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Fish meal and other alternatives in the diet of fish

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ABSTRACT

The two aspects of fish production- feed cost and disease prevention are considered the pillars of success for the growth of aquaculture in any culturing system. As feed involves about 60% input cost towards the production of fish and disease affecting the profitability of the culturing system. In order to work on these important aspects, a common approach is needed to solve both these problems which in turn improve fish health and growth to increase fish production. Reducing the dependency of aquaculture on fishmeal and other costly fish feed ingredients is key to sustainable development for the aquaculture industry. One of the major bottlenecks in the expansion of cold-water fish culture is the availability of quality fish feed at low cost. Recognizing the importance of proper feeding in successful fish production, the present review paper is aimed at the formulation of quality feed using locally-available by-products, insect meal and other plant and animal-based feed ingredients making the feed cost-effective as well as environmentally friendly. The production of quality protein will create economic development among the poor sections of society and employment generation for the uneducated/educated, skilled or unskilled sections of society.

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Introduction

Fishmeal is a common term used to describe a nutrient-rich fish ingredient that is predominantly employed in the diets of both terrestrial and aquatic animals. Fish meal is crushed and powder is made from the cooked flesh of fish. Though fish meal was earlier used as fertilizer, it is presently principally used in animal feed, particularly for chicken, swine, farm-raised fish, and household pets. Fish meal and fish oil are mostly obtained from oily fish species such as menhaden and anchovy. When chopped fish is driven via a screw conveyor or continuous steam cookers, the processing of fish meal begins. The oil and water is then squeezed (pressed) out of the cooked mash. Cooked mash quickly spoils during storage. Hot air is used to dry the pressed fish cakes, providing a meal that is rich in vitamin B12 and contains up to 50% protein [1]. Fish meal as animal protein source is without a doubt, one of the most important sources of essential amino acids for fish. The high concentration of well-balanced proteins with high digestibility present in fish meal making it valuable. The fish's high need for balanced and easily digested proteins can be addressed by using plant-based ingredients instead of marine raw materials. This can be accomplished with meal or protein concentrates derived from soybeans, canola, peas, and other relatable sources. A well-balanced plant-based diet can also aid maintaining the availability of essential amino acids) [2].

Global Scenario

Over the last two decades, the proportion of world fisheries devoted to the production of fishmeal and fish oil has declined (Fig. 1). The average annual fishmeal output from 2001 to 2010 was around 5,5 million tonnes, but it hovered around 5 million tonnes from 2011 to 2020.

Fish oil is produced in quantities ranging from 0,8 to 1,3 million tonnes per year. The quantity of forage fish, notably the Peruvian anchoveta fishery, influences the changes from year to year to a large amount, the latter being the world's largest in terms of volume, with annual output ranging between 3 and 7 million tonnes. The large changes in this species' landings are connected to the El Nino 4 climatic occurrences, which drive warm water into the upwelling zones. When this happens, fisheries suffer, and catches might drop by several million tonnes in a single season. Global fishmeal output increased by 20% from 2017 to 5,8 million tonnes in 2018, marking the highest level since 2011.Fish oil output reached approximately 1.3 million tonnes, the highest amount in 20 years. High catches of Peruvian anchoveta contributed to the increased yield. Global output is expected to be substantially lower in 2019 and 2020 (Fishmeal: 4,9 and 5 million tonnes and Fish oil: 1,17 and 1,25 million tonnes respectively). Lower catches in Peru are once again the major reason of the decline. To a greater or lesser extent, several countries produce fishmeal and fish oil. In 2019, the top nine fishmeal and fish oil manufacturers produced 61% of total fishmeal and 70% of total fish oil. Ninety percent of fishmeal and 93 percent of fish oil were produced by the top 25 manufacturers. Peru is the world's greatest producer, accounting for around 20% of worldwide fishmeal output and 15–20% of global fish oil outputs since 2010.Peru and Chile produced 24 percent of the world's fishmeal and 22 percent of the world's fish oil in 2019. Fishmeal and fish oil are marketed on the international market since local consumption is minimal in Peru. In Chile, however, a large portion of fishmeal and fish oil output is utilized to make salmon and trout feed. China, Thailand, and Vietnam are the top three fishmeal producers in Asia, with a combined production of 1,03 million tonnes in 2019, the bulk of which was consumed in Asian markets. In 2019, the US produced 240.000 tonnes of fishmeal and 90.000 tonnes of fish oil, respectively. Menhaden catches serve as the foundation for both. Norway and Denmark combined to generate 390.000 tonnes of fishmeal and 120.000 tonnes of fish oil in Europe in 2019.Norway is one of the world's major users of fishmeal and fish oil owing to its aquaculture production (salmon and trout) [3].

