Optimizing Aquaculture: Harnessing the Growth and Immunological Benefits of Olive Plant Compounds for Blue Food Production

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Abstract: Blue foods are a diverse food group that can provide essential nutrients, enhance human health and development in global food systems. They are crucial to maintaining food shortage and security. The increasing global population is driving up the need for sustainable aquatic protein sources for human consumption. Sustainable Development Goals 2 and 14 of the UN call for "zero hunger," and blue foods are one way to achieve this goal. Blue foods generate energy from the nutritionally composed feed. They utilize this energy for reproduction and growth. Diets high in fat, protein, and carbohydrates supply the energy needed to produce blue foods. These diets promote the active enzyme breakdown of lipids, proteins, and carbohydrates and are very digestible. For all aquatic animals, this meal results in general body building. Therefore, this study investigates the potential benefits of olive plant extracts for the production of blue foods and immunological response, focusing on the by products as a novel resource for sustainable aquaculture. The effects on fish growth and health of bioactive substances derived from olive plants were taken into consideration. The inclusion of olive plant in blue food is a major solution for agricultural inclusiveness.

Keyword: Blue food

1. Introduction

Aquaculture is a rapidly growing industry in the global food sector, with fish products serving as a crucial source of aquatic blue food. This fastest growing industry in food production plays a vital role in meeting the dietary protein needs of humans (Dawood *et al.,* 2020). This industry has grown at an average annual rate of roughly 5.3% over the past 20 years, with an output of 114.5 million tons in 2018 (FAO, 2020). Additionally, this growth rate exceeds the 2.1% annual growth rate of other livestock and animal production sectors (FAO, 2020). Globally, 424 aquatic species are farmed, providing millions with sustenance, food security, a sustainable way of life, and a reduction in poverty (Galappaththi *et al.,* 2020). For people, fish provides a significant, affordable, healthy source of protein and fats in their daily diets (Tacon *et al.,* 2020). According to data from 2017, cereal and milk were the two most significant sources of dietary protein for human consumption, with fish and marine products coming in third (FAO, 2021). Aquaculture has, however, encountered numerous challenges recently, including a rise in viral diseases brought on by warmer weather (Reverter *et al.* 2020), and unnecessary use of antibiotics (Dawood *et al.,* 2020). In order to overcome these challenges, there is need for sustainable feed methods. In 2018, it was noted that fed aquaculture accounts for around 69.5% of the total world aquaculture than non-fed aquaculture (FAO, 2020).

This gave a clear indication of high demands and usage of aquafeed. This clearly shows that there will be a need for more aquafeeds, according to IFFO (2020), the supply gap of aquafeed ingredients will be around 30 million tons by 2030. The aquafeed industry have fishmeal and fish oil as the major aquafeed ingredients sourced from wild captured fish and few portions from processed fish (Mitra, 2021). Price increases in supply and demand components of the market result in a decline in aquafeed inclusion, which leads to the dependence on wild fish stock as the primary element (Mitra, 2021). Fish farmers are working extremely hard to reduce the cost of fish feed, which accounts for more than half of the total cost of raising fish. A lot of research is being done to create more economical feed to increase the production of fish and shrimp. Fishmeal can be replaced with other plant-based components to reduce the cost of fish feed without sacrificing the nutrient profile. Several plant-based substances, such as sesame meal, soybean meal, rapeseed meal, cottonseed meal, cassava starch, maize gluten meal can be used in place of fishmeal in a fish diet (Prabu *et al.,* 2017). Fish growth and health can be improved through sustainable approaches, which are necessary to meet the growing demand for fish as a source of protein. Discovering a secure method to enhance the well-being and development of fish in the aquaculture sector is therefore imperative (Sokoti *et al.,* 2021). There is feed ingredient that are more sustainable and can serve as alternatives. These include plant-based oils and proteins, yeast, insects, and algae. Due to its numerous health benefits, olive plants have grown in popularity over the past 20 years, with the Mediterranean region becoming its main producer. (Manzanares *et al.,* 2020). This paper aims to investigate the potential benefits of olive plant in aquafarming by examining their effects on fish growth and immunological responses.

Role of blue foods in aquaculture and their nutritional importance

In developing countries, blue foods are among the largest traded food products, their net revenue from commerce exceeds that of every agricultural commodity combined. (Tigchelaar *et al.,* 2022). For billions of humans, blue foods play an essential role in their nutrition and food security. They also form the basis of many coastal and riparian communities' lives, economies, and cultures as well as providing essential nutrition for a growing human population (Golden *et al.,* 2021). Blue foods are helping to achieve the UN Sustainable Development Goal 2 of "zero hunger" while lowering reliance on limited natural resources, but more innovation and new approaches are required to make the sector more "circular" and sustainable, especially when it comes to obtaining the basic ingredients for aquafeeds (Colombo *et al.,* 2023). Blue foods are incredibly diverse, often high in important micronutrients and fatty acids, and can be generated through processes that are more environmentally sustainable compared to those obtained from terrestrial animals. Human diets contain about 2500 different species of aquatic creatures, including freshwater and marine animals, plants, and algae (Golden *et al.,* 2021). According to Short et al. (2021), blue food systems are maintained by a variety of habitats that are incorporated into agricultural systems and provide populations with access to wholesome food through both local and international markets. They are the cornerstone of a nutritious diet, excellent nutritional compositions, and general well-being. This makes it possible for communities and the government to create nutrient-balanced, healthful, and sustainable food systems. Bioavailable micronutrients found in abundance in blue food protect against stunting, cognitive impairments, and reduce the risk of maternal and infant mortality. Blue foods have healthy fats, which can lower obesity and non-communicable diseases, making them a healthier source of animal protein than livestock raised on land (Golden *et al.,* 2021). Blue foods are a healthier source of animal protein than terrestrial livestock reared on land because they include necessary lipids that can help minimize obesity and non-communicable diseases. (Golden *et al.,* 2021).

