



Sustainable and accessible fish feeds for small-scale fish farmers



Photo credit: Sakel Mahmud, Tano, WorldFish

Aquaculture is the fastest growing food producing sector in the world, providing critical sources of income and nutrition for millions of small-scale fish farmers and their communities.¹ Access to sustainable and affordable fish feeds is a key determinant for productive and profitable aquaculture.

Globally, aquaculture feeds rely on forage fish (anchovies, herring, sardines) as a source of essential nutrients, using almost one-third of the global fish catch. Small-scale fish farmers in Africa and Asia generally produce herbivorous or omnivorous tilapia, carp and catfish in ponds, and while the inclusion of forage fish-derived ingredients in their feeds is low, in total these species are still large consumers of forage fish.² Conventional fish feeds also remain inaccessible to many small-scale fish farmers because of prohibitive costs. This is particularly true for women and youth in the sector, who often have less income, fewer assets and greater barriers when accessing inputs.

Improving the social, economic and environmental sustainability of fish feeds and feeding practices for tilapia, carp and catfish will enhance aquaculture's contribution to poverty reduction and food and nutrition security. For this reason, Wageningen University developed the innovative concept of [nutritious pond feeds](#)³ and partnered with WorldFish to study [locally available ingredients](#) for use in feeds. The research is based in Bangladesh, China, Costa Rica, Egypt, France, India, Indonesia, Malaysia, the Netherlands, Vietnam and Zambia, in cooperation with small-scale farmers and commercial feed companies Aller Aqua Zambia, Royal de Heus Asia and

Key messages

- Improving feed accessibility for small-scale fish farmers is crucial to the inclusive growth of aquaculture.
- “Nutritious pond feeds” nourish the farmed fish and the pond organisms that help break down fish wastes and produce natural food for the fish. Their ingredient composition makes them less expensive than conventional feeds while maintaining or increasing fish production in a healthy pond environment.
- Local, underused and inexpensive agricultural co-products can be effectively used as fish feed ingredients, thereby reducing dependency on ingredients that can be directly consumed by humans.
- The FeedCalculator mobile phone application equips small-scale feed millers and farmers to formulate nutritious pond feeds from local ingredients.

Skretting Egypt. Three main objectives were developed to improve small-scale farmers' access to sustainable fish feeds and feeding practices:

1. Develop nutritious pond feeds for tilapia that increase farm productivity and profitability, enhance natural food production in the pond, and pollute less.

¹ [FAO] Food and Agriculture Organization. 2018. The State of World Fisheries and Aquaculture 2018: Meeting the sustainable development goals. Rome: FAO. Licence: CC BY-NC-SA 3.0 IGO.

² Froehlich HE, Jacobsen NS, Essington TE, Clavelle T and Halpern BS. 2018. Avoiding the ecological limits of forage fish for fed aquaculture. *Nature Sustainability* 1:298–303. <https://doi.org/10.1038/s41893-018-0077-1>

³ Nutritious pond feeds are dual purpose feeds formulated to feed the farmed species and provide a balanced nutrient composition to the pond's food web. In doing so, nutrient-rich wastes resulting from fish feeding (e.g. fish feces, uneaten feed) are converted by other pond organisms (e.g. bacteria, plankton, protozoa) into natural food sources that nourish the farmed species, which increases the retention of fed nutrients in the farmed species and reduces nutrient accumulation in the pond. See [Table 1](#) for further information about ingredient and nutrient composition of nutritious pond feeds.

2. Identify locally available ingredients for inclusion in pelleted fish feeds that provide sustainable, accessible alternatives to forage fish and other ingredients that could otherwise be directly consumed by humans.
3. Create tools to integrate knowledge of locally available feed ingredients in nutritious pond feeds and disseminate them to fish farmers.

The research was carried out using [genetically improved tilapia](#) to develop better management practices around fish feeds and feeding systems that help farmers realize the maximum productive potential of their fish.