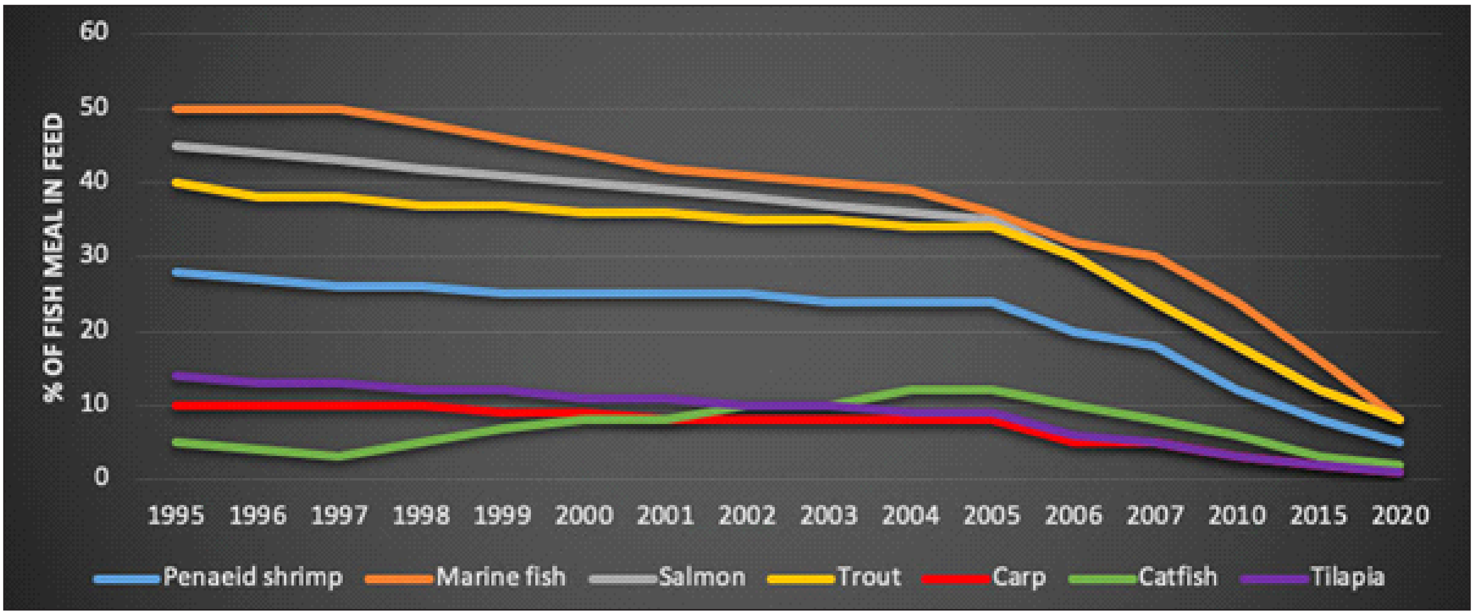

Figure 1. Percentage of fishmeal used in aquaculture feeds from 1995 to 2020.
Source: Tacon & Metian, 2008

Importance of Fish meal

Feed performance and increase of animal biomass increase because of addition of fishmeal within the diet. This is because of higher food palatability, enhanced nutrient uptake, digestion and absorption [4]. Fishmeal complements and affords synergistic consequences due to the balanced amino acid composition to inspire fast growth and shop feeding expenses through which include diverse animal and vegetable proteins into the weight loss plan[5]. For maximum improvement, boom, and reproduction, fishmeal contains a balanced amount of important amino acids, phospholipids, and fatty acids such as DHA (Docosahexaenoic acid) and EPA (Eicosapentaenoic acid) in larval and brood inventory nutrition. So one can improve immune gadgets. The nutritarians in fishmeal additionally resource in disease resistance. Formulation of nutrient dense-diets are possible due to high-quality fishmeal which promotes optimal growth [6] . As fishmeal has a higher nutritional digestibility, it has been discovered that including it in fish diets reduces water pollution. When compared to wild fish, including fishmeal into the diets lends a "natural/wholesome" attribute to the final product [5].