Production Process of Olive Trees

Olive tree cultivation is a complex agricultural process that yields various products and by-products. The outputs include olive tree pruning biomass, olive fruits, olive oil, pomace, wastewater, olive stones, pomace oil, and pomace dry residues. Each component has its own production metrics and significance. The production of various products and by-products from one hectare of olive trees highlights the multifaceted nature of olive.

Figure 1.
Production from 1 Hectare of Olive Trees (Espeso et al., 2021)

Olive trees require pruning in order to remain healthy and productive. Every hectare of olive tree yields 1500 kg, or two to five tons, of pruning biomass annually. This biomass has numerous applications such as mulch, compost, and a source of renewable energy. Olive farming's primary product is olive fruit. An acre of olive trees that are well-nurtured yields about 2500 kg, or 3-7 tons, of olives per year. The production may be impacted by a number of variables, including the kind, age, and cultivation techniques of the tree (Rodríguez et al., 2019).

The gathered fruits are processed to obtain olive oil. Depending on the extraction process and oil concentration, 100 kilograms of olives can yield 20 to 25 liters of olive oil. An estimated 1,000–1,250 liters of olive oil can be produced from an acre of 5 tons of olives. The solid residue left over from the oil extraction process is called pomace. This comprises of the water content, stone, pulp, and skin (Ying *et al*., 2017).

Roughly 3 tons of pomace are made from 5 tons of olives. This pomace can be utilized for composting, animal feed, or the creation of biofuel. It can also be processed further to obtain pomace oil (Alonso-Fariñas *et al.*, 2020). The refined oil is either used in industry or for human consumption. It has lower standard than virgin olive oil. Dry residue left behind after pomace oil is extracted can be used as fuel, fertilizer, or animal feed.

Large amount of Olive mill wastewater (OMWW) is produced during the extraction of olive oil. An estimated 6 to 7.5 cubic meters of wastewater are produced during the processing of 5 tons of olives. This wastewater contains organic chemicals and must be treated before disposal (Alkhalidi *et al.*, 2023). Olive stones, sometimes known as pits, are a component of pomace but are frequently isolated for special use. Four tons of olives can yield 400 kg of olive stones. These stones are utilized in the production of biofuel, abrasive materials, and even activated carbon (Mallamaci, *et al.*, 2021; García Martín *et a*l, 2020).

The Potential of Utilizing Natural Compounds from Olive Plants in Fish Farming

Production of high-quality fish feed is one of the major elements influencing noteworthy growth, feed utilization efficiency, and fish flesh quality in aquaculture. Researchers are examining novel fish feed options, such olive plants with the correct nutritional makeup, to determine whether they may supplement or improve conventional aquaculture. Olive plants contain bioactive compounds that can be used to improve aquaculture's anti-stress, growth, appetite stimulation, tonicity, and immune stimulation, as well as the development of culture species and aphrodisiac qualities. These bioactive compounds include phenolics, glycosides, alkaloids, terpenoids, saponins, tannins, flavonoids, steroids, and essential oils (Hodar *et al.,* 2021; Farag, *et al* 2020). Aquaculture has found medicinal plants to be a very appealing alternative in the past ten years due to their abundance of bioactive compounds (Zhu, 2020). Administering plant extracts to farmed fish increase their appetite for feed and encourage weight gain (Gupta *et al.,* 2021). It has been demonstrated that plant extracts boost nutrient availability and digestibility, which raise feed conversion and increase protein synthesis (Chojnacka *et al.,* 2021). Utilizing plant-enriched diets enhance immunological indices, digestive enzymes, antioxidant activity, and fish development (Zemheri-Navruz *et al.,* 2020). In recent years, there has been a lot of interest in the application of functional feed supplements that enhance the immune system and physiological state of fish to boost their resistance to disease. Reverter *et al.,* (2020) have reported that these substitutes are not only cost-effective and may be employed in various aquaculture systems, but they also demonstrate efficacy against a wide spectrum of pollutants. Various studies have tracked the immunological parameters following intraperitoneal injections or oral administrations of plant extracts on various fish species. The results have shown that fish treated with these agents exhibit elevated levels of respiratory burst activity, plasma protein, lysozyme activity, phagocytic activity, and complement activity (Elumalai *et al.,* 2021: Yakubu *et al.,* 2020). These findings suggest that adding Olive plants or olive oil to fish diets can improve their health and strengthen their immune systems, which may help to minimize cases of disease in the aquaculture industry. According to Dawood *et al.,* (2018), immune stimulants can be a great substitute for both immunizations and antibiotics in the prevention and management of diseases affecting fish. Given their many benefits such as lower environmental concerns, no drug resistance, affordability, and accessibility, plant-based immune stimulants are the most favored among the several types of immune stimulants (Gabriel, 2019). The olive (Olea europapaea L.) plant is one of the stimulants included in herbal remedies, its leaves and fruits are the most valuable parts of the plant (Gokdogan and Erdogan, 2018). Olive leaves possess natural bioactive substances. Numerous research shows the positive effects of olive leaf extracts on aquatic species, such as increased immunity and survival rates. Olive plants are among the plant extracts that have demonstrated antiparasitic properties against fish infections (Alagawany, *et al.,* 2020). Baba *et al.,* (2018) reported that 0.1% olive leaf extract increases *Oncorhynchus mykiss* survival rates and serum biochemical markers. Zemheri-Navruz *et al.,* (2019) provided *Cyprinus carpio* meals with four doses of olive leaf extract in a similar manner. Their findings demonstrated that fish immunological parameters and survival rate are improved by a diet containing 1 g/kg of olive leaf extract. Additionally, the effects of olive leaf extract on *Cyprinus carpio* growth performance, hematological parameters, immunological response, and carcass composition were assessed (Sokooti *et al.,* 2020). This implies that fish oil might be replaced with vegetable oils such as olive oil when employed in research. For aquaculture purposes, this can therefore be a valuable source of feed.

