in fish diets causes skeletal abnormalities [88], lowers blood glucose [89], increases haemoglobin level and glycolytic activity [90], and decreases VE concentration in fish tissues [91]. Appropriate levels of -tocopherol supplementation can partially or completely alleviate these symptoms. In contrast, as lipid peroxidation of frozen seafood products progresses, α-tocopherol concentrations in these products decrease [92]. This, in turn, causes the grade of seafood to decline. Supplementation of VE to oxidized lipid in aquaculture feed has been shown to reduce lipid peroxidation and enhance fish performance, health status, and product quality, as demonstrated in Sea bream (*Acanthopagrus schlegeli*) [93], hybrid Tilapia (*Oreochromis niloticus X Oreochromis aureus*) [94] and Turbot (*Scophthalmus maximus*) [95] and Gilthead Sea bream (*S. aurata*) [96].

Impacts of VE with dietary selenium (Se)

The beneficial synergistic effects of dietary selenium (Se) and vitamin E (VE) were seen in Grouper (*Epinephelus malabaricus*) [97-99] and Yellowtail kingfish (*Seriola lalandi*) [100]. The growth rates of fish fed diets with low levels of or lacking in vitamin E were enhanced by the addition of supplementary selenium. Furthermore, the concurrent administration of both selenium and vitamin E resulted in improved growth and health indices. Additionally, the growth, intestinal health, blood parameters, oxidative status, and immune related gene expression of Nile Tilapia (*O. niloticus*) [101] and Rainbow trout were enhanced with food supplementation of Nano Se and/or VE [102].

The concurrent presence of micronutrients yields synergistic effects in the regulation of haematological responses associated with high density stress. According to findings in rainbow trout, the implementation of this approach has the potential to mitigate the consequences of oxidative stress, enhance antioxidant levels, and bolster innate immunological reactions [103]. Extensive research has been conducted on the interplay between VE and Se in various fish species to support the notion that VE and Se exhibit a synergistic effect, resulting in the preservation of each other's metabolic demands. Additionally, a lack of dietary selenium (Se) can lead to decreased levels of tissue vitamin E, while a deficiency in both micronutrients can result in conditions such as anaemia, muscular dystrophy, and abnormal protein levels in the plasma [104-107]. This implies that adequate supplementation of either vitamin E or Selenium can compensate for the lack of the other nutrient. Both Se and VE are recognized as important biological antioxidants that play a crucial role in preventing the oxidative damage of cell membranes resulting from the peroxidation of polyunsaturated fatty acids (PUFAs) [108-110].

The inclusion of Selenium has the potential to decrease the dietary vitamin E required for maintenance purposes, as well as enhance the preservation of VE in animal tissues and blood plasma lipoproteins. Likewise, vitamin E have the capacity to diminish the Selenium necessity by impeding the depletion of Selenium within the body or by upholding its bioactive state. Research has indicated that the inclusion of both Vitamin E and Selenium in the diet of fish can effectively shield them against oxidative damage caused by the oxidation of dietary oil. Previous studies have also reported the absence of synergistic effects of dietary vitamin C, vitamin E, and Selenium on the growth performance of Nile Tilapia [111]. Nevertheless, the provision of adequate dietary supplementation of VE or VC individually resulted in a significant enhancement of growth performance.

Dietary VE requirements for fish growth

It is important to highlight that there are several interactions between VE and other nutrients, including VC, selenium, and dietary lipid levels and composition, which have an impact on fish performance and health status. Hence, it is imperative to consider these interactions when establishing the dietary VE requirement for aquaculture fish. Furthermore, it is important to note that the VE need may vary across different response variables. To clarify, the quantity of vitamin E needed for various biological processes such as development, antioxidant capacity, immune response, meat quality, and reproductive effectiveness can exhibit substantial variations across species and even within different size categories within the same species.

Vitamin E requirements for fish

The VE need of cultivated fish exhibits considerable variation, contingent upon factors such as the species and size of the farmed fish, the sources and quantities of dietary lipids, and the conditions under which they are cultured. The dietary need of VE is significantly influenced by the function for which it is provided. Several freshwater fish species were shown to have relatively low voluntary energy (VE) requirements, which can be attributed to their diets including comparatively low levels of lipids. For instance, a dosage range of 40-66 mg VE kg^{-1} feed was shown to be effective in enhancing the growth performance of sub-adult Nile Tilapia [112,113].