Nutritional Profile of Fish Meal

Fish meal is a obviously balanced feed aspect this is excessive in protein, strength, and mineral elements like phosphorus and calcium when in comparison to different animal proteins.FM is also an herbal source of vitamins together with choline, biotin, and diet B12, as well as vitamins A, D, and E, as well as hint elements like selenium and iodine.FM is distinguished from other dietary supplements by the fundamental quality of the nutrients included in it, particularly in terms of having essential amino acid content and unsaturated fats (omega-3 fatty acids). The most popular omega-3 fatty acid sources in the diet are fish meal and fish oil. There are two varieties of FM: those made from waste from the processing of different edible human fisheries products (salmon, tuna, etc.) and those made from fish specially collected to make FM (herring, menhaden, pollack, etc.). Raw fish is cooked or dried, and then the oil is extracted to make fish meal.FM is a by-product of both the processing of fish for human consumption and the manufacture of fish oil.FM is the principal supplementary protein source offered to cattle in several regions of the world since plant-derived alternatives are either unavailable or too costly. For the maximum advantage of young pigs in the diet, 5 to 10 percent FM was employed [5].

Protein in Fish meal

Fish meal is one of the most important protein constituents in fish diets; it is high in protein, has a well-balanced EAA profile, and has a good nutritional profile(Table:2).Fish meal has traditionally been a key source of protein in fish feed since most experts agree that carnivorous fish require more than 40% of fish meal, while omnivore fish only need 30 to 40% [7] .The crude protein content of excellent-grade fish meal is usually between 60 and 72 percent by weight. FM is one of the most popular animal protein sources in farm animal diets from a nutritional aspect. On a dry matter basis, a typical incorporation rate of FM in terrestrial livestock diets is 5 percent or less. Protein is required in a balanced diet, however its nutritional value is determined by its amino acid profile and digestibility index. Amino acids are the building blocks of proteins, and when they are digested, they are released into the bloodstream for absorption. Only some particular amino acids are required in the diets of monogastric animals, not large amounts of protein [8].

*Table 2. Crude protein (CP) and essential amino acids (EAA) composition of fish meal (FM: anchovy), rendered meat meal (MM), poultry by-product meal (PBM), blood meal (BM), and soybean meal (SBM)**

Items	FM	MM	PBM	BM	SBM
CP, %	64.6	54.0	64.1	77.1	47.5
Ash†, %	15.0	25.0	19.0	4.4	6.0
Na, %	0.88	0.80	0.30	0.50	0.02
EAA, g/100g CP					
Arginine	5.70	6.67	6.15	4.33	7.33
Histidine	2.41	2.11	1.95	6.56	2.69
Isoleucine	4.74	2.96	3.14	1.18	4.55
Leucine	7.74	7.11	6.07	14.25	7.71
Lysine	7.91	5.69	5.18	9.13	6.36
Methionine	3.02	1.48	1.73	1.28	1.41
Cystein	0.94	1.11	1.01	1.41	1.56
Phenylalanine	4.12	4.02	3.53	6.93	5.03
Tyrosine	3.33	2.59	2.43	2.94	3.83
Threonine	4.37	3.65	3.40	5.25	3.89
Tryptophan	1.18	0.65	0.75	1.40	1.37
Valine	5.43	4.93	3.92	9.14	4.78

- **NRC (1998).*
- *†Batal and Dale (2010).*

For its high protein content and nutritional value of lipids and other elements, fishmeal is an excellent aqua-feed and pet-food ingredient [9]. For many species, fishmeal is regarded as a kind of indispensable source of protein to support their growth and activity. Fish diets can range from 32 percent to 45 percent total protein by weight [10].