2. Literature Review

Historical applications and significance of olive plants

The olive tree *Olea europaea* L. belongs to the Oleaceae family. Many Mediterranean populations played an essential role in promoting the olive tree farming industry. For more than 6,000 years, the Mediterranean basin has supported the development of cultivated olives, which are now farmed commercially. New plantings have also been implemented in California, South Africa, Australia, Chile, and Argentina. Countless distinct cultivars were generated through a range of non-scientific selection methods. The olive tree can withstand hot, dry weather, needs minimal hydration during bloom, and even flourishes in adverse conditions. It just needs an occasional cold period. It appears that people and edible olives have coexisted since 5000–6000 years ago (3150–1200 BCE). The spread of the olive tree most likely coincided with the vegetative multiplication and trading of date palm, wine grape, and fig selections. Bibliographies to plants and fruits found in Hebrew, Bibles, and the Koran (Qur'an) have attracted historical attention because they provide a comprehensive understanding of the interactions and beliefs of Middle Eastern with their environment. Olive plant greatest value was then derived from its use as lamp fuel by all the cultures. Olive was used in many rites and ceremonies, such as the holy anointing of warriors, rulers, and the general populace. The majority of the world's olive oil is produced by exploiting the crop, and the primary producers of olive oil are still found in Europe.Thus, olive oil production plays a major role in the agricultural economy of Mediterranean nations. Oil extracted from olive has been a staple of Mediterranean cooking for a long time, but in recent years, its health benefits have made it increasingly prevalent around the world (Alemán *et al.,* 2016). Olive oil has numerous health advantages, which had been documented, and novel benefits are recently recorded. Exotic olive oils were used as therapeutic ointments to treat illnesses, as sacrifices to the gods, and as sacrifices to the gods, and to improve the appearance of hair and body generally.

Exploration of bioactive compounds found in olive plants and their potential benefits for fish health and growth

In the agriculture industry, olive crop and olive oil production processes have resulted in by-products such as olive leaf, Olive Pomace oil and Olive mill wastewater. The use of olive and its derivatives as fish feeds was first documented in 2004 (Yilmaz *et al.,* 2004). Since then, numerous research has been conducted to investigate the health benefits on fish, showing improvements in fish immunity and fish carcass composition depending on the type of derivatives used and fish species. The olive tree is biochemically enriched with secoiridoids, carbohydrates, sugar alcohols, flavonoids, and terpenoids (Centrone *et al.,* 2021). According to Guinda *et al*. (2015), olive leaves contain essential natural phytonutrients such as oleuropein, oleanolic acid, oleocanthal, hydroxytyrosol as well as mannitol (3%DW). These bioactive compounds are also presence in other notable plants such as *Pistacia vera, Melissa officinalis,* and *Origanum vulgare* and can also be used to improve agricultural sector. These plant derivatives can increase the body's capacity for antioxidants and genes linked to the immune system in Nile tilapia (Mohammadi *et al.,* 2022). Olives and olive oil are also good sources of monounsaturated fat. The highest percentage of monounsaturated fat found in any edible oil is found in extra virgin olive oil which is more than 70%. It contains high concentrations of antioxidants, fat-soluble vitamins, E, A, D, and K. along with anti-inflammatory substances.

The effects of olive oil derivatives on carcass composition have been documented several aquatic species, it includes rainbow trout, gilthead sea bream, Africa catfish, red sea bream (Arsyad *et al.,* 2018). Fish species investigated have shown that the amount of fatty acid has been influenced by olive pomace, out of all the derivatives of olive oil. Refined olive pomace oil contains a variety of bioactive components, including oleic, linoleic, stearic, palmitic, and palmitoleic acids. These compounds can be added to the diet to assist regulate the immune system and prevent infection (Hazreen-Nita *et al.,* 2022). Abdel-Razek *et al*. (2017) found that there were differences in the phenolic components found in olive leaves, olive oil, and pomace olive pomace. The pomace has been adequately utilized in the livestock and aquaculture industries for a variety of purposes such as inclusion as feed ingredients for animal feeds. Due to their high protein content and alternative to conventional protein sources as a means to cost reduction and value-added of agro-industrial waste. Olive pomace has been used in a number of studies to formulate feed and it has also been fed to tilapia species. The results demonstrate that olive pomace can substitute wheat meal without adversely affecting feed evaluation or growth performance. There are no negative effects and no reductions in fish growth performance or feed utilization efficiency when olive pomace was substituted for wheat bran in tilapia diets (Yildirim and Guroy, 2015). Olive pomace meal has the potential to aid the development of more affordable feedstuffs because it has been used severally as a feed ingredient in tilapia diets. Nutritionally, the meals are natural by-products that are inexpensive and are not genetically modified. The fish's acceptance of the meals remained unchanged upon the addition of olive pomace meal, and its presence did not affect feed taste (Yildirim and Guroy, 2015). Olive oil derivatives have been employed in aquafeed as a partial replacement for fish oil because of its benefits for intestinal health and microbial diversity. When the fish were fed varying amounts of olive oil bioactive extract in their diets, it was discovered that the goblet cell population in the intestinal epithelium increased (Gisbert *et al.,* 2017). Furthermore, extra virgin olive oil and their derivatives have been shown to have anti-allergic properties; the majority of these derivatives, such as hydroxytyrosol, tyrosol, and oleuropein, were mostly detected in the intestinal lumen (Centrone *et al.,* 2021). Moreso, studies have shown that the vegetable oils that were substituted for fish oil in fish feed, particularly olive and rapeseed oil, had lower cholesterol levels in fish intestinal tissue than fish oil (Liland *et al.,* 2018). Derivatives of olive oil stimulate the growth of *Lactobacillus acidophilus*, a probiotic candidate that is beneficial in fish gut microbiota (Banerjee and Ray, 2016; Gavahian *et al.,* 2019). Bioactive compounds from olive oil by-products were found to improve gilthead seabream intestinal mucosal immunity (Gisbert *et al.,* 2017).