However, a greater dosage range of 100-200 mg VE kg^{-1} was necessary for achieving similar results in fingerlings [114]. A significant increase of over ten times in vitamin E was required to enhance fillet texture and serum antioxidant capacity. Similarly, a higher VE retention was observed in fish flesh, along with the activation of the immune system response and antioxidant capacity in fish [115]. The optimal performance of Blunt snout bream (*Megalobrama amblycephala*) larvae (0.59 g) was observed when a low dietary VE concentration of 55.5 $mgkg^{-1}$ was provided [116]. Nevertheless, it has been observed that the early developmental phases of Grass carp (*Ctenopharyngodon idellus*) [117] and Rohu (*Labeo rohita*) [118] exhibit a greater demand for vitamin E compared to their later stages of growth.

Within a single species, the need for vitamin E can also change as a species develops. In contrast to sub-adult fish, which need substantially greater VE concentrations in their diets for improved non-specific immune responses and high VE retention in the liver, kidney, muscles, and gonads, juvenile eels (15 g) require very little VE (21 mg kg^{-1}) for optimal growth [119]. These results clearly show that a variety of factors influence the VE requirements of farmed fish. To get accurate data and create meaningful comparisons, these elements should be considered when evaluating the VE requirements of farmed fish.

The development rates, feed efficiency, and antioxidant activity of Channel catfish (*Ictalurus punctatus*) and Yellow catfish (*Pelteobagrus fulvidraco*) were supported by small quantities of VE (33–45 mg kg^{-1}). However, a notably greater quantity of VE was needed for Dark barbel catfish (*Pelteobagrus vachelli*) to function at their best [120-124]. The variations in fish sizes and developmental stages, food lipid levels and sources, fatty acid content, and water temperature have all been linked to these disparities. For instance, compared to dark barbel catfish, which require roughly 20% of their diet in lipids, Yellow catfish require significantly less (approximately 8–11%), which may account for the latter species' higher VE requirement [125-130]. Furthermore, the antioxidant activities and immunological response of yellow catfish were found to be strongly influenced by the fatty acid profiles and dietary lipid sources [130-134]. The growth performance Yellow catfish and antioxidant response were enhanced by modest amounts of dietary arachidonic acid (ARA). The growth performance, immunological response, and antioxidative activity of these fish have all been optimized by the ideal pairing of lipid level [135-136].

Due to the high levels of lipids and n-3 HUFAs in marine fish diets, it is reasonable to infer that marine fish have higher VE requirements than freshwater fish. However, this may not always be the case, as some marine species require low dietary VE levels for optimal performance. For optimal performance, Grouper (*Epinephelus malabaricus*), European Sea Bass (*Dicentrarchus labrax*), Coho Salmon [110], and Cobia (*Rachycentron canadum*) [125] require less than 100 mg VE kg^{-1} of forage. In addition, only 38 mg VE kg^{-1} was adequate to sustain the growth of Parrotfish (*Oplegnathus fasciatus*), despite the fact that >500 mg kg^{-1} was required for optimal immune response [137-139].

In contrast, other marine fish species require much higher levels of dietary VE for growth and health. For example, subadult Gilthead Sea Bream requires 1200 mg kg^{-1} of food for optimal health and non-specific immune response [140]. In addition, it has been reported that larval Sea Bream supplement their diet with significantly more VE [29,30]. The highest survival, growth, and osteocalcin gene expression, as well as the lowest incidence of bone anomalies, were observed at 1783, 1921, and 7000 mg kg^{-1} VE, VC, and taurine, respectively [29]. Moreover, when Gilthead Seabream larvae are fed exceedingly high levels of dietary HUFA, it appears that even higher levels of dietary VE are required for optimal performance [30]. This study also demonstrates the antioxidant effect of VE and suggests a greater protection value when HUFA are scarce. Increasing dietary VE and VC to 3000 mg kg^{-1} results in an unbalanced VC/VE ratio in the body, up-regulation of antioxidant enzyme genes, the highest incidence of bone anomalies, and the lowest survival rates [141].

The previously mentioned factors (fish sizes and maturation stages, dietary lipid and fatty acid profiles, other micronutrients, water temperature, etc.) that influence the VE requirement of freshwater fish may also influence the response of marine fish to dietary VE. Due to the high dietary content of LC-PUFA and pro-oxidants such as minerals, marine fish larvae fed inert diets become extremely susceptible to oxidative stress [71]. As reported in Sea Bass larvae, the inclusion of high levels of anti-oxidants in the diet, such as VE, is necessary to prevent oxidative damage and enhance larval survival and performance [142]. These studies also demonstrated that the presence of other dietary nutrients, such as VC, Se, and taurine (and their ratios with VE), modulates the VE requirements of marine fish [29,71] Also in meagre, the VE requirement (800 mg kg^{-1}) is higher in the early phases of life than in the later stages of growth [36].