Lipids in fish meal

Linolenic acid, docosahexaenoic acid (DHA), and eicosapentaenoic acid (EPA) are the most prevalent omega-3 fatty acids found in fishmeal and fish oil. Small algae and zooplankton synthesize DHA and EPA fatty acids, which are then transferred through the food chain [11]. Liquid fish oils and solid fats can be isolated from the lipids in fish. During fishmeal processing, the majority of the oil is typically extracted and the leftover lipid is usually between 6% and 10% by weight, but can range from 4% to 20%.Fish lipids are great sources of important polyunsaturated fatty acids (PUFA) in both the omega-3 and omega-6 families of fatty acids, and are easily digested by all animal species. Omega 3 or n-3 fatty acids are found in greater amounts in fishmeal and oil than n-6 fatty acids. Most plant lipids, on the other hand, have larger levels of n-6 fatty acids.Linoleic acid, an omega-6 fatty acid, is abundant in oil derived from corn, soybeans, or cottonseed, is such an example. Although certain oils, such as those from canola and flax seeds, contain linolenic acid (an omega-3 fatty acid), however, most animals' ability to convert it into essential DHA and EPA is likely constrained [5].

Energy in fish meal

In order to evaluate animal energy requirements, digestible energy and metabolizable energy are both utilized as measurements in expressing feedstuff nutritive evaluation. Digestible energy is the portion of energy input that is absorbed in the digestive system, while metabolizable energy is digestible energy minus energy lost in external excretions (urine and via the gills) [12] . When consumed as an energy source by fish, various feedstuffs supply varying quantities of energy [13]. Direct and indirect approaches are the two most common ways for determining digestibility. The direct approach involves the calculating total intake of food by means of a collection of total feces, whereas the indirect method uses a (external or internal) marker, or indication, with enough feces samples [12].The lipids in fishmeal offer a high level of energy as well as a great nutritional profile of essential fatty acids. Fishmeal's calorie content is directly proportional to the quantity of protein and oil it contains, as there is very little carbohydrate in it. The amount and quality of oil in fishmeal is determined by the fish's species, physiology, sex, reproductive state, age, eating patterns, and processing technique. The lipids in fishmeal not only give a good profile of essential fatty acids to the diet, but they also supply a large amount of energy.

The lipids in fishmeal not only give a good profile of essential fatty acids to the diet, but they also supply a large amount of energy [14].

All animals, including fish, shrimp, poultry, pigs, and ruminants like cows, sheep, and goats, can readily digest the lipids in fishmeal and fish oil. The lipid digestibility of these animals is 90% or higher. Fish lipids have a high digestibility, which means they can deliver a lot of useful energy. If a fish or shrimp's food is insufficiently energy-dense, they will have to break down important proteins for energy, which is costly and can result in harmful ammonia generation [15].

Mineral and Vitamins in fishmeal

The vitamin content of fishmeal varies greatly depending on various aspects, including the origin and composition of the fish, the technique of fishmeal processing, and the freshness of the product. The fat-soluble vitamins are removed during oil extraction, which's why the level of fat-soluble vitamins in fishmeal is low. Fishmeal is a reasonably good source of B-complex vitamins, including cobalamine (B12), niacin, choline, pantothenic acid, and riboflavin [9] .The presence of high niacin concentration in the tiny fish *Kapenta* and low niacin content in numerous big fish species (*Mbubu*) suggests that niacin content varies by species.Stadlmayr et al. (2012) found low niacin levels in Mormyrids (the family to which all samples of *Mbubu*belong) and high niacin content in Anchovies, which supports this hypothesis [16]. Bogard et al. (2015) discovered significantly lower quantities of folate in fresh fish, confirming that tiny fish ingested whole had greater levels of folate [17]. Haug et al. (2010) and Bogard et al. (2010) both confirm the findings of this study on vitamin B12 concentration in big and small fish species (2015) [18]. Lukmanji et al. (2008), on the other hand, found much lower vitamin B12 levels in fresh fish, regardless of size, with only their dried samples holding comparable levels [19]. All documented discrepancies in fishmeal might be attributable to a variety of variables, including species, processing methodology, and analytical methodologies. Small fish contains more minerals than big and medium fish, according to Nils Nölle et al. (2020), independent of processing [20]. The reason behind this may be the small fish nevertheless contain rich mineral containing components such as bones, heads, and innards(Kawarazuka and Béné –2011) [21]. Prior to analysis, all of these were removed from large fish. This is especially noticeable in species like Matuku, where samples come in a variety of sizes.Variations in mineral concentrations between small and medium fish were also discovered to be less prominent than between tiny and big fish.This is mostly owing to the fact that Distichodusmaculatus, Mbilya, and Mintesa samples are devoured whole or just have their innards removed, containing more minerals than other samples in this size category. To begin with, the bones of medium and large fish were extremely fragile and could not be entirely removed during the preparation of the samples for examination. Second, the skin of big and medium samples, which can contain significant levels of minerals, was examined (Kabahenda et al. 2011) [22]. As a result of the low water content of processed samples, mineral concentrations in the skin may develop.When calcium, iron, and zinc levels in dried Kapentaand Chisense samples are examined on a dry weight basis, Steiner-Asiedu et al. (1993) report results that are remarkably comparable to Nils Nölle, et al., (2020).

