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Role of Vitamin E on Growth Performance, Immunity and Flesh Quality of Fish

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Vitamin E, a fat-soluble antioxidant, plays a crucial role in maintaining the health and well-being of fish. This review explores the multifaceted benefits of vitamin E in fish, focusing on its role in growth promotion, immune system enhancement, and improvement of flesh quality. Vitamin E acts as a potent antioxidant, protecting cells and tissues from oxidative damage caused by reactive oxygen species (ROS). By neutralizing these harmful free radicals, vitamin E helps maintain cellular integrity and prevents oxidative stress-induced diseases. The growth-promoting properties of vitamin E in fish are attributed to its involvement in various physiological processes. Firstly, it enhances nutrient absorption and utilization, resulting in improved feed conversion efficiency and overall growth rates. Secondly, vitamin E supports the biosynthesis of proteins, lipids, and nucleic acids, crucial components for tissue growth and repair. Furthermore, it has been observed that vitamin E supplementation positively affects the development of skeletal structures and enhances muscle growth, leading to improved flesh quality. In addition to growth promotion, vitamin E plays a pivotal role in boosting the immune system of fish. It strengthens the fish's defense mechanisms by enhancing the production and activity of immune cells, such as lymphocytes and phagocytes. Moreover, vitamin E enhances the antibody response, improves vaccine efficacy, and reduces susceptibility to infectious diseases. By reducing inflammation and modulating immune responses, vitamin E helps maintain optimal health and disease resistance in fish. The quality of fish flesh is a critical factor for both aquaculture and the seafood industry. Vitamin E supplementation has been shown to enhance the sensory attributes and nutritional value of fish flesh. It inhibits lipid oxidation, thereby preserving the freshness and preventing the development of off-flavors in stored fish. Moreover, vitamin E improves the texture, color, and juiciness of fish meat, enhancing its market value and consumer acceptance.

Keywords

Vitamin E, Antioxidant, Growth promotion, Immunity, Flesh quality

Introduction

Vitamins are chemical compounds that are important for animal spermatogenesis and oogenesis as well as for health, growth, and maintenance. The vitamins must be obtained from the diet, because fish cannot synthesize vitamins at all or synthesize them in insufficient amounts for normal development, growth, and maintenance, they must be supplied through diet (Falahatkar et al., 2011). While fishes can obtain some essential vitamins from their diet, it is sometimes necessary to supplement their food with specific vitamins to ensure optimal growth and development. Vitamin E functions as an antioxidant and aids in preventing oxidative cell damage. It promotes fish growth and development and immune system support. Vitamin E comes in eight different forms, but alpha-tocopherol has the most significant effect on the structure of fish. Most vitamin supplements are available in this form. Unsaturated fatty acids are stabilized by vitamin E, also known as α-tocopherol, which is a fat-soluble intracellular antioxidant (Hepher, 1988). Additionally, vitamin E helps to maintain healthy blood capillary permeability and the strength of the heart muscle. Vitamin E plays a crucial role in the growth, immunity, and flesh quality of Indian major carp, which is an important fish species in aquaculture. The availability of vitamins E (tocopherol) is the most crucial nutrients impacting the immune system, can decrease fish mortality and boost growth (Montero et al. 2001, Shiau and Hsu 2002). By decreasing fatty acid peroxide radicals, vitamin E breaks the process of lipid oxidation to produce fatty acids. The effect of vitamin E on both male and female reproductive performance must be emphasized. Vitamin E-deficient fish have been found to exhibit a variety of clinical symptoms, including poor development, exopthalmia, ascites, erythrocyte fragility, anisocytosis, microcytic anaemia, dermal depigmentation, and lordosis (Woodall et al., 1964; Murai and Andrews, 197 4; Smith, 1979; Reaid et al., 1981). Literature review reveals the quantification of Vitamin E supplement in the diet of fastest growing IMC.