A number of studies indicated that dietary VE supplementation considerably improved the quality of various fish products. When Coho Salmon were fed various antioxidants, a VE-supplemented diet produced the greatest sensory and physical qualities in the long-term frozen salmon product [143-145]. Textural characteristics, cohesiveness, and chewiness of GIFT fillets significantly more Nile Tilapia were produced by fish fed VE-supplemented diets than by those fed VE-deficient diets [144]. In addition, the addition of VE increased serum and muscle SOD and CAT activities, and decreased serum and muscle MDA levels, supporting the antioxidant role of VE. Also, as dietary VE increased, muscle HUFA in Meagre (*Argyrosomus regius*) increased and saturated fatty acids and TBARS values decreased [34]. Similarly, a positive correlation was observed between dietary VE levels and concentrations of α -tocopherol in Turbot (*S. maximus*), Atlantic Halibut (*H. hippoglossus*), and Rainbow Trout fillet [142,146]. In addition, prolonged feeding with high VE diets increased the proportion of total USFAs, PUFAs, and n-3 fatty acids, while decreasing the proportion of Saturated Fatty Acids (SFAs) and n-6 fatty acids. In addition, the addition of tocopherols substantially decreased TBARS levels in Carp (*Ciprinus carpio*) fillets stored at 5°C when compared to samples lacking tocopherols [147].

As evidenced in the case of Red Sea Bream (*Pagrus major*), vitamin E may also improve the fillet quality of fish fed Oxidized Fish Oil (OFO) [120] Compared to fish fed raw oil, fish fed OFO had higher fillet TBARS values and lower VC and VE concentrations during storage. In addition, supplementation with VE increased fillet VE levels and decreased fillet TBARS values, whereas supplementation with VC had no effect on fillet quality parameters. Consequently, the positive effects of VE on the fillet quality of fish fed OFO have been linked to the reduction of lipid peroxidation, saturated fatty acids, and TBARS values, in addition to the increase in VE body content [88,95,138]. Other antioxidants, such as VC and Se, may also contribute to the quality of fish fed OFO.

Reproductive performance of fish treated with VE supplemented feed

It has been hypothesized that quickly expanding tissues exhibit elevated metabolic rates, leading to the generation of significant levels of free radicals [148]. The present study revealed that the levels of antioxidant enzymes, namely lipoxygenase, Superoxide Dismutase (SOD), Catalase (CAT), peroxidase, and glutathione reductase, exhibited an upward trend in five distinct species of fish inhabiting the Black Sea. Notably, this increase was observed during the developmental stages of eggs and continued until the hatched larvae phase. This implies that the inclusion of antioxidants is essential for safeguarding tissues against peroxidation, so indicating that VE may have a notable impact on these metabolic processes. Regarding this matter, elevated concentrations of VE were detected in the eggs and seminal fluid of European Seabass (*Dicentrarchus labrax*) both prior to and following egg fertilization. Furthermore, during the developmental stages of the embryos and upon hatching, substantial quantities of VE were also present. Conversely, deceased eggs and embryos with low survival rates exhibited diminished levels of VE [149]. The results of this study indicate that VE plays a crucial role in the growth and maturation of eggs and larvae in this particular fish species. Furthermore, the incorporation of VE and Arachidonic Acid into the diet resulted in a combined impact that enhanced non-specific immune responses in broodstock of the Japanese Eel species (*Anguilla japonica*) [150]. A positive linear connection was observed between the intake of dietary VE and the concentration of VE in the ovarian tissue.

The dietslacking in VE have been observed to result in under developed reproductive organs, reduced rates of egg fertilization and hatchability, and decreased survivalrates of larvae [134,137,138,139] When Zebrafish (*Danio rerio*) and Goldfish (*Carassius auratus*) brood stock were provided with diets deficient in VE, they displayed reduced reproductive capacity and delayed spawning. Further more, the viable embryos produced by these brood stock had lower concent rations of VE, and exhibited higher rates of malformation and mortality compared to embryos from brood stock that were fed diets supplemented with VE.