3. Methodology

A thorough search of all peer-reviewed journal articles and theses from Google Scholar was used to examine the significance of aquaculture in providing sustainable food sources and, the impact of olive plant compounds as a blue food on the growth, immunity, and disease resistance of fishes from 2015 to the recent. A literature search was performed, and the following keyword combination was used: (Sustainable) AND (aquatic) AND (blue food) AND (olive plant). Articles were reviewed to determine whether they met the following criteria of the paper: i) Explore how olive plant crop extracts can promote the growth of blue food species. ii) Evaluate how the health and disease resistance of aquatic creatures are affected by the immunological impacts of crop products from olive plants. iii) For optimal effectiveness in aquaculture systems, optimize the composition and application techniques of olive plant crop extracts. iv)Investigate possible mechanisms behind the increase of immune function and encouragement of growth in aquatic organisms caused by crop derivatives from olive plants. v) Establish the ideal proportions of olive plant derivatives to include in blue food formulations in order to boost immunological response and growth. Find patterns, trends, and gaps in the literature to synthesizing and summarizing the data that was extracted. Sort the results according to major themes, such as how aquatic species' ability to thrive, fight disease, and act as an immune system is affected by derivatives of olive plants. Take into account differences in methodological techniques, species-specific responses, and experimental settings between studies. Other considerations imply analyzing the total economic and environmental advantages of aquaculture techniques using crop derivatives from olive plants. Provide suggestions for the environmentally responsible incorporation of crop derivatives from olive plants into aquaculture enterprises. To help aquaculture stakeholders transfer and accept new information, disseminate research findings through this publication in academic journals, and outreach initiatives. To encourage the adoption of cutting-edge techniques for the development of sustainable aquaculture, encourage cooperation and collaborations between researchers, aquaculture producers, and industry stakeholders. Provide evidence-based tactics to enhance growth, health, and sustainability in blue food production systems, thereby advancing aquaculture methods.

Importance of Nutritional Components in Aquatic Organisms

Nutrition is an important factor that needs to be addressed for aquaculture to be both affordable and sustainable. Nutritional components in aquaculture is the science of a nutrient's interaction with some element of a living organism, such as feed composition, ingesting, energy release, waste disposal, and synthesis for maintenance, growth, and reproduction (Prabu, *et al.,* 2017). Feeding the fishes with nutritionally enriched feeds may dramatically increase the overall production. Therefore, nutrition is one of the essential areas to be focused by aquaculture industry. Aquaculture nutrition contribution varies greatly, not only on the species raised and fed (Fry *et al.,* 2016; Tacon *et al.,* 2020) but also importantly the operating environment, social, and economic context of production and distribution systems. Due to their high nutrient quality, aquatic animals are effective and necessary food sources for enhancing the nutritional state of the nation's population (Fujita *et al.,* 2019). Fish's development, ability to reproduce, overall health, and reaction to infections, physiological and environmental stressors are all influenced by their diet and feeding habits. In aquaculture, nutrition is most important feature. Providing the fish with enriched feed that is high in nutrients can significantly boost their overall yield. Thus, one of the most important areas on which the aquaculture business should concentrate is nutrition. It is necessary to assess the nutritional contributions of seafood, which calls for a systems approach to comprehend its distribution and the financial value it adds to the product trends (Gephart *et al.,* 2021). It has been reported that olive is a good source of phenolic compounds with antioxidant activity (Fernández-Prior *et al.,* 2020). Aquatic animals absorb nutrients from the water by feeding on plants, seeds, fruits, and tubers, then recycle those nutrients as they decompose. Aquatic organisms require carbohydrates, protein, minerals, vitamins, lipids and other feed additives for meeting the physiological needs of growth and reproduction (Prabu, *et al.,* 2017). Protein in the aquatic diet provides ten important amino acids, while fat provides vital fatty acids. The diet also contains fat-soluble and water-soluble vitamins. Combination of the aquatic feeds with water supply minerals.

Protein

Protein is the most important consideration when developing blue feed formulations. It is the most expensive and essential factor influencing the development and nutritional performance of aquatic species (Henchion *et al.,* 2017). Protein provides energy, amino acids and meet the dietary requirements of functional proteins. Amino acids are a necessity in protein for the fish diet but not all amino acids are digestible. According to research, amino acid needs of different fish species vary significantly (Mohanty *et al.,*2019). Most characterized olive proteins are located in the fruit, mainly in the seed, where different oleosins and storage proteins have been found. There are other parts of olives which contain lower amount of protein such as olive pulp, this could also serve as a nutrient enrichment for blue food production.

Carbohydrates

For fish diets, the most cost-effective and affordable sources of energy are carbohydrates. They are not necessary in fish diet but are utilized to reduce feed cost. Carbohydrate content should not be higher than the protein in the feeds. Fish are capable of efficiently breaking down simple carbohydrates but difficult to digest complex ones (Sadasivam *et al.,* 2022). Their digestion ability varies with different species, Warm water fish can easily digest food carbohydrate than cold water fish. Different animals use carbohydrates differently as an energy source. Glycogen buildup and hepatic enlargement might result from eating too many carbohydrates in the diet. Craig *et al.,* (2017) reported that a few amino acids and nucleic acids can be synthesized from carbohydrates, which also promotes growth.

Fat

The amount of fat in the food, the kind of fat, the temperature of the water, the degree of unsaturation, and the length of the carbon chain all affect how digestible fat is. Dietary fats supply essential fatty acids (EFA), which are necessary for appropriate growth and development in fish, in addition to being a significant source of energy for fish (Mejri, *et al.,* 2021). Fish can derive their nutrient from olive. Olives contain 11–15% fat, 74% percent of which is oleic acid, a type of monounsaturated fatty acid. It is the main component of olive oil.

Vitamins

Organic substances called vitamins are needed in the diet for proper development, reproduction, and health. They participate in a range of bodily chemical processes. Fish diets absolutely require vitamin supplements because of their straightforward digestive systems (Caipang, and Lazado, 2015). There are two types of vitamins: fat-soluble and water-soluble. Choline, Thiamin, Myoinositol, Riboflavin, Vitamin C, Folate, Niacin, Biotin, Pyridoxine, Vitamin B12 are among the water-soluble vitamins. Myoinositol, choline, and vitamin C have several uses. Choline serves as a methyl group supplier for chemical reactions, a component of membranes, and a precursor to acetylcholine, a neurotransmitter. Myoinositol is a signaling agent that is used in several physiological functions. Vitamin C plays a role in bone marrow production, wound healing, and connective tissue formation. It also aids in preventing tissue lipids from peroxiding and makes iron easier to absorb from the colon. In the body's metabolic processes, most of the water-soluble vitamin's function as coenzymes. The vitamins that are fat soluble are vitamin A, vitamin D, vitamin E, and vitamin K. Together with dietary lipids, fat-soluble vitamins are absorbed in the intestine. Fat-soluble vitamins, as compared with water-soluble vitamins, can be retained in bodily tissues.

