Untapped Potential of Fish Waste in Organic Farming: A Nutrient-Rich Alternative

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ABSTRACT

The global fishing industry generates over 20 million tonnes of nutrient-rich waste each year, much of which remains unused despite its high potential in organic farming. Fish waste, rich in nitrogen, phosphorus, minerals, and amino acids, can be converted into effective fertilizers through processes such as emulsion, enzymatic or acid hydrolysis, and composting. These products improve soil fertility, enhance plant growth, and support sustainable crop production while promoting circular resource use. Key challenges including odour, pathogen risks, and nutrient imbalance—can be mitigated through proper processing and regulated application. Fish waste serves as a valuable, eco-friendly substitute for synthetic fertilizers, providing strong potential to enhance sustainable and organic farming.

INTRODUCTION

The fishing industry forms a vital component of the economy in many countries, including China, India, Spain, the United States, Canada, and Norway. However, the sector generates substantial waste during fish harvesting, processing, and marketing, with nearly 50% of total biomass—such as heads, fins, skin, and viscera—commonly discarded. Globally, fisheries produce over 20 million tonnes of waste each year, representing nearly one-quarter of the marine catch (Chen *et al.,* 2020). This growing volume of fish waste (FW) has raised environmental concerns but also presents a significant opportunity. Rich in essential nutrients like nitrogen, phosphorus, and calcium, FW is well suited for agricultural applications, and several fish-based fertilisers are already approved for organic farming (Khairul *et al.,* 2024). Innovative approaches, including composting and liquid extracts, have shown promise in enhancing crop performance through sustainable recycling of FW. Unlocking this underutilized resource can strengthen organic farming systems by improving soil fertility, reducing environmental impacts, and contributing to resilient, future-ready agriculture.

Methods of Utilizing Fish Waste in Organic Farming

1) Emulsion process:

Fish emulsion is produced by heating fish waste above 80 °C to extract oils and eliminate putrefactive bacteria (Ghaly *et al.,* 2013). The remaining solids are pressed into a cake, which can be dried to form fish meal, while the liquid residue—rich in water-soluble nutrients and containing moderate to low levels of oil-soluble compounds—serves as a valuable fertiliser.

Depending on the processing method, fish-waste–derived products are referred to as fish soluble or fish emulsion, fish soluble nutrients, hydrolysed waste or fish hydrolysate (also called fish silage), fish meal, and fish powder (Maksimenko *et al.,* 2024). The nature of the raw material dictates the processing steps, which may include heating, pressing, centrifugation, separation into liquid and solid phases, drying of solids, and grinding to the desired particle size.

2) Fish hydrolysate (fish silage)

a) Fish hydrolysate(s) through enzymes

Proteolytic enzymes such as alcalase, neutrase, papain, pepsin, and trypsin are commonly used to produce fish protein hydrolysate (FPH). In the enzymatic pre-treatment stage, fish waste and by-products are ground and mixed with water at a 2:1 (w/w) ratio before being transferred to a reactor and heated to the required temperature (Arvanitoyannis and Tserkezou, 2014). To prevent lipid oxidation—which can darken the product and generate brown pigments—FPH must maintain a tightly controlled fat content (<0.5% w/w). Thus, fatty fish are typically defatted using organic solvents, which also help reduce microbial spoilage.

Key processing parameters—including temperature, pH, reaction time, enzyme type, and enzyme dosage—must be carefully optimised, as they strongly influence product quality and functionality. Depending on the enzyme used, suitable operating ranges include temperatures of 35–60 °C, reaction times of 10–600 minutes, pH values of 1.5–11.0, and enzyme concentrations of 0.01–5%.

b) Fish hydrolysate through acid

Acid fish silage is a liquid product produced from whole or minced fish residues. In the presence of added organic or inorganic acids, natural enzymes break down the material, resulting in liquefaction—a process known as acid-preserved silage (Domínguez *et al.,* 2024). This method offers a simple and effective way to stabilise fish-processing by-products. The type and quantity of acid used depend on the raw material, though formic acid is most commonly applied. The resulting liquid silage can be condensed, dried, or incorporated directly into moist feed formulations, where it serves as a nutrient-rich fertiliser or a valuable ingredient in animal feed.

3) Compost

Composting is the aerobic biological degradation of organic materials into a stable, humus-like product. Although similar to natural decomposition, composting accelerates the process by blending organic waste with supplementary materials that stimulate microbial activity. Composting fish waste (FW) is an effective way to reduce disposal burdens while producing a nutrient-rich organic fertiliser.

FW composting typically involves adding bulking agents to improve aeration and provide carbon sources for microorganisms (Fig. 1). Successful composting requires close monitoring of pH, moisture, bulk density, and especially the carbon-to-nitrogen (C:N) ratio, which should ideally fall between 20:1 and 30:1 (Azis *et al.,* 2023). Fish waste naturally helps lower the C:N ratio, making it suitable for co-composting with high-carbon materials. A wide range of bulking agents—such as sawdust, wood shavings, bark, crop residues, rice hulls, leaves, grass clippings, wheat bran, and straw—have been used in FW-based composts, along with amendments like seaweed, poultry litter, and peat.