Analytical methods for tocopherols in fish diet

Titrimetric or, currently, instrumental approaches such as electrochemical, fluorometric, spectrophotometric gas chromatography (GC), and high-performance liquid chromatography (HPLC) are available for the determination of tocopherols content in fish diet (Moszczynski and Pyc 1999), although some drawbacks and restrictions prevail. Recently, spectrophotometric approaches for determining antioxidative vitamins were modified to be more practical in analytical praxis (Rutkowski and Grzegorczyk, 2007).

Diet formulation and preparation

Formulation and preparation a diet with adequate levels of vitamin E for fish involves several steps.

Determine Vitamin E Requirements

Scientific literature, nutritional guidelines, or expert advice are required to be consulted to determine the specific vitamin E requirements for the reared fish species. Vitamin E requirements can vary depending on the species, life stage, size, and environmental conditions. (Hidiroglou *et al*., 1992).

Select Vitamin E Sources

Vitamin E can be obtained from natural sources or synthetic forms. Natural sources include vegetable oils like soybean oil, wheat germ oil, and fish oil. Synthetic forms, such as dl-alpha- tocopherol acetate, are also available (Rizvi et al., 2014; Pignitter et al., 2019). Suitable vitamin E source can be selected based on availability, cost, stability, and the specific needs of the fish species (Cantoni et al., 2008).

Calculate Inclusion Levels

Once the vitamin E requirement and source are determined, inclusion levels to meet those requirements need to be calculated by considering factors such as the nutrient density of the diet, the inclusion level of other ingredients, and the expected feed intake by the fish.

Formulate the Diet

A feed formulation software in manually form an aquaculture nutritionist needed to be consulted to develop a balanced diet for meeting the nutritional requirements of the fish, including the desired level of vitamin E, where the fare consideration of other essential nutrients such as protein, lipids, carbohydrates, vitamins, and minerals to be ensured for a well-rounded diet.

Ingredient Selection

Selection of appropriate feed ingredients, including vitamin E-containing vegetable oils, fish oils, or specific vitamin E supplements, such food supplements and ingredients need to be of good quality and meet safety standards.

Manufacturing and Mixing

Good manufacturing practices (GMP) and utilization of proper equipment to mix and process the feed. Add the selected ingredients, including the vitamin E source, to the feed mixer and ensure thorough and uniform mixing.

Quality Control

Implementation of quality control measures throughout the manufacturing process is necessary. This may involve analysing feed samples to verify the nutrient content, including the vitamin E level, and ensuring that the formulated diet meets the desired specifications. Regular monitoring of the quality and stability of vitamin E during storageis admissible.

Feed Management

Proper storage and handling of the formulated feed to maintain its nutritional integrity need to be ensured. Recommended feeding practises must consider factors such as feed presentation, feeding frequency, and feeding rates to optimise nutrient intake by the fish (Eriegha et al., 2017).

Requirement of vitamin E in fish

Adequate vitamin E supplementation in fish diets under intensive rearing is essential for survival and growth performance (Chagas *et al.,* 2003). In addition, vitamin E is a potent antioxidant that offers protection against oxidative damage to various fish tissues (Rainis *et al.,* 2007), enhances the resistance of red blood cell membranes (Kiron *et al.,* 2004), and protects leukocyte functions (Sahoo and Mukherjee, 2002). The effect of vitamin E on female and male reproductive performance is important too. According to Serezli *et al*. (2010), egg size is not affected by dietary vitamin E dose, but there is a positive relationship between total fecundity and dietary vitamin E dose, especially at the first stripping. This further supports the point that vitamin E is essential for the reproductive performance of fish. Vitamin E is an indispensable nutrient required to maintain flesh quality, immunity, normal resistance to red blood corpuscle haemolysis, permeability of capillaries, and heart muscle (Halver, 2002). Dietary requirements of vitamin E (tocopherol) have been demonstrated in a number of fish species (NRC, 1993). Feeding high-HUFA (highly unsaturated fatty acid) diets results in increased peroxidation stress in juvenile marine fish (Tocher *et al.,* 2002). This caused a higher requirement for vitamin E in fish species (Hamre and Lie, 1995). The capabilities of the antioxidant system may be species-dependent and perhaps related to developmental stage (Tocher *et al.,* 2003). Deficiency signs of vitamin E are poor growth, erythrocyte fragility, anaemia, epicarditis, ceroid in the spleen, and muscle dystrophy (Halver, 1995). The Indian major carp species *Labeo rohita* (rohu), *Cirrhinus mrigala* (mrigal), and *Catla catla* (catla) are cultured throughout the country and enjoy consumer preference. Feeding high-HUFA (highly unsaturated fatty acid) diets results in signs of increased peroxidation stress in juvenile marine fish (Tocher *et al., 2002).* This caused a higher requirement for vitamin E in fish species (Hamre and Lie, 1995). The capabilities of the antioxidant system may be species-dependent and perhaps related to developmental stage (Tocher *et al.,* 2003).