Nyirenda (2009) observed calcium levels for fresh and dried Kapenta that are similar to Nils Nölle, et al., (2020), but her findings on the calcium content of fresh Barbus species are much lower [23]. This could be connected to the fact that only the muscle of one of the bigger Barbus species was examined throughout the study. In comparison to big and small fish species, the iron and zinc contents in fresh fish reported by Bogard et al. (2015) are comparable; however, the zinc quantities reported by Nils Nölle et al. (2020) may be somewhat higher due to variations in location, species, or analytical techniques. According to research, fish meal has a strong nutritional profile. Fish meal's limited supply and affordable pricing piqued interest in alternatives to fish meal sources.

ALTERNATIVES TO FISH MEAL

Fish meal is undoubtedly a significant source of vital amino acids for fish. Alternatives to fishmeal must be able to meet the fish's high need for well-balanced, highly digestible proteins. This can be done with meal or protein concentrates made from plant and animal by-products. A well-balanced plant-based diet can also aid in the delivery of essential amino acids. Anti-nutritional factors should also be taken into account; some plant raw materials include these chemicals, which might inhibit the feed from being properly digested. These are more likely to withstand feed processing and so end up in the finished product [25].

Due to a large spectrum of anti-nutritional factors (ANFs), the use of plant-derived materials is limited, and these sources can only replace a limited amount of fishmeal protein. In 2001, a study of ANFs revealed that levels commonly seen in fish diets derived from commercially accessible plant sources are unlikely to alter fish development performance. According to recent research, interactions between ANF effects appear to be quite essential, and the microbiota in the gut may influence the effects of ANFs. Increased inclusion levels of plant-based substances can be achieved by removing ANFs through better processing methods, supplementing with limiting amino acids, and incorporating enzymes. Plant protein sources, on the other hand, may substitute fishmeal at a lower level than animal protein sources. Invertebrate and nut meals[27]. Algal [28] and bacterial proteins [29], chicken by-products and a range of plant-based proteins have all been found as potential replacements for animal proteins [30]. Without compromising health or performance, significant progress has been achieved in reducing or replacing fishmeal in the diets of many aquaculture species (Rossi, 2011).Recent research shows that fishmeal-free diets including different protein mixes can provide equivalent development in rainbow trout Oncorhynchus mykiss when compared to typical fishmeal-based diets [32].

Plant-Based Feeds

A new biomass census combined data from hundreds of research to identify which kingdoms, classifications, and species had the most global significance. According to the findings, plants (mainly those on land) account for 80% of total biomass.[33] Plant-based feed is the most popular alternative to conventional fishmeal. Soy, wheat, canola oil, or corn is used to substitute fish-based ingredients in such diets. Although effective as a feed substitute for a variety of fish, it comes with a price. According to researchers, this option has an influence on land farming since it requires more land, water, and fertilizers to create the feed and all have environmental consequences.