Themobilization of Vitamin E, primarilythroughlipoproteins, has been documented during vitello genesis in various fishspecies [138-140]. During the reproductive season, it was observed that the inclusion of a VE-supplemented meal (1000 mg kg^{-1}) in the feeding regimen of Japanese Flounder *(Paralichthys olivaceus)* broodstock resulted in the association of α-tocopherol with vitello genesis. Further more, it was found that α-tocopherol was carried to the gonads and retained the rein. Following the initiation ofdevelopment, serum α-tocopherol was subse quentlymixed with the progress ivelyrising lipoprotein. Moreover, theadministration of vasotocinanaloguestoprimarypituitarycellscultured in vitro has been shown to induce the upregulation of gonad otropin hormones, specifically Follicle-Stimulating Hormone (FSH) and LuteinizingHormone (LH), in thepituitarygland of Turbot (*Scophthalmus maximus*) [141].

Environmental implications and recommendations

There is ample evidence available that clearly demonstrate an increase in vitamin E requirements after consuming high levels of dietary n-3 polyunsaturated fatty acids, such as those found in fish oil. Given the anticipated significant incorporation of plant proteins and oils, namely n-6 Polyunsaturated Fatty Acids (PUFA), in fish diets, it is plausible that reducing dietary Vitamin E levels may be necessary to enhance fish performance and mitigate lipid peroxidation [25]. The nutritional needs of fish may undergo alterations in response to the presence of other micronutrients,such as Se and VC, which interact with VE. This implies that future study should prioritise the reassessment of these micronutrients,given the anticipated formulations of plant-based aquafeed.

The utilization of plant proteins and oils,particularly those from oilseeds, has been experiencing a notable increasein their application within aquafeeds. Extensive study has been conducted on the partial or complete replacement of fishmeal and fish oil with plant-derived alternatives [146].Based on the aforementioned forecast, it is probable that there would be a substantial decrease in the utilization of fishmeal and fish oil in fish diets. As a result, it is probable that the requirements for VE will undergo modifications.

Fish has the ability to acclimatize to fridge temperature through the process of biochemical control, namely by modulating the fluidity of the membrane bilayer. This adaptive mechanismis crucial for maintaining optimal cellular functionality under low temperature conditions [37,38]. In such circumstances, the maintenance of membrane homeostasis is ensured through the synthesis of abundant quantities of low molecular weight, unsaturated fatty acidsinside the lipids of cellular membranes [39]. Increased lipid unsaturation in cellular membranes can lead to heightened susceptibility to oxidative damage, resulting in potential impairment of cellular functioning.This implies that Vitamin E may have a noteworthy impact as an antioxidant in mitigating the anticipated cellular harmcaused by low temperatures. Antarctic fish exhibit significantly higherplasma VE concentrations compared to temperate water fish species [147].

In terrestrial vertebrates, such as land animals, elevated temperatures have been observed to decrease the levels of many vitamins, including VE, and micro minerals in the serum [148]. Given that VE is recognized as the primary defensive mechanism against lipid peroxidation induced by heat stress, it is advisable to increase the dietary intake of this micronutrient, together with other essential vitamins and minerals, in order to mitigate the effects of heat stress [149]. The fish had reduced levels of visceral VE concentrations, haematological parameters, alternative complement activity, and survival when subjected to stressful water temperatures and fed a diet lacking in VE, in comparison to those that were provided diets enriched with VE [150].

Conclusion

Farmed fish are subjected to different types of stress, in cluding grading, transfer, crowding, and vaccination, which can expose the fish to differen trisks leads to an increase in the spread of diseases, negatively affecting on the growth of fish, causing fish to be exposed to oxidative stress. The trace elements which is utilized by the organism in both organic and inorganic forms can improve the performance and health of fish through its entry into the synthesis of antioxidant enzymes. The most important action of Seleniumis its action as an antioxidant, which is the formation of selenocysteine, which is part of glutathione peroxidase, and therefore Selenium affects the activity of glutathione peroxidase. Vitamin E is an essential fat-soluble antioxidant that prevents oxidation and the formation of free oxygen radicals in the lipids of cell membranes. By enhancing immune system function, stress reduction, and boosting disease resistance, vitamin E is also crucial for promoting fish health. In farmed fish, optimal vitamin E levels have been shown to enhance stress to lerance, antioxidant properties, and growth performance. The inter action of Selenium and vitamin E has been discovered to have a strong synergis ticeffect.

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