Positive benefits of vitamin E supplementation in fish diets

Tocopherols protect food from oxidation by protecting the stability of oils and fats (Tangolar *et al.,* 2011). The antioxidative functions of vitamin E include the scavenging of free radicals to terminate lipid peroxidation, which can initiate damage to unstable intracellular components including membranes, nucleic acids, and enzymes, thereby resulting in pathological conditions and indirectly resulting reduced growth (Agradi *et al*., 1993; Paul *et al*., 2004). Lipid peroxidation in body tissues decreases when dietary vitamin E increases (Huang *et al*., 2004).

Deficiency of Vitamin B

A condition in which adverse effects are caused by taking too much of one or more vitamins is called hypervitaminosis. Hypervitaminosis of E results in poor growth, toxic liver reactions, and death (Udo et al., 2013). Poston and Livingston (1969) reported that lower hemocrit was observed in brook trout fry fed a diet containing a high level of vitamin E (5000 mg/kg). Baker and Davies (1996) also reported that African catfish fed a high -tocopheryl acetate dose (500 mg/kg dry feed) were observed to have significantly lower hematocrit than fish fed the basal diet. However, Bai and Lee (1998) showed in *Sebastes schlegeli that the* hematocrit of the fish fed the control group was lower than that of the fish fed a high level of vitamin E. High vitamin E doses (1000 mg kg-1) result in undesirable immunological effects, either as an immunoglobulin reduction or from leucocyte phagocytosis (Kiron *et al.,* 2004; Puangkaew *et al.,* 2004) and leucocyte number (Puangkaew *et al.,* 2004). Among tilapia, Hussein *et al.* (1996) and Ispir *et al.* (2011) also reported low hemocrit, erythrocytes, and haemoglobin concentrations in *Oreochromis aureus* and *O. niloticus,* respectively. Tocopherol deficiency is caused by mutations in the tocopherol transfer protein and a low dietary intake of the vitamin (Ouahchi *et al.,* 1995). One of the first signs of vitamin E deficiency is erythrocyte fragility, closely followed by anaemia, ascites, xerophthalmia, poor growth, poor food conversion, epicarditis, and ceroid deposits in the spleen and liver (Halver, 2002). Symptoms of low vitamin E levels include ataxia, anaemia caused by the breakdown of red blood cells, and peripheral neuropathy (Ouahchi *et al.,* 1995). Non-specific forms of degenerative conditions have been described in several species of fish fed large quantities of polyunsaturated fatty acids with inadequate tocopherol in the ration.

Role of vitamin E to increase the growth and immunity of fish

The precise mechanisms by which vitamin E promotes fish growth are not fully understood, but several processes are thought to contribute to its growth-enhancing effects. (El-Sayed and Izquierdo, 2021)

Enhanced Protein Synthesis

Vitamin E is involved in protein synthesis, which is crucial for growth and development in fish. It promotes the production of proteins needed for muscle growth, tissue repair, and enzyme function (Roem et al., 1990; Huang and Huang, 2004; Lygren et al., 2001; Wu et al., 2017). By facilitating protein synthesis, vitamin

E supports overall growth (Lu et al., 2016, Bae et al., 2013, Amlashi et al., 2011).