Soybean meal

Ingredients arising from are a popular substitute for fish meal in aquaculture [34]. Soybeans are extremely edible, abundant in protein, and have a well-balanced amino acid profile [35, 30] .Soybeans, on the other hand, include antinutritional factors that make it difficult for fish to digest [36] and they can also induce gastrointestinal problems including enteritis [37]. Soybean also contains lecithin and oil, in addition to a high quantity of crude protein. Soybean meal is the most researched fishmeal substitute and is extensively employed as a main plant protein source in aquafeed. Due to the antinutritive elements and carbs in soybean products, many predatory animals cannot eat them [38]. Gamma radiation can significantly increase the amount of fishmeal replacement with soybean meal. When compared to alternative plant-based ingredients, a fishmeal-free soy compound diet using chicken waste (30 percent crude protein) was the most economical for tilapia. Yet, it has been demonstrated that soybean meal can promote inflammation in some farmed fish's distal intestines at certain inclusion levels.

Other plant sources

Peas, lupins, corn, rice, canola, rapeseed, barley, and wheat are all plant-based sources. It's not straightforward to substitute fishmeal with these sources, especially in formulations for carnivorous species that demand a lot of protein [39]. Improved processing technology boost the nutritional value of plant-based sources and its use as a fishmeal substitute. ANFs can be removed during processing, resulting in higher crude protein levels. Plant proteins, in conjunction with other plant protein sources or proteins from other sources, can be used to replace most, if not all, of the fishmeal in practical diets[41].

Plant-based components support high-quality fillet development in some species, whereas entire fishmeal substitution is achievable in others, although with reduced biological performance. Rice protein concentrate is one plant-based ingredient that is a good raw material because of its high crude protein (75 percent) and fat (11 percent) content, as well as the fact that it has no negative effects on fish development up to a 20% inclusion level [41]. The underlying ingredient, however, is rice, and its usage may not be encouraged in regions where rice is a staple meal.

Algae

Microalgae have a huge economic potential since they have the highest areal biomass productivities of any photosynthetic organism, including fodder crops (Fig. 2). Environmentally sustainable, microalgal-based feed also has a minimal impact on water and agricultural land [42]. Seaweeds and phytoplankton, which are at the basis of what all wild fish ingest, are the most probable candidates as a fishmeal replacement. Amino acids, taurine (a substance not present in land plants), lipids, and pigments are abundant in algae. To coincide with the nutritional demands of the fish, the type of algae utilized as a replacement would need to be evaluated and matched with the type of fish it would be feeding. Algae is a possible alternative to costly and finite fish-based diets, as it is currently commercially harvested (Kristin Elliott,2019the usage of microalgae-based tilapia feed that is affordable and improves the nutritional value of farmed fish, The study by Pallab K. et al., published in 2020, is a step towards ending reliance on fishmeal and fish oil. In a research published in 2021, Oyas A. et al. investigated the effects of algal meal supplementation on common carp (*Cyprinus carpio var. communis*) fingerling growth, body composition, and survival [43]. The findings showed that the treatment group fed with 40% algal meal displayed substantially better values for percentage weight increase, specific growth rate, and feed conversion ratio (p 0.05). The research also demonstrated that the fish meal in the diet of common carp may be changed upto 40% without affecting growth. That will directly impact cost savings.

Recycling Food Waste

Despite the fact that the globe is making a concerted effort to decrease waste, there is still a significant amount of food waste (Fig. 2). More than 40% of human food is thrown out, and those in the aquaculture business searching for a more sustainable feed have discovered a method to use it [44]. Food waste and feed pellets were used in polyculture of low-trophic level fish [bighead (Aristichtysnobilis), grass carp (Ctenopharyngodonidellus), and mud carp (Cirrhinamolitorella)] with the goal of producing safe and high-quality products for local consumption. The findings showed that bighead and grass carp fed with food waste feed pellets were found to be significantly free of organochlorine pesticides (HCHs 0.03; DDTs 1.55-2.56 ng/g ww; HCHs 0.03; and DDTs 1.42-3.34 ng/g ww, respectively) [45]. An investigation on Nile Tilapia demonstrated that a Lebanese restaurant food-waste-based aquaculture feed may substitute between 25% and 33% of commercial feed used during feeding regimens without affecting the fish's survival, health, or growth [46]. Farmers who now use more standard commercial feeds may find that this discovery reduces their costs dramatically. There are also studies underway to see how it will be recycled throughout the ecosystem to benefit fish besides the ones that were fed originally.