Phosphate

Dietary phosphate is the source of phosphorus, it prevents deformities of the bones, increase feed efficiency, and prevent poor growth. Phosphorus is a necessary nutrient for the formation of blue foods. it is an essential component for several physiological functions in fish, including bone formation, tissue growth, acid-base balance maintenance, energy metabolism, and reproduction. Numerous factors, such as species, life stage, growth rate, and water temperature, affect fish phosphorus requirements (Suguira, 2015). Growth and skeletal development are linked to higher phosphorus requirements, and this is especially intriguing for fish raised for food. One of the three key nutrients is phosphorus, which olive roots mostly take as orthophosphate. In activities involving Adenosine diphosphate (ADP) and Adenosine triphosphate (ATP), phosphate plays an essential role for the transmission and storage of energy for use in later growth and reproduction processes.

Calcium

The chemistry of water dictates how much calcium is needed. Fish absorb calcium directly from water by its gills and skin (Sanderson *et al.,* 2021). Combination of calcium and phosphorus in fish bodies makes it crucial to maintain the blue food diet.

Microminerals

Fish health depends on microminerals even though they are only found in trace amounts in their bodies. Copper (Cu), Iodine (I), Iron (Fe), Manganese (Mn), Selenium (Se), and Zinc (Zn) are among the microminerals.

Copper (Cu)

Cu is an essential microelement required for aquatic organisms to grow and thrive to their full potential, It supports several physiological, metabolic, and biological processes across the aquatic animals' whole bodies (Dawood, 2022). Many enzymes include Cu, which is necessary for their function. Although Cu is necessary for fish health, it can be hazardous at concentrations of 0.8 to 1.0 m per liter of water. Cu is more easily absorbed by fish from feed than it is from the water (Saha *et al*., 2024).

Iodine (I)

The thyroid gland needs iodine in order to produce hormones. Iodine can be found in both water and food for fish. For heme compounds (hemoglobin and myoglobin) to develop, iron is required (Ems *et al*., 2024).

Iron (Fe)

Sufficient dietary iron supplementation enhances antioxidant status, feed utilization, and development. Fe plays major role in oxygen transfer, electron transport, and cellular respiration with emphasis for the function of haemoglobin in fish. Aquaponics rely on bacteria to convert nutrients, and these microbes' growth requires Fe (Farooq *et al.,* 2023). Iron has potential use as a component for aquafeeds and may aid to improve palatability and increase feed intake (Glencross, 2020). High Fe intake may cause fish to grow more slowly, probably because it is poisonous (Evliyaolu *et al.,* 2022), dietary Fe will enhance the quality of fish feed used in aquaculture.

Manganese (Mn)

Manganese serves as a cofactor or component of enzymes. Manganese metabolism, lipid buildup, growth, and antioxidant capability were all enhanced at an ideal dietary level. For living things to continue having regular metabolic and physiological processes, manganese (Mn) is a micronutrient that is necessary. Growth and feed utilization were improved with an ideal dietary manganese (Mn) level. For skeletal growth and development, manganese is an essential trace mineral. Inadequate mineralization, a rise in skeletal anomalies, and stunted growth can result from dietary Mn deficiencies (Lall and Kaushik, 2021).

Selenium (Se)

Selenium offers defense. Cells and membranes are shielded from the peroxide threat by selenium. Several fish species have been found to have better overall growth when their diets contain adequate levels of selenium. Sufficient selenium addition in feed has been linked to increased growth rates, weight gain, and feed efficiency to produce blue foods. It is only a very potent antioxidant and is crucial to fish's antioxidant defense system. Aquatic species' intestine and liver are healthier when they consume dietary nanoselenium. The pigment and phenol content of extra virgin olive oil enhanced with selenium significantly increased (D'Amato, *et al*., 2017).

Zinc (Zn)

Zinc is also found in many other enzymes. Zinc consumed through feeding works better than zinc dissolved in water for blue food production. The type of phytic acid protein, dietary calcium, phosphorus and zinc all affect how well zinc is absorbed and used in the blue food system (Prabu *et al*., 2017). Growth retardation, cataracts, fin and skin erosion, dwarfism, and even mortality can result from a zinc deficiency. Ten of these olives would provide over 80 percent of the daily recommended zinc intake. (Hazreen-Nita, *et al.*, 2022)

Other trace minerals

There is little evidence to support the potential importance of other trace minerals including chromium and fluoride. Other elements that can impact fish health are present in many fish diets. While some of these components are added, others are natural. Water, fiber, hormones, antibiotics, antioxidants, colors, binders, and feeding stimulants are a few examples of these elements. In several animals, protection against muscular dystrophy requires both vitamin E and selenium.