Improved Nutrient Absorption

Vitamin E has been shown to enhance the absorption and utilisation of dietary nutrients, particularly lipids and fatty acids, in fish. These nutrients provide energy and are essential building blocks for growth. By improving nutrient absorption, vitamin E ensures that fish can efficiently utilise available nutrients to support growth (Amlashi et al., 2012).

Antioxidant Protection

Vitamin E is a potent antioxidant that helps protect cells and tissues from oxidative stress. Oxidative stress can impair fish growth by damaging cellular structures, including proteins and DNA (Valko et al., 2005; Livingstone, 2003; Halliwell 1999). By neutralising harmful free radicals and reducing oxidative damage, vitamin E supports optimal cellular function and growth (Tocher et al., 2002).

Immune System Support

A healthy immune system is crucial for fish growth. Vitamin E plays a role in maintaining immune function by supporting the integrity of immune cells and enhancing their ability to respond to infections and diseases (Meydani et al., 2018; Wu et al., 2008; Pae et al., 2017). By keeping fish healthy and disease-free, vitamin E indirectly promotes growth.

Hormonal Regulation

Vitamin E is involved in the regulation of various hormones in fish, including growth- promoting hormones like insulin-like growth factor (IGF-1) (Cheng et al., 2018). These hormones play a key role in regulating growth processes such as cell division and protein synthesis (Cao et al., 1989; Duan et al., 1993a; Duguay et al., 1994; Sakamoto and Hirano, 1993; Shamblott et al., 1995; Duguay et al., 1996; Kajimura et al., 2001; Shepherd et al., 1997; Maures et al., 2002; Hashimoto et al., 1997; Vong et al., 2003). By modulating hormone levels, vitamin E can influence growthrates in fish.

Enhancing Disease Resistance

Vitamin E supplementation has been shown to enhance disease resistance in fish. It can improve the fish's ability to fight off infections and reduce the severity and duration of diseases (Blazer and V. S, 1992). By boosting the immune system, vitamin E helps fish mount a stronger immune response, leading to better resistance against various pathogens, including bacteria, viruses, and parasites (Kiron et al., 2004; Puangkaew et al., 2004).

Stress Reduction

Fish can experience stress due to various factors, such as changes in environmental conditions, handling, transportation, or crowding. Stress can weaken the immune system, making fish more susceptible to diseases. Vitamin E has been found to have stress-reducing effects in fish by minimising the negative impact of stress on the immune system (Lewis et al., 2019). By supporting the immune system, vitamin E helps fish cope better with stressful situations and maintain their overall health.

Vitamin E plays an important role in improving the flesh quality of fish

In semi-intensive and intensive culture methods, the quality of the nutrition and feed can have an impact on the nutritional value, colour, texture, fragrance, and appearance of the product (Khan *et al.*, 2011). Various scientists have already undertaken some research on these sensory qualities of fish flesh in relation to water quality, nutritional therapies, and artificial feeding (Oliveira *et al.*, 2006; Kilinc *et al.*, 2009; Ng and Bahurmiz, 2009; Sehgal *et al.,* 2010; Brinker and Reiter, 2011).

Antioxidant Protection

The importance of vitamin E as an antioxidant is incomparable (Steven Craig, 2002). Vitamin E is a potent antioxidant that protects fish flesh from oxidative damage. As fish are exposed to oxygen during handling, processing, storage and cooking, they are susceptible to oxidation, leading to the breakdown of fats and proteins and the development of off-flavors and rancidity taken place (El-Shebly and A. A, 2009). Vitamin E prevents such oxidation by neutralizing harmful free radicals and reducing lipid peroxidation, thereby preserving the quality and flavor of fish flesh especially fatty fish.

Shelf-Life Extension

By inhibiting oxidation, vitamin E extends the shelf life of fish & fishing products. It prevents the formation of off-flavors and odors, preserving the freshness and overall quality of the fish flesh during storage and transportation.

Texture Preservation

Fish flesh quality is influenced by its texture, including firmness and tenderness. Vitamin E helps maintain the integrity and texture of fish flesh by protecting the structural proteins, such as collagen and myosin, from oxidation. This preservation of protein structure contributes to improved flesh firmness and prevents softening and degradation.