Research innovations in fish feeds and feeding practices

Nutritious pond feeds nourish the food web

Over the past two decades, improved understanding of fish nutrition have resulted in the development of commercially produced, nutritionally complete fish feeds. These feeds are formulated to meet the nutrient requirements of the farmed species but also lead to nutrient-rich fish wastes that, when released, contribute to pollution in water bodies. Conventional feeds also typically account for 30 to 70 percent of production costs,⁴ making them unavailable to many small-scale farmers across Africa and Asia.

Nutritious pond feeds, in contrast, nourish both the farmed species and other pond organisms, like bacteria, plankton and protozoa, to stimulate the pond's inherent capacity to break down fish wastes and produce natural foods for fish. Nutritious pond feeds have more carbohydrates, which fish only partially digest. Once passed, the carbohydrates provide energy for bacteria to break down fish wastes and any uneaten feed and release nutrients into the pond. Other organisms metabolize these nutrients to grow and multiply, becoming nutritious food sources for the farmed species and reducing nutrient accumulation in the pond. The high levels of carbohydrates in nutritious pond feeds

can be sourced from inexpensive and often locally available ingredients, which reduce feed costs while maintaining or increasing fish production, thereby raising profits.

On-farm research in Bangladesh shows that nutritious pond feeds increase tilapia production by stimulating natural food production. In combination with the lower cost of nutritious pond feeds, farm income increased 22 percent as compared to a conventional tilapia feed.⁵ Intermediate results from ongoing farm trials in Zambia comparing conventional and nutritious pond feeds from Aller Aqua have revealed similar outcomes, with great promise for small-scale fish farmers across Africa and Asia.

Local ingredients increase availability and accessibility of feeds

The use of local ingredients to formulate fish feeds can reduce reliance on often expensive or imported ingredients that may compete with direct human use, like fishmeal and fish oil or soya, while increasing feed accessibility to small-scale farmers. Local ingredients can also be readily used to formulate nutritious pond feeds to further increase farm productivity and profitability. This has implications for improved livelihoods, food and nutrition security, and climate change mitigation.

To identify inexpensive, largely underused ingredients with year-round availability, WorldFish surveyed literature, agricultural databases and stakeholders, including fish farmers, feed manufacturers, ingredient suppliers and other feed experts, across Bangladesh, Egypt, Malaysia, Myanmar, Nigeria and Zambia. Fifteen ingredients, including [banana and cassava peels](#), [cocoa husks](#), [palm kernel cakes](#), [rice and maize bran](#) and soldier fly meal, were identified and analyzed to determine how well genetically improved tilapia used the nutrients. With Skretting Egypt, we continue to assess novel ingredients across Africa and Asia, including algae, aquatic plants, fish processing co-products, food loss,⁶ insects and worms, that can be used to formulate sustainable and accessible fish feeds, including nutritious pond feeds.



Photo credit: Filip Milosavljevic/WorldFish



Photo credit: Mike Lunmore/WorldFish

⁴ Boyd CE, D'Abramo LR, Glencross BD, Huyben DC, Juarez LM, Lockwood GS, McNevin AA, Tacon AGJ, Teletchea F, Tomasso JR Jr et al. 2020. Achieving sustainable aquaculture: Historical and current perspectives and future needs and challenges. *Journal of the World Aquaculture Society* 51:578–633. <https://doi.org/10.1111/jwas.12714>

⁵ Kabir KA, Verdegem MCJ, Verreth JAJ, Phillips MJ and Schrama JW. 2019. Effect of dietary protein to energy ratio, stocking density and feeding level on performance of Nile tilapia in pond aquaculture. *Aquaculture* 511:634200. <https://doi.org/10.1016/j.aquaculture.2019.06.014>

⁶ Food loss refers to any food that is disposed of along the food supply chain from production (e.g. harvest, slaughter, catch) up to, but excluding, retail and does not reenter the food supply chain in any other productive use, such as feed or seed.