Current Research on Olive Plant Extracts in Aquaculture

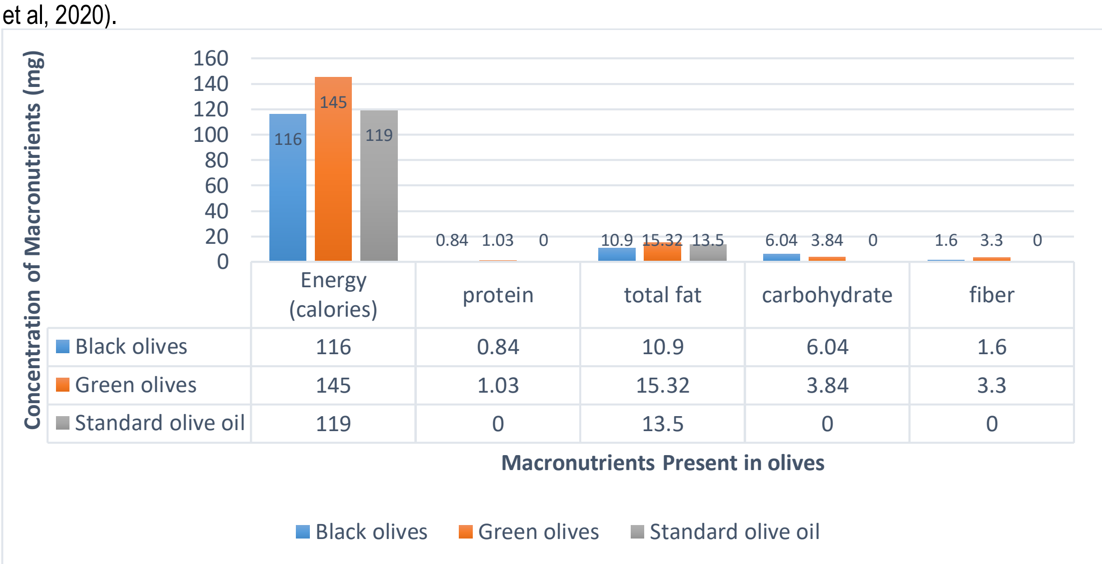
Blue food supplements and stimulants are added to aquatic diets to improve growth, immunity, growth, survival, efficient feed use, and digestion. Olive plant extracts was discovered to be an effective additive against viral infection in fish and other blue foods such as crustacean. Many of olive by products are also thought to be beneficial for use as feed additives because of their high protein content. Olive pomace is a known olive plant by-product, which have been widely utilized in the livestock and aquaculture sectors. It has been extensively used in several ways especially for animal nutrition. Given the increasing focus on agro-industrial waste value addition and cost reduction, olive extracts can be a useful substitute protein source for feed formulation. Rahman *et al.,* (2021) report that feeding livestock animals and aquaculture species with agriculture industry by-products is a frequent practice worldwide. Utilizing agricultural byproducts reduces the expenses related to feeding and waste management for animals, as well as their dependency on grains (Mat *et al.,* 2021). According to Fazio *et al.* (2021), fishmeal supplemented with 1% olive extracts can boost *Oreochromis niloticus* and Nile tilapia immune systems while also accelerating their growth. Sokooti *et al.* (2021) and Arsyad *et al*. (2018) reported similar findings in research, which suggested that fish texture and quality might be enhanced by supplementing feed with olive leaves. According to a study by Arsyad *et al.* (2018), olive leaves can improve the quality of fish texture since they contain a much higher amount of collagen and myofibril than fish in the control group. Therefore, giving fish feed enriched with 0.1% or less of olive extracts for 40 days or longer can greatly strengthen their immune systems and increase their resistance to a variety of diseases. Olive extract was added to shrimp meal for seven days in a row before the study sample Penaeus vannamei (white leg shrimp) was exposed to the white spot syndrome virus (WSSV). A meal enriched with 0.02% olive extracts was given to experimental shrimp, and these shrimps had the greatest observed survival rate (65%). Olive extract was found to be able to strengthen the immune system of crustaceans. Furthermore, studies have shown that fish treated with olive extracts can survive in environments with low water quality. Rajabiesterabadi *et al*. (2020) corroborated the claim that fish health is enhanced, and the harmful effects of ammonia toxicity are mitigated by olive extracts. According to Rajabiesterabadi *et al.* (2020), common carp fish were found to be tolerant of high concentrations of ammonia at 0.5 ppm when they were fed feed supplemented with 0.1% olive extract for 60 consecutive days. Olive leaf extract was tested on Common carp (*Cyprinus carpio*) for 75 days, it shows that weight gain, specific growth rate and protein efficiency ratio values were significantly higher in the groups fed the diet containing 200 mg/kg of olive leaf extract compared with the control group (Sokooti *et al.,* (2021). Olive leaves extract was tested on Nile tilapia (*Oreochromis niloticus*), with 1% extract in a period of 2months, the immunity, growth and health of fish was enhanced (Fazio *et al.,* 2021). Persian sturgeon (*Acipenser persicus*) is shown to have a lower FCR and higher specific growth rate after two months of feeding 5% of olive oil (Hosseinnia *et al.,* 2021). Olive oil was used as partial or total dietary replacement in feeding young yellowtail (*Seriola quingqueradiata*) for 40 days, it prevents discoloration of dark muscle without affecting the growth of young yellowtail (Seno-o *et al.,* (2008). Improved growth rate and feed utilization was witnessed after feeding Rainbow trout (*Oncorhynchus mykiss*) with 2.5 g Olive waste kg−1 for 6 weeks (Hoseinifar *et al.,* 2020).

Nutritional Content of Different Types of Olive that can Serve as an Additive to Blue Food Production

The nutritional content of different olives (black and green) shows that it is richly embedded with macro-nutrient, minerals, vitamins and other trace element that can improve blue food production. Macronutrients are essential for the growth and health of aquatic organisms, playing a critical role in boosting the production of blue foods such as blue-green algae, fish, and shellfish. The macronutrient content of green olives, black olives, and standard olive oil varies due to differences in their preparation and composition. These values provide an average nutritional composition and can vary slightly depending on the specific type and processing method of the olives and olive oil.