Color Retention

Vitamin E also aids in maintaining the color of fish flesh. Oxidation can cause discoloration, leading to a loss of the desirable bright and natural color of fish. By inhibiting oxidation, vitamin E helps retain the attractive color of fish flesh, making it visually appealing to consumers. Nutritional Value Apart from its antioxidant properties, vitamin E is also an essential nutrient for fish. It contributes to overall fish health and well- being, enhancing growth, reproduction, and immunity (Sayed et al., 2022). Healthy and well-nourished fish are more likely to have better flesh quality.

Conclusion

The role of vitamin E in the growth performance, immunity, and flesh quality of fish has been extensively studied and recognised. Vitamin E, a potent antioxidant, plays a crucial role in the growth, development, and overall health of fish. It is involved in various physiological processes, including the maintenance of cell integrity, protection against oxidative stress, and modulation of immune responses. It promotes efficient nutrient utilisation, enhances feed efficiency improves weight gain and growth rates in fish. Its multifaceted benefits include promoting growth by improving nutrient utilisation and tissue development, enhancing immune responses, and improving the sensory attributes of fish flesh. Understanding the role of vitamin E in fish nutrition and incorporating appropriate supplementation strategies can significantly enhance the health, productivity, and marketability of fish in the aquaculture and fisheries sectors.

Author contributions

All authors listed have made a substantial, direct, and intellectual contribution to the work, and approved it for publication.

Conflict of interest

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References

Amlashi, A. S., Falahatkar, B., & Sharifi, S. D. (2012). Dietary vitamin E requirements and growth performance of young-of-the-year beluga, Huso huso (L.) (Chondrostei: Acipenseridae). *Fisheries & Aquatic Life*, *20*(4), 299-306.

Bai, S. C., & Lee, K. J. (1998). Different levels of dietary DL-α-tocopheryl acetate affect the vitamin E status of juvenile Korean rockfish, Sebastes schlegeli. *Aquaculture*, *161*(1-4), 405-414.

Baker, R. T. M., & Davies, S. J. (1996). Oxidative nutritional stress associated with feeding rancid oils to African catfish, Clarias gariepinus (Burchell) and the protective role of α-tocopherol. *Aquaculture Research*, *27*(10), 795-803.

Bera, P., Sau, S. K., Paul, B. N., Ali, M. H., & Ghosh, T. K. (2022). Functions, metabolism, interactions, growth and requirements of vitamin E in fish: A Review. *Indian J Anim Health*, *61*(2), 200-209.

Blazer, V. S. (1992). Nutrition and disease resistance in fish. *Annual Review of Fish Diseases*, *2*, 309-323.

Cheng, C. H., Guo, Z. X., & Wang, A. L. (2018). Growth performance and protective effect of vitamin E on oxidative stress pufferfish (Takifugu obscurus) following by ammonia stress. *Fish physiology and biochemistry*, *44*, 735-745.

Catoni, C., Peters, A., & Schaefer, H. M. (2008). Life history trade-offs are influenced by the diversity, availability and interactions of dietary antioxidants. *Animal Behaviour*, *76*(4), 1107-1119.

Eriegha, O. J., & Ekokotu, P. A. (2017). Factors affecting feed intake in cultured fish species: A review. *Animal Research International*, *14*(2), 2697-2709.

El-Shebly, A. A. (2009). The Role of Antioxidant (Vitamin E) in the Control of Lead (Pb) Pollution and Ehancement of Growth Within Nile Tilapia (Oreochromis niloticus). *The Journal of Applied Research in Veterinary Medicine*, *7*(3), 97.

El-Sayed, A. F. M., & Izquierdo, M. (2022). The importance of vitamin E for farmed fish—A review. *Reviews in Aquaculture*, *14*(2), 688-703.

El-Sayed, A. F. M., & Izquierdo, M. (2022). The importance of vitamin E for farmed fish—A review. *Reviews in Aquaculture*, *14*(2), 688-703.