In collaboration with the [Technologies for African Agricultural Transformation](#) program, the ingredient information has been used to [train feed millers and fish farmers](#), one-quarter of whom are women, across Africa on local ingredients in fish feed formulation. We have also partnered with the International Institute of Tropical Agriculture to identify locally available ingredients in the Democratic Republic of Congo and evaluate their [performance in fish feeds](#)—the findings of which are spurring investment in commercial feed mills in support of local fish farmers.

However, a shift to using local ingredients in fish feeds and the development of related businesses may have uneven reach or benefits, placing some social groups, especially women and youth, at risk. For example, women may feed rice bran to their poultry and peels to their small livestock as their only income source, so diverting agricultural co-products from their current use may cause women undue financial risk. In partnership with Includovate, we are developing improved methods for needs and risk assessments to support the inclusive development and scaling of local feed ingredients.

The integration of the ingredient information, including their chemical composition and nutrient digestibility, into an open access database will allow for wider access. Challenges of unequal access, which are often exacerbated for women and youth, will need to be addressed through targeted interventions, including more tailored training and improved access to technology.

In addition to the valorization of local, underused ingredients in fish feeds, strengthened [integration of fish and crop production](#) systems can also lower fish farming costs by reducing dependency on external inputs. Integrated production may also generate additional income streams and improve food and nutrition security by diversifying farm outputs.

The FeedCalculator app equips small-scale feed millers and farmers to make sustainable and affordable feeds

Findings regarding nutritious pond feeds and local feed ingredients are integrated into the [FeedCalculator](#), an open access feed formulation app. The FeedCalculator can be used by feed millers and farmers worldwide to develop recipes for fish feeds using local and affordable ingredients.

Work is ongoing to develop regional language versions of the app that include relevant local ingredients. Such a version is now available in Bangladesh and training sessions have reached 55 feed millers and farmers to date, with the goal that they will disseminate this knowledge through their networks. The FeedCalculator can equip small-scale feed millers and farmers with the technical knowledge needed to design local fish feeds, but wider use is dependent on assessing barriers to access or use.

Scaling research innovations to improve productivity and profitability of small-scale aquaculture

Policy and investment recommendations

To fully contribute to national goals for inclusive, equitable and sustainable agri-food systems, sustainable feeds and feeding practices must (i) be tailored to the needs of farmers and other value chain actors, (ii) be accessible and affordable for poor and marginalized groups, including women and youth, and (iii) strengthen the circular economy without competing with food for direct human consumption. To support the sustained adoption of nutritious pond feeds and integration of local ingredients by small-scale farmers, we must prioritize the following:

- **Strengthen farmer networks and co-develop better management practices.**⁷ Our efforts with the Food and Agriculture Organization, the Freshwater