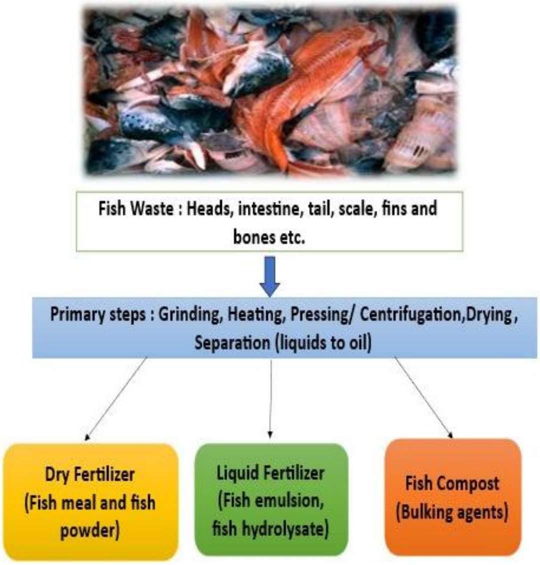

Figure 1. Flowchart of fish waste (FW) processing into compost, liquid fertilisers, and dry fertilisers

Benefits of Fish Waste in Organic Farming

The use of fish-based fertilisers in organic farming offers multiple agronomic advantages (Fig. 2). When applied to field crops, fish fertiliser enhances plant vigour, growth, and overall productivity. In fruit trees, foliar applications improve budwood quality and tree vitality, and can even help suppress pests such as codling moths.

In viticulture, table grape growers use fish fertiliser as a foliar nutrient source to regulate bunch size and shape, improve berry development, and increase sugar content (James *et al.,* 2023). Because fish fertilisers contain natural growth hormones, trace minerals, amino acids, and organically bound nitrogen, they support robust tissue formation and balanced plant nutrition. Unlike pure inorganic nitrogen— which triggers rapid growth that often benefits weeds—fish-based nitrogen is released more steadily, improving nitrogen-use efficiency for nursery growers and fruit producers.

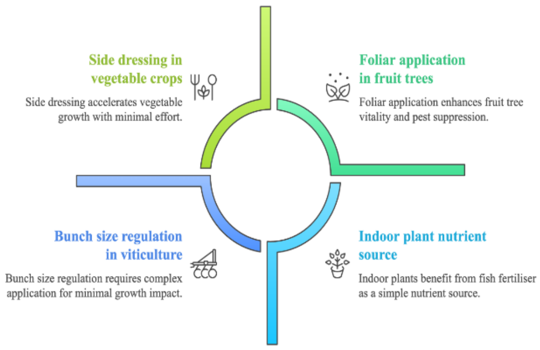

Figure 2. Key Benefits of Fish Waste Utilization in Organic Farming

In vegetable crops, applying fish fertiliser as a foliar spray or side dressing during transplanting reduces stress, improves survival, and accelerates early growth. Research on radish, tomato, corn, strawberry, lettuce, and soybean consistently demonstrates its growth-promoting effects. Maize, soybean, and horticultural producers commonly apply fish fertiliser blends during key developmental stages such as flowering and fruit set (Fernandez-Salvador *et al.,* 2015). Even household gardeners report that fish fertiliser can serve as a complete nutrient source for indoor plants and ornamentals, supporting healthy and sustained growth.

Challenges and Limitations

Limitation

- Rapid decomposition of fish waste produces strong odours that can attract scavengers, rodents, and insects.
- The high nitrogen content of fish waste can lead to soil nutrient imbalances if applied improperly; excessive nitrogen may harm plants or contaminate groundwater.
- Mismanagement or overapplication can cause nutrient runoff, contributing to eutrophication and water pollution.
- Untreated fish waste may attract pests and undesirable wildlife to cultivated areas.

Challenges and Mitigation Strategies

- Proper composting stabilises nutrients, reduces pathogens, and significantly minimises odour.
- Processing fish waste into hydrolysate or emulsion yields a more user-friendly, widely accepted fertiliser product.
- Compliance with local regulations and organic standards ensures safe and approved use.
- Conducting soil tests before application enables appropriate nitrogen management and prevents overuse.

CONCLUSION

Fish waste holds remarkable potential as a nutrient-rich and sustainable input for organic farming. Packed with essential nutrients such as nitrogen, phosphorus, and trace minerals, it can significantly enhance soil fertility and support vigorous crop growth. By converting what is often treated as discardable waste into a valuable resource, its use also aligns with circular economy principles and contributes to environmental sustainability. Realizing this potential, however, requires addressing key challenges related to processing, handling, pathogen risks, and regulatory standards. Advances in composting technologies, liquid fertilizer production, and improved supply-chain logistics can help overcome these barriers. When properly managed, fish waste offers a cost-effective and eco-friendly alternative to synthetic fertilizers, strengthening organic farming practices. With growing awareness and technological progress, fish waste could become an integral component of sustainable agriculture—unlocking its untapped capacity to nourish crops while safeguarding the environment for future generations.

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