Harsij, M., Kanani, H. G., & Adineh, H. (2020). Effects of antioxidant supplementation (nano-selenium, vitamin C and E) on growth performance, blood biochemistry, immune status and body composition of rainbow trout (Oncorhynchus mykiss) under sub-lethal ammonia exposure. *Aquaculture*, *521*, 734942.

Huang, C. H., & Huang, S. L. (2004). Effect of dietary vitamin E on growth, tissue lipid peroxidation, and liver glutathione level of juvenile hybrid tilapia, Oreochromis niloticus O. aureus, fed oxidized oil. *Aquaculture*, *237*(1-4), 381-389.

Hamre, K., & Lie, Ø. (1995). α-Tocopherol levels in different organs of Atlantic salmon (Salmo salar L.)—Effect of smoltification, dietary levels of n-3 polyunsaturated fatty acids and vitamin E. *Comparative Biochemistry and Physiology Part A: Physiology*, *111*(4),547-554.

Hamre, K., & Lie, Ø. (1995). Minimum requirement of vitamin E for Atlantic salmon, Salmo salar L., at first feeding. *Aquaculture Research*, *26*(3), 175-184.

Hidiroglou, N., Cave, N., Atwal, A. S., Farnworth, E. R., & McDowell, L. R. (1992). Comparative vitamin E requirements and metabolism in livestock. In *Annales de Recherches Veterinaires (Vol. 23, No. 4, pp. 337-359)*. Halliwell, B. (1999). Antioxidant defence mechanisms: from the beginning to the end (of the beginning). *Free radical research*, *31*(4), 261-272.

Ispır, U., Yonar, M. E., & Oz, O. B. (2011). Effect of dietary vitamin E supplementation on the blood parameters of Nile tilapia (Oreochromis niloticus). *J Anim Plant Sci*, *21*(3), 566-569.

Kiron, V., Puangkaew, J., Ishizaka, K., Satoh, S., & Watanabe, T. (2004). Antioxidant status and nonspecific immune responses in rainbow trout (Oncorhynchus mykiss) fed two levels of vitamin E along with three lipid sources. *Aquaculture*, *234*(1-4), 361-379.

Khan, N., Qureshi, N. A., Nasir, M., Vandenberg, G. W., Mughal, M. S., Maqbool, A., ... & Zikria, N. (2012). Effect of artificial feed on sensory attributes of flesh of Indian major carps (Labeo rohita, Catla catla and Cirrhinus mrigala) fed in monoculture and polyculture systems. *Pak. Vet. J*, *32*, 349-353.

Lewis, E. D., Meydani, S. N., & Wu, D. (2019). Regulatory role of vitamin E in the immune system and inflammation. *IUBMB life*, *71*(4), 487-494.

Mourente, G., Dıaz-Salvago, E., Bell, J. G., & Tocher, D. R. (2002). Increased activities of hepatic antioxidant defence enzymes in juvenile gilthead sea bream (Sparus aurata L.) fed dietary oxidised oil: attenuation by dietary vitamin E. *Aquaculture*, *214*(1-4), 343-361.

Mourente, G., Bell, J. G., & Tocher, D. R. (2007). Does dietary tocopherol level affect fatty acid metabolism in fish?. Fish Physiology and Biochemistry, 33, 269-280.

Meydani, S. N., Lewis, E. D., and Wu, D. (2018) Perspective: should vitamin E recommendations for older adults be increased? Adv. Nutr. 9, 533–543.

Ouahchi, K., Arita, M., Kayden, H., Hentati, F., Hamida, M. B., Sokol, R., ... & Koenig,

M. (1995). Ataxia with isolated vitamin E deficiency is caused by mutations in the α–tocopherol transfer protein. Nature genetics, 9(2), 141-145.

Pae, M., and Wu, D. (2017) Nutritional modulation of age-related changes in the immune system and risk of infection. Nutr. Res. 41, 14–35.

