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Editorial

Fish Nutrition and Feed Technology

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This Special Issue was designed to address advances in feeding and feed technology and challenges in aquaculture in order to achieve a greater understanding of its management and improve the sector. According to the FAO (Food and Agriculture Organization of the United Nations), aquaculture and fisheries provide approximately 17% of global edible animal proteins; aquaculture and fisheries are thus considered crucial sources of animal protein for human diets. Importantly, aquaculture exceeded fishery production in 2016, contributing 52% of the total aquatic foodstuff produced for human consumption in 2018 (FAO, 2020).

After years of a decreasing trend, the COVID-19 pandemic caused an increase in the number of malnourished people, with an additional 9.3 million children suffering from acute malnutrition presently. Aquaculture is a sustainable and environmentally friendly practice with significant potential to feed the rapidly increasing world population and combat malnutrition. It can provide highly nutritious food containing high-quality proteins and essential ingredients for human health. Al-Banna et al. [1], in their review, reported that dried fish could be used to address malnutrition in Bangladesh, thanks to its high protein and supply of minerals such as iron, zinc, and calcium, which are essential for children and pregnant and lactating women. These results are supported by the analysis of the nutrient composition of dried fish in the databases Web of Science, PubMed, Google Scholar, ScienceDirect, Banglajol (a Bangladesh-based database), and ResearchGate, in addition to literature searches. The authors conclude with the hope that policymakers will work together with experts in food and nutrition to promote the consumption of dried fish via encouraging the inclusion of dried fish in the diet of vulnerable populations (children and pregnant and lactating women).

Based on current fish consumption worldwide, aquaculture production is expected to increase from 82,087 Kt in 2018 to 129,000 Kt by 2050 to meet the needs of the growing population. However, the diet of aquatic species includes fishmeal (FM) and fish oil (FO) derived from wild fish stocks. Generally, sardines or anchovies are used, which are fish of little economic value but essential for maintaining the food web. Due to the constant depletion of natural resources, the awareness of the need for sustainable aquaculture has become increasingly evident and has led scientific research to look for new solutions. To increase the production of farmed fish, it is necessary to develop new feed compositions with innovative ingredients that can replace FM and FO. Zaman et al. [2] estimated that FM substitutions of 7.0% with meat meal (MM) reached the highest value of weight gain and specific growth rate in the juvenile olive flounder (*Paralichthys olivaceus*), without any negative consequence on feed consumption, protein retention, hematological parameters, or innate immune system functionality. Thus, the authors concluded that the substitution of up to 20% MM for FM is safe for juvenile olive flounder.

As pointed out by Hameed et al. [3] in their review, insects have spurred considerable interest in both fish and crustacean aquaculture, as innovative ingredients, thanks to their excellent nutritional value, although not comparable to FM. However, their nutrient composition may vary according to the species and developmental stage. In general, insects have a lower protein content with respect to FM and lack several essential amino acids. However, in their feeding experiments, Carral and Saez-Royuela [4] report that

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substitutions of up to 47% FM with black soldier fly larvae (*Hermetia illucens*) did not modify the quantity of essential amino acids in the body of tench (*Tinca tinca*) juveniles.

Certainly, while the variety of ingredients that can be employed in artificial diets is virtually endless, the time and economic resources needed to test them are not. In their study, McKay and Jeff [5] compared three commercial diets for giant kokopu (*Galaxias argenteus*) larvae to identify the nutritional needs and improve their commercial aquaculture production. Indeed, they reported evident differences in groups fed different commercial diets.

In this respect, we turn to the contribution of Campbell et al. [6] reporting on the initiative carried out by the F3 Consortium Feed Innovation Network (f3fin.org), which aims to tailor diets to suit user demands and the availability of local ingredients. This process is based on the acknowledgement that a proper diet does not need to be manufactured with specific ingredients, but rather it should provide a balanced variety of ingredients to meet the nutritional requirements of the targeted species. Indeed, substitutions must take into account that the amount of protein included can influence the metabolism, immune response, and disease resistance of the target species, as reported by Huang et al. [7] in genetically improved farmed tilapia (*Oreochromis niloticus*) adapted to high temperatures, for which an overall proportion of 29.28–31.69% dietary protein was suggested.

The emerging picture is a complex one, and the mere evaluation of the protein requirement may not be sufficient to define a suitable diet. Indeed, the nutrient availability can be modified during feed manufacturing due to the fact that raw proteins are denatured during the heating process, with consequently reduced amounts of amino acids and peptides. As Cho et al. [8] report, aquafeeds available on the market are heat-processed, and therefore have a low nutritive value, making the counterpart produced without the heating process preferred as a feed source for juvenile pacific bluefin tuna (*Thunnus orientalis*)

Plant proteins represent a good FM replacement in aquaculture. Soybean is one of the most common replacements due to its cost-effectiveness and high nutritional value. However, the presence of plant ingredients has been proved to negatively impact the growth, gut and liver health and structure, intestinal microbiota, and immunological response of fish. Moreover, in order to meet the increasing demand for fish, intensive aquaculture practices are sought. It is unlikely that intensive aquaculture poses a source of stress for fish and favors the transmission of infectious and stress-related diseases. Usually, antibiotics are employed to treat diseases and combat pathogens with the consequent development of antibiotic resistance, which is a global issue in humans as well as in animal farming, including aquaculture. Research is committed to bringing to light sustainable alternatives to antibiotics by using macro- and microalgae, fungi, plant extracts, or parts of plants alone or as prebiotics and probiotics, as oral integrators to stimulate growth performances and disease resistance by boosting the immune system and antioxidant defenses. This is reported by Faheem et al. [9] in their study carried out on the inclusion of 5% *Spirulina platensis* in the juvenile grass carp (*Ctenopharyngodon idella*) diet, resulting in positive effects on their growth, digestive enzymes, antioxidant status, and innate immune system. Similarly, the integration of the crustacean decapod *Litopenaeus vannamei* with the microalgae *Haematococcus pluvialis* and the fungus *Yarrowia lipolytica* into their diet as sources of astaxanthin improved the body color as well as the growth performance, metabolism, and antioxidant status of the fish, as reported by Liu et al. [10].

The following contributions focus on this area of research. Abdel-Latif et al. [11] analyzed the impact of extract of *Astragalus membranaceus*, or mongolian milkvetch, on the growth performance, physiological response, and serum immunity of *Pangasianodon hypophthalmus* juveniles, with positive outcomes. Extract from *Macleaya cordata*, or plume poppy, positively affected the growth performance, serum parameters, and intestinal health of juvenile American eel (*Anguilla rostrata*) (Chen et al. [12]). Wang et al. [13] reported that the addition of *Phragmites australis*, or common reed, to feed can improve the liver morphology and functionality, as well as the non-specific immune response, of grass carp (*Ctenopharyngodon idellus*). Outama et al. [14] found that dietary supplementation with passionfruit (*Passiflora edulis*) peel powder positively stimulated the immune system and the antioxidant defenses in Nile tilapia (*Oreochromis niloticus*) cultured in a biofloc system.

Finally, Orso et al. [15], in their review, underline how Lamiaceae, including medical herbs such as oregano, rosemary, sage, thyme, and mint, have been increasingly used in aquaculture as feed additives due to their low cost and simple use. However, they also underline in their conclusions that various critical issues still remain and limit their use on a large scale, and that the contribution of scientific research is crucial to improve their applicability. In particular, the dosage, part of the plant used, extraction technique, and the administration method and its duration are aspects that require further investigation.

I hope that the high-quality contributions in this Special Issue stimulate insights into ongoing research and at the same time open up new lines of research.

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