Terrestrial animal by-products

Terrestrial animal by-product meals are a useful replacement for fishmeal because of their high nutritional content. Blood meal, meat and bone meal, and chicken by-product meal have all been utilized in the preparation of aquafeed, and the amounts of these by-products are considered to be higher than fishmeal [47]. To avoid disease transmission, these substances, on the other hand, must be handled properly. Despite the fact that some nations have banned the importation of these items, data reveals that the hazardous mammalian agent in these by-products is not the same as that found in fish and is unable to overcome fish intestinal barriers. Meat and bone meal (50%) is a rich source of crude protein, but its high ash level (29%) prevents it from being used as a fishmeal substitute. This material might become a viable alternative protein source if processing methods to reduce ash levels are enhanced.

Non-traditional feed Ingredients

Non-traditional fish feeds are feed components that have not been employed in the manufacturing of fish feed in the past for a variety of reasons. For instance, correct dose and production methods are unknown, they are not widely available, and they might be harmful or dangerous [48]. Insects, bacterial proteins, earthworms, silk worm pupae, mopane worm, and maggot meal, among other renewable sources, have been studied as fishmeal replacements. Silkworm pupae have high nutritional content and are abundant in some areas, so they might be utilized to manufacture low-cost feed. The feeding trails in Coldwater aquaculture has proved its ability to improve the growth and survival of Common carp [49]. Insect meal has a lot of promise as a fishmeal substitute, but there are a few things to consider before using it, such as the cost of manufacturing, customer acceptance, and commercial availability. Increased study on these substances, together with technology advancements, might make possible fishmeal alternatives more essential and extensively utilized in the future. In contrast to plant-based meals, insects are high in protein, calories, and fats while being low in fibre and anti-nutritional elements. Insects are being tried as substitutes for fishmeal and plant-based feeds, with success in substituting up to 30% of their diet with insect-based feed thus far [58].

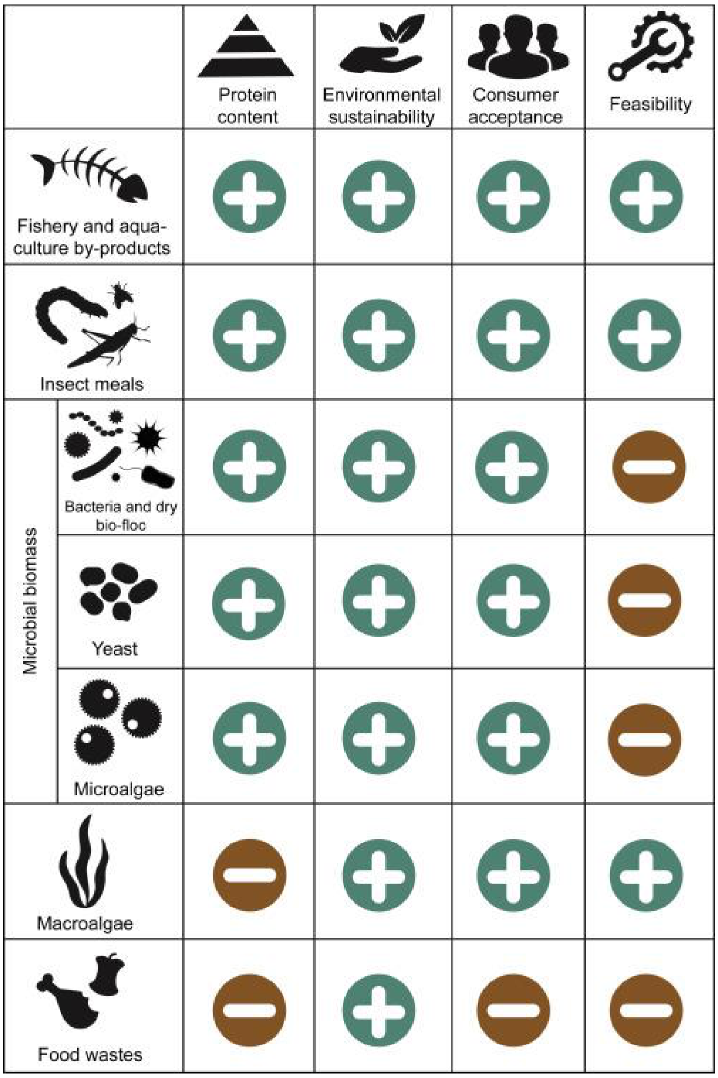

Figure 2. Qualitative Feasibility Assessment of Alternative Protein Sources for Fed-Aquaculture Diets (KathelineHuaet.al., 2019)