Paul, B. N., Sarkar, S., Giri, S. S., & Mohanty,S. N. (2005). Vitamin E requirement of Catla catla fry. Indian Journal of Animal Nutrition, 22(4), 237-240.

Pignitter, M., Grosshagauer, S., & Somoza, V. (2019). Stability of Vitamin E in foods. Vitamin E in human health, 215- 232.

Prieto, A. I., Jos, A., Pichardo, S., Moreno, I., & Cameán, A. M. (2008). Protective role of vitamin E on the microcystin-induced oxidative stress in tilapia fish (Oreochromis

niloticus). Environmental Toxicology and Chemistry: An International Journal, 27(5), 1152-1159.

Puangkaew, J., Kiron, V., Somamoto, T., Okamoto, N., Satoh, S., Takeuchi, T., & Watanabe, T. (2004). Nonspecific immune response of rainbow trout (Oncorhynchus mykiss Walbaum) in relation to different status of vitamin E and highly unsaturated fatty acids. Fish & shellfish immunology, 16(1), 25-39.

Rizvi, S., Raza, S. T., Ahmed, F., Ahmad, A., Abbas, S., & Mahdi, F. (2014). The role of vitamin E in human health and some diseases. Sultan Qaboos University Medical Journal, 14(2), e157.

Rutkowski, M., & Grzegorczyk, K. (2007). Modifications of spectrophotometric methods for antioxidative vitamins determination convenient in analytic practice. Acta Scientiarum Polonorum Technologia Alimentaria, 6(3), 17-28.

Saheli, M., Islami, H. R., Mohseni, M., & Soltani, M. (2021). Effects of dietary vitamin E on growth performance, body composition, antioxidant capacity, and some immune responses in Caspian trout (Salmo caspius). Aquaculture Reports, 21, 100857.

Sau, S. K., Paul, B. N., Mohanta, K. N., & Mohanty, S. N. (2004). Dietary vitamin E requirement, fish performance and carcass composition of rohu (Labeo rohita) fry. Aquaculture, 240(1-4), 359-368.

Serezli, R., & Akhan, S. (2010). The effect of vitamin E on black sea trout (Salmo labrax) broodstock performance. Kafkas Üniversitesi Veteriner Fakültesi Dergisi, 16(1).

Sevcikova, M., Modra, H., Slaninova, A., & Svobodova, Z. (2011). Metals as a cause of oxidative stress in fish: a review. Veterinární medicína, 56(11), 537-546.

Sinha, A. R. C. H. A. N. A., & Sinha, Y. K. P. (1994). Role of vitamin E in growth of an Indian major carp, catla (Catla catla).

Tangolar, S. G., Özogul, F., Tangolar, S., & Yağmur, C. (2011). Tocopherol content in fifteen grape varieties obtained using a rapid HPLC method. *Journal of Food Composition and Analysis*, *24*(4-5), 481-486.

Tocher, D. R., Mourente, G., Van der Eecken, A., Evjemo, J. O., Diaz, E., Wille, M., ... & Olsen, Y. (2003). Comparative study of antioxidant defence mechanisms in marine fish fed variable levels of oxidised oil and vitamin E. *Aquaculture International*, *11*, 195-216.

Tocher DR, Mourente G, Van der Eecken A, Evjemo JO, Dı´az E, Bell JG, Geurden I, Lavens P, Olsen Y. (2002). Effects of dietary vitamin E on antioxidant defence mechanisms of juvenile turbot (Scophthalmus maximus L.), halibut (Hippoglossus hippoglossus L.) and sea bream (Sparus aurata L.). Aquac Nutr 8:195–207.

Udo, I. U., & Afia, O. E. OPTIMIZATION OF DIETARY VITAMIN E (Tocopherols) IN FISH: A.

Wood, A. W., Duan, G., & Bern, H. A. (2005). Insulin-like growth factor signaling in fish. *International review of cytology*, *243*(1), 215-285.

Wu, D., and Meydani, S. N. (2008) Age-associated changes in immune and inflammatory responses: impact of vitamin E intervention. J. Leukoc. Biol. 84, 900–914.