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Editorial: Innovative, non-conventional ingredients for sustainable aquafeeds

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Editorial on the Research Topic
Innovative, non-conventional ingredients for sustainable aquafeeds

Most countries and regions of the world have single-handedly or jointly engaged in efforts to achieve the 17 United Nations Sustainable Development Goals (UN SDG) by the year 2030. Currently, aquaculture already feeds billions of people and will continue to do so, hence, addressing the problems of global food security and nutritional health, poverty alleviation, and even economic growth. Nevertheless, the advantages gained from aquaculture must not be offset by the negative environmental and social consequences that it may impart. As one of the fastest growing food-producing industries in the world, aquaculture must assure sustainable, long-term efforts, practices, and actions to heed the global call to meet the UN SDG.

A major component in sustainable aquaculture is fish feed development and discovery of novel feed ingredients. As more than half of the cost in aquaculture production comes from feeds, different feed reduction schemes have been employed and adopted. One of the more promising approaches is the adoption of circular bioeconomy in aquafeed use and development. Circular bioeconomy in aquaculture is achieved through the use, reuse, and/or recycling of non-conventional but modern, innovative fish feed ingredients such as by-products, agricultural industry processing wastes, and natural raw materials that do not compete with human food consumption. These revalorized feed ingredients are often cost-effective, environmentally sustainable, and pose no serious negative effects on the environment. Before utilizing novel feed ingredients, they undergo rigorous testing and evaluation. Two ways are generally employed to evaluate the feasibility and potential of candidate feed ingredients—via systematic review and meta-analysis and through *in vivo* testing. Each method has its own advantages and caveats.

Systematic review and meta-analysis are standard tools in the field of medicine that aim to provide a more accurate picture of the effects of different medical treatments (Egger et al., 2001; Impellizzeri and Bizzini, 2012). More recently, however, numerous studies using systematic review and meta-analysis of various feed ingredients and effects thereof on fish performance and overall health have been published (Bertocci and Mannino, 2022; Li et al., 2022; Mugwanya et al., 2022; Tran et al., 2022; Moyo and Rapatsa-Malatji, 2023; Trevi et al., 2023). The use of systematic review and meta-analysis in aquaculture can provide a precise estimate of the consistent effects of feed ingredients on fish performance across various culture species. A major caveat of these tools, however, is the inherent heterogeneity of the data systematically collected, screened and reviewed.

Factors such as the type of cultured species, feed formulations and preparations, culture conditions, and other external or environmental influences differ among the data. These factors introduce variability across studies making it difficult to achieve an unbiased and accurate combination and comparison of results. Nonetheless, this tool can still be exploited as an initial filter for screening potential and candidate fish feed ingredients, especially when coupled with *in vivo* testing. A confirmatory evaluation of the results from the systematic review and meta-analysis through *in vivo* testing may resolve the issues of potential biases, differences, skewed data, and/or confounding factors.

In the Research Topic, Magbanua and Ragaza(a) subjected the effects of copra meal on growth and carcass composition of Nile tilapia as a dietary fishmeal replacement to systematic review and meta-analysis. Copra meal is a by-product of the coconut processing industry. It is treated as a waste product of the extraction of coconut oil from the dried coconut meat. When fermented, copra meal in various inclusion levels (Laining et al., 2017; Mamauag et al., 2019; Harlina et al., 2021; Intoy and Traifalgar, 2021) showed promising results as an aquafeed for several fish species. In Magbanua and Ragaza(a), however, a lower dietary crude protein in copra meal-based diets translates to enhanced tilapia growth. Due to the relatively lower nutritional values of copra meal, such as an imbalanced amino acid profile, low protein content, poor digestibility, and high fiber, it remains subpar to fishmeal. The values of the tilapia proximate composition, however, were comparable and on par with those fed fishmeal-based diets. The co-variates (i.e., dietary levels of fishmeal and copra meal, length of feeding, developmental stage of the cultured fish, and dietary protein content) selected did not cause the heterogeneity. Other untested factors such as the method of feed and ingredient preparation (especially the fermentation of copra) and the inherent nutritional properties of the copra meal may have attributed to the variability in the data.

In another meta-analysis by Magbanua and Ragaza(b), the use of dietary pea meal for Nile tilapia are affected by factors such as the length of the feeding, developmental stage of the cultured fish, and dietary protein content. These factors should be critically considered to maximize the potential of pea meal as a fishmeal replacement. For example, diets with pea meal that are characterized by high crude protein contents may lead to growth reduction of fish. On the other hand, a longer period may promote better fish performance. Although peas contain adequate quantities of protein and essential amino acids (Millar et al., 2019), they possess anti-nutritional factors such as saponins, tannins, phytic acid, lectin and trypsin inhibitors (Ganzon-Naret, 2018; Wu et al., 2023) that directly affect the quality of proteins, the availability of amino acids, and overall nutrient absorption. Hence, processing and quality control measures (e.g., dehulling, autoclaving, and heating) are crucial steps to reduce the effects of anti-nutritional factors.

In vivo testing involves the practical and realistic evaluation of potential fish feed ingredients. Target cultured species can be selected which allows for an optimized feed formulation and feeding regimen for the chosen fish species. Other than measuring growth, feed and health performance, this tool can also provide information on the optimum levels or ranges for specific feed ingredients. These levels and ranges can then be used for strategies to reduce feed costs.

Squid by-product meals are considered as high quality protein sources and feed stimulants for many aquatic species (Samaddar, 2018). Squid by-products include squid parts that are rendered as wastes or unfit for human use and consumption such as the head, tentacles, fins, viscera, skin, pen, and mantle (Ezquerra-Brauer and Aubourg, 2019; Ramakrishnan et al., 2023). In Pan et al., squid industry processing wastes were enzymatically hydrolyzed and supplemented in diets for black tiger shrimp. Hydrolysis increased the crude protein content of the ingredient by 10% while the chemical score indices of most of the essential amino acids were close to or more than 100%. The hydrolysates were also composed of low-molecular weight peptides. The growth performance of shrimp fed with 1% squid hydrolysates in a plant-based diet was found comparable to the group fed with fishmeal based diets. These findings could increase the utility of squid processing industry by-products and wastes and could lower the use of fishmeal in shrimp diets.

Long-chain, highly unsaturated fatty acids are abundant in marine microalgae and diatoms (Yi et al., 2017). These bioactive fatty acids are almost non-existent in terrestrial sources such as plant oils. In Huervana et al., the marine diatom *Thalassiosira weissflogii* was used for the diets of seawater-tolerant Nile tilapia for improvement of the fish fatty acid profile. Due to the high levels of omega-3 or n-3 fatty acids in the marine diatom, the tilapia exhibited improved n-3 fatty acid profile, n-3 long-chain, polyunsaturated fatty acids, and n-3:n-6 ratios. Moreover, genes related to growth in the muscle were upregulated. An optimum dose of 2.55% *T. weissflogi* improved tilapia growth. Findings of this work suggest that cultured marine diatom could be successfully used as a source of omega-3 or n-3 fatty acids for the diet of saline tilapia. This could decrease the reliance of aquaculture on the use of fish oil as an important ingredient for fish diets. Marine diatoms could be a sustainable and renewable resource of important fatty acids for fish diets.

Author contributions

JR: Conceptualization, Project administration, Supervision, Writing—original draft, Writing—review and editing. VK: Writing—review and editing, Project administration. RT: Project administration, Validation, Writing—review and editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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