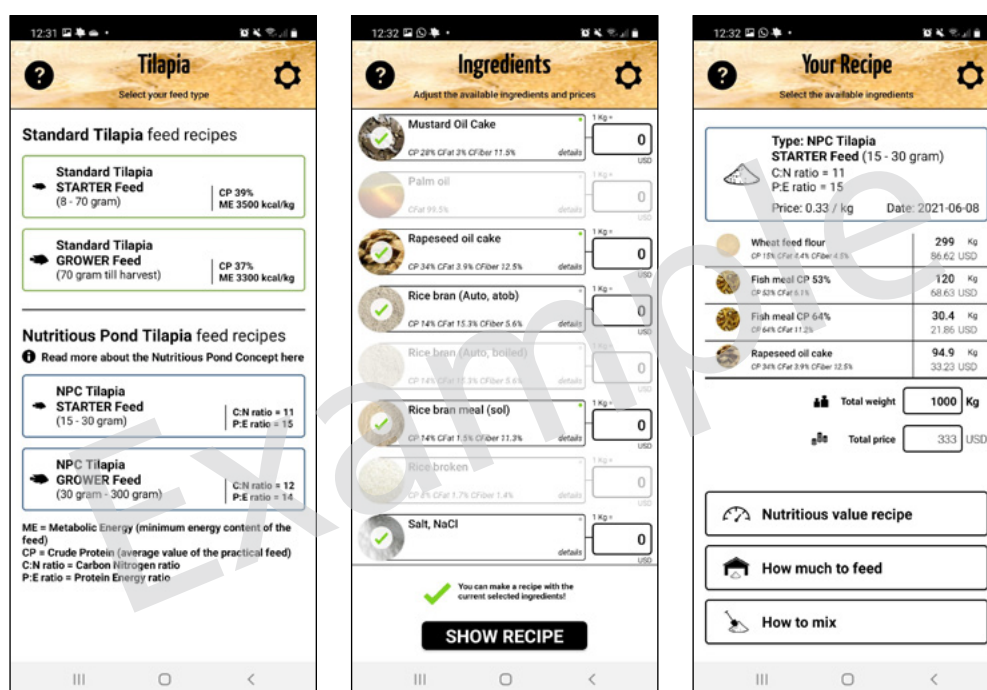


Plate 1. The FeedCalculator app interface.

⁷ Joffre OM, De Vries JR, Klerkx L and Poortvliet PM. 2020. Why are cluster farmers adopting more aquaculture technologies and practices? The role of trust and interaction within shrimp farmers' networks in the Mekong Delta, Vietnam. *Aquaculture* 523:735181. <https://doi.org/10.1016/j.aquaculture.2020.735181>

Fisheries Research Centre, and Bogor Agricultural University to develop and package technical guidance and tools require the support of national governments and research institutes to ensure that the reach and benefits of this work are inclusive.

- **Improve small-scale farmers' access to fish feeds and technical advice** through innovative financing models, targeted opportunities for capacity development, especially for women and youth, and further exploration of novel feed ingredients.
- Ensure governments, private companies and research institutes address **regulatory and technological barriers** associated with use of local, underused ingredients to appropriately scale research innovations. This may include changing restrictions on using novel ingredients as fish feed and building capacity to process ingredients.

Priority research frontiers

Further research in the following areas will inform the development and dissemination of nutritious pond feeds and local feed ingredients by small-scale fish farmers:

- Small-scale fish farmers use a variety of farming systems. Polycultures of herbivorous and omnivorous species or the integrated production of species from different trophic levels,

including fish, crustaceans, molluscs and algae, are especially common. These systems are expected to respond differently to changes in feeds or feeding practices, so **the benefits associated with nutritious pond feeds and local feed ingredients must be verified and quantified for the range of species and systems commonly used by small-scale farmers.**

- Sustainable feeds and feeding practices are **expected to contribute to climate mitigation and adaptation efforts in aquaculture** through increases in efficiency of feed use and reduced reliance on imported or intensively farmed feed ingredients. However, these contributions still need to be validated and quantified.
- To date, limited evidence exists on the **links between sustainable feeds and feeding practices and the nutritional value of fish to humans.** However, the nutritional value of farmed fish can be modified through feeds,⁸ and preliminary indications are that access to natural foods in ponds, which is optimized with nutritious pond feeds, can improve the nutritional quality of farmed fish.⁹

Wageningen University, WorldFish and partners continue to engage with national governments and aquaculture centers, small-scale feed millers and farmers, private companies and research institutes to develop an enabling environment for the integration of nutritious pond feeds and local, underused feed ingredients in agri-food systems.

⁸ Kwasek K, Thorne-Lyman AL and Phillips M. 2020. Can human nutrition be improved through better fish feeding practices? A review paper. *Critical Reviews in Food Science and Nutrition* 60:3822–35. <https://doi.org/10.1080/10408398.2019.1708698>

⁹ Karapanagiotidis IT, Bell MV, Little DC, Yakupitiyage A and Rakshit SK. 2006. Polyunsaturated fatty acid content of wild and farmed tilapias in Thailand: Effect of aquaculture practices and implications for human nutrition. *Journal of Agricultural and Food Chemistry* 54:4304–10. <https://doi.org/10.1021/jf0581877>

Authors

Marc Verdegem,¹ Rodrigue Yossa,² Killian Chary,¹ Johan W Schrama,¹ Malcolm C. M. Beveridge² and Nisha Marwaha²

Affiliations

¹ Wageningen University & Research

² WorldFish

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