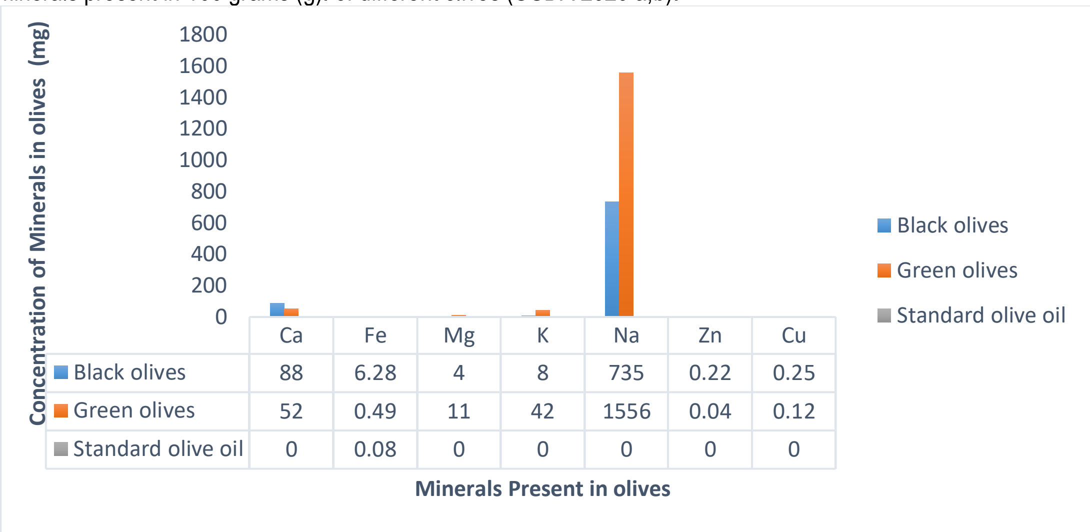
Figure 2

Comparison of the macronutrient content per 100 grams for green olives, black olives, and standard olive oil (Rocha et al, 2020).



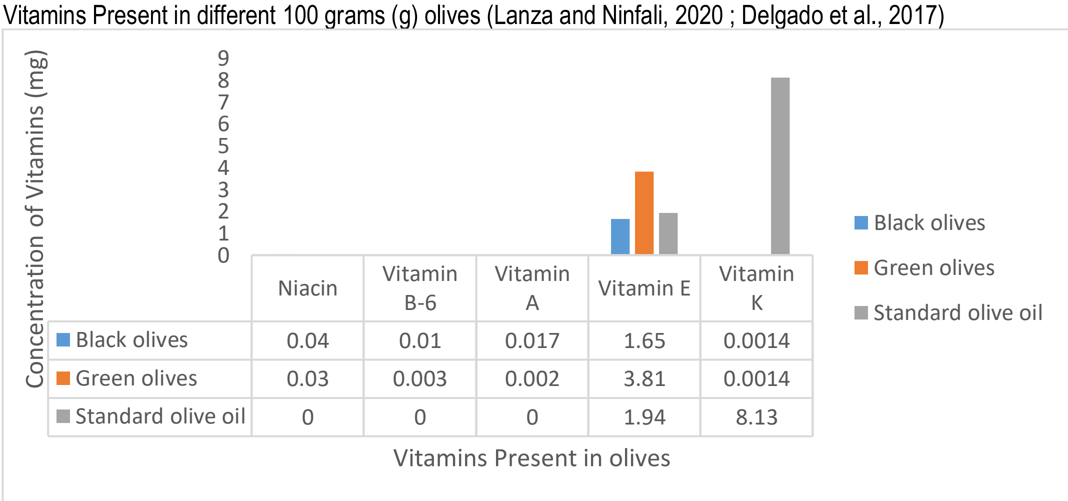
Green olives are usually harvested before they ripen and are often cured in a brine solution. Black olives are typically harvested when fully ripe and cured in brine or other solutions Standard olive oil is typically extracted from ripe olives through pressing or other extraction methods. Figure 2 It is almost entirely composed of fat.

Figure 3.
Minerals present in 100 grams (g). of different olives (USDA 2020 a,b).



Green olives, black olives, and standard olive oil are all derived from the same fruit but differ significantly in their processing and, consequently, their nutritional profiles. Green olives are high in sodium and moderate in calcium, iron, magnesium, potassium, and phosphorus. Black olives are high in sodium and calcium, significantly higher in iron, but lower in magnesium, potassium, and phosphorus compared to green olives. Standard olive oil is very low in minerals compare to green olives and black olives, with only trace amounts of iron, there are no values for others. These differences highlight the impact of processing on the nutritional content of olives and their derivatives. While olives are good sources of several essential minerals, olive oil, valued more for its healthy fats and antioxidants, does not provide significant mineral content. These mineral contents can be highly valued for blue food production.

Figure 4.
Vitamins Present in different 100 grams (g) olives (Lanza and Ninfali, 2020 ; Delgado et al., 2017)



Green olives are rich in vitamins A and E, and contain moderate amounts of vitamins K and B3 (niacin). Black olives can provide slightly less vitamin A than green olives but have comparable levels of vitamins E and K, and slightly higher amounts of vitamin B3 (niacin). Standard olive oil is high in vitamin E and vitamin K, with minimal amounts of vitamin A (the value is not indicated) and almost no water-soluble vitamins (such as B vitamins and folate). These differences are primarily due to the stage of ripeness at which the olives are harvested, and the processing methods used to produce olive oil. While whole olives are a good source of a variety of vitamins, olive oil is particularly rich in vitamins E and K, making it beneficial for heart health and as an antioxidant. Vitamin E and vitamin K play vital roles in the health and productivity of aquatic ecosystems, including aquaculture and the cultivation of blue foods like blue-green algae, certain fish, and shellfish (Kumar, 2017)

Effects of Olive Plant Compounds on Fish Growth

Natural feed additives contain active compounds, which influence the growth performance of aquatic animals. Plant proteins are the most practical option because they are widely available and reasonably priced. Consequently, there has been ongoing interest in expanding global aquaculture business to identify and develop plant-based components as a replacement for fishmeal and its high cost (Kari *et al.,* 2022). When formulating fish feed, it is crucial to ascertain the ideal amount of plant protein source inclusion. Fish growth and health outcomes are adversely affected by high inclusion rates (Hosseinnia *et al.,* 2021; Zulhisyam *et al.,* 2020). Several research on growth performance have been carried out to determine the effects of plant products on aquaculture (Zemheri-Navruz *et al.,* 2019). Varied fish species showed improved weight gain, feed efficiency ratio, and nutrient digestibility as well as greater disease resistance when varying concentrations of herbal extracts were applied (Xu *et al.,* 2020). Nutritional enrichment with 1% olive is recommended for carp feed formulation since it promotes specific immunological and antioxidant characteristics in common carp. It also has remarkable effects on the growth performance, digestive enzyme activity, growth hormone in four different tissues (brain, muscle, liver, and head kidney. Nonetheless, it is suggested to avoid higher concentration of raw olives since they may result in hepatotoxicity and oxidative stress (Hoseini *et al.,* 2021). Given that the goal of aquaculture is to increase products of higher quality and quantity, it stands to reason that aquatic organisms can grow more quickly when given the right number of extracts from olives leaves in their typical diets. Therefore, using olive as a feed additive in fish production appears to be a feasible and environmentally benign tactic.