Issues and gaps

Fishmeal is primarily used in aquaculture (fish farms), but it is also found in a wide range of other goods. Fishmeal is used in huge quantities in agricultural feeds for farm animals and pet diets since it is a low-cost protein source. So we have a low-cost, globally traded commodities product that is linked to indiscriminate overfishing and slavery, and that is largely manufactured in factories that do not satisfy minimum acceptable standards, according to trade agencies.[51]

The essential attributes of aquaculture products generated from different sources must be assessed since the nature of alternative sources for fishmeal and fish oil may impact the quality of fish fillets and customer acceptability. A cost-benefit analysis and assessment of attainable quantities for commercial use should be carried out, with special consideration paid to potential industrial consumers of these alternative sources, since they may compete for volume with aquaculture.

Way forward

- In order to reduce the pressure on overfishing for the production of fishmeal, reduce inclusion levels with other alternate protein-rich by-products without affecting growth performance or nutrient uptake, despite the fact that the amount of fishmeal and fish oil in aquafeed formulations has been significantly reduced in recent years. To accomplish this goal, it is necessary to:
- Through concentrated study, an ongoing effort is being made to enhance, refine, and modify aquaculture feed compositions.
- Despite the fact that farmed freshwater fish have a lower percentage of fish meal in their feeds than marine fish and crustaceans, the global output of these fed carp, catfish, and tilapia is quite large [52]. As a result, even small amounts of fish meal result in significant amounts of fish meal overall. Substituting alternative protein sources for fish meal in these diets will result in a significant reduction in the overall amount of fish meal consumed, given the expected rise in production of these species and accompanying aquafeed demand. According to estimates made by Froehlich et al.(2018), this sector has the best chance of reducing the consumption of forage fish by mid-century.
- Combining unfed aquaculture with fed aquaculture or developing, promoting, and expanding polyculture-based systems, which result in the concurrent culture of multiple fed species in a single system, can also significantly increase aquaculture production to supply more protein, especially for freshwater fish [53]. The associated integrated multi-trophic aquaculture systems, which mix extractive aquaculture with feed aquaculture, provide a variety of goods to increase the yield of protein [53,54, 55].
- Insect meals are one of the most important animal-based protein sources currently being explored worldwide. When fed genuine wastes like (pre-consumer) food waste or animal manures, insects might be generated in a somewhat sustainable way. Human night soil is even used by one African enterprise, which would be illegal in Europe owing to biosecurity concerns. However, if efficient R&D and disinfection methods can assure biosafety, it's a fantastic example of really ending the nutrient cycle. The black soldier fly (*Hermetiaillucens*), which has been tested in several fish species, has been shown to be a good fishmeal alternative [56].

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ETHICAL STATEMENT

The ethical statement is not required for this study.

CONSENT TO PARTICIPATE

I understand that even if I agree to participate now, I can withdraw at any time or refuse to answer any question without any consequences of any kind. I understand that I can withdraw permission to use data from my interview within two weeks after the interview, in which case the material will be deleted.

CONSENT TO PUBLISH

The Authors have taken consent from other individuals have no object to publish their data.

AUTHORS CONTRIBUTION

Prof. Oyas Ahmad Asimi: Conceptualizing the review paper and technical inputs.Prof. Irfan Khan: Editing and language correction.Prof. Sajad Hassan Baba: Economic part of fish feed. How to reduce the cost of feed.Ms.HafsaJavaad: Writing of manuscript.*All authors read and approved the final manuscript.”*

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DATE AVAILABILITY STATEMENT

The data that supports the findings of this study are available from the corresponding author upon reasonable request.