Immunological Effects of Olive Plant Compounds on Fish

Fish immune system reactions are controlled by a variety of cells that release soluble mediators that work systematically to provide complete protection. The innate (non-specific) and adaptive (specific) immune systems are the two components of the immune system in fish and other higher vertebrates. The fish immune consists of lymphocytes (T cells, B cells), and phagocytes (monocytes and neutrophils), Leucocytes are considered as the backbone of all immune responses. lymphoid organs categorized into tissues and organs used in the immune responses. Fish have three primary lymphoid organs: the thymus, head, kidney, and spleen, and secondary lymphoid organs that include the gut, liver, and gills (Mustafa and AL-Taee, 2020). There has been a lot of interest in the use of medicinal plants in aquaculture since they supply safe and environmentally beneficial ingredients. These substances operate as chemical and conventional antibiotic substitutes, boost immunological responses, and manage fish illnesses (Ghosh *et al.,* 2021). As an inexpensive source of protein, many medicinal plants had been employed successfully to replace the protein in fishmeal. Medicinal plants can simultaneously function as an immunomodulator and a growth stimulator. Because they are rich in a wide range of nutrients and chemical compounds, medicinal plants are employed in the aquaculture industry not only as feed additives but also as chemotherapeutics (Dawood *et al.,* 2018). Medicinal plants such as olive have shown a wide range of biological effects, which includes promoting growth, enhancing appetite, boosting immunity, acting as an antibiotic, and reducing stress in fish. Furthermore, the existence of numerous active components, including phenolics, alkaloids, tannins, saponins, glycosides, and flavonoids, is thought to be responsible for the mode of action of those plants and their derivatives (Alamgir, and Alamgir, 2018). Large-scale uses of plants in aquaculture to simultaneously provide better growth and protection are also encouraged by their cheap price and ease of access. They have been used in a variety of ways, either as crude, plant extracts, or active ingredients. They are occasionally combined with a livestock product or a probiotic (Holkem, *et al.,* 2023). Olive leaf extract offers enormous potential for usage as an immunostimulant agent in aquaculture, according to recent research and inferences. These results demonstrated that an extract from olive by-products has immunostimulant qualities that can strengthen fish raised for commercial purposes' resistance to a range of infections and diseases (Hazreen-Nita *et al.,* 2022).

Mechanisms Underlying Olive Plant Compounds for Fish Growth and Immunity

Due to the abundance of bioactive compounds found in medicinal plants such steroids, phenols saponin, polysaccharides and flavonoids, it has been proven that these products improve fish growth, immunological responses, appetite, antioxidation, and control reproduction. Improvements in humoral, and mucosal immune parameters, and antioxidant enzyme activities are typically correlated with fish growth rates performance (Hoseinifar *et al.,* 2020). Baba et al. (2018) study on *Oncorhynchus mykiss* reveals that the species' serum biochemical parameters and survival rate were improved by olive oil leaf. Due to their beneficial biologically active metabolites, olive as a medicinal plant have indicative effects on growth promotion, appetite-stimulating and digestive enhancement. When administered properly, to immune modulation, medicinal herbal extracts tend to be a promising alternative to synthetic drugs in aquaculture.

Application and Sustainability in Aquaculture

Aquaculture feeds are designed with a balanced nutrient content to fulfill the needs of various species. They provide all the essential nutrients and energy required to meet physiological demands of fish. Blue foods have advantages over other animal-based foods in many regions of the world, including accessibility and affordability, as well as health benefits (Ryckman *et al.,* 2021). Optimizing nutrition provided in aquaculture is therefore necessary to raise fish for food production. Atlantic salmon (*Salmo salar*) diets have been studied by substituting terrestrial plant oil from olive (Glencross *et al.,* 2014) for fish. Compared to many other foods derived from animals, blue foods typically have lower environmental footprints (Gephart *et al.,* 2021). Sustainability in the aquaculture sector is of social, economic, and environmental importance. Producing an enormous diversity of blue foods, these systems encourage robust diets and adaptability to market swings and global warming. Blue foods can also play a significant role in socio-economic practices and cultural heritage as well as wealth opportunities (Ban *et al.,* 2019). Aquafeed production requires sustainable alternative feed sources. The most practical substitute sources are terrestrial plant and animal-based materials, there are also recent findings on insects and byproducts from fisheries and aquaculture.

4. Conclusion

Blue foods are the cheapest protein and of higher benefits to human nutrition. The use of plant-based materials in their feeds has shown to be a crucial way to lessen aquaculture's dependency on wild fish. Technological advancements as therefore presented a great opportunity to consistently, produce high-quality olive oil and derivatives with improved nutritional profiles for blue food. Olive derivatives possess antioxidant, antibacterial, antimicrobial, antioxidant, antifungal, and antioxygenic properties that enhance fish's intestinal health and immunological response. The nutritional value of all olive plant derivatives, such as olive cake, olive leaves, and branches, or vegetative waters should not be ignored. Research into the potential benefits of olive plants and derivatives for various fish species' diets as positive impact and can be used continuously for utilization. Given the substantial benefits reported here, adding olive derivatives to feeds utilized by blue foods does not negatively affect growth performance. Going forward, olive crop and derivatives can be utilized in blue foods; however, an extraction and purification process for key polyphenols needs to be developed. Adding these derivatives to blue foods solves the problem of managing agricultural waste. More developmental studies are needed to determine whether adding olive plant or its derivatives to diets can enhance the nutritional value of blue foods.

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