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Role of Native Microbial Starter Cultures in Directing the Fermentation of Fish Products

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Abstract

Fermentation is one of the oldest methods used by coastal and riverine communities to preserve fish and to develop distinct sensory qualities in food. Traditionally, fish fermentation relies on the spontaneous activity of the microbiota already present on the raw fish, in the surrounding environment or in the fermentation vessel. In recent decades, researchers have promoted the deliberate use of autochthonous starter cultures, meaning microorganisms isolated from the same fish species, the same fermented product or the same processing environment, and then reintroduced in controlled amounts to drive the fermentation. This article reviews the influence of such native starter cultures on the biochemical, microbiological, sensory and safety attributes of fermented fish products. Evidence from lactic acid bacteria strains isolated from products such as plaa som, pla ra, salami like fish sausages, salted fish and Hukuti demonstrates that autochthonous starters shorten fermentation time, lower pH more predictably, suppress spoilage and pathogenic organisms, reduce the accumulation of biogenic amines and nitrosamine precursors and improve flavour consistency compared with spontaneous fermentation.

Keywords: Autochthonous, Starter, Fermentation, Fish, Quality, Safety

Introduction

Fish is a highly perishable commodity because of its high moisture content, neutral pH, abundant free amino acids and active endogenous enzymes. Communities located along coasts, rivers and lakes across Asia, Africa and Europe have therefore developed a wide variety of fermented fish products such as fish sauce, fish paste, fermented fish sausage and whole salted fermented fish, allowing surplus catches to be preserved for months while creating unique flavours that carry strong cultural value (Li et al., 2025). Traditional fermentation of fish is normally spontaneous, meaning the process depends entirely on the microorganisms naturally present on the raw material, the salt used, the containers and the surrounding air. Because this microbial community is uncontrolled, the resulting product often shows batch to batch variation in taste, texture, safety and shelf life.

To overcome this inconsistency, food microbiologists have looked toward the meat, dairy and vegetable fermentation industries, where the addition of selected starter cultures has long been standard practice, and have begun applying a similar concept to fish. Two broad categories of starters exist for this purpose. Allochthonous starters are strains that originate from an unrelated matrix, for example a commercial Lactobacillus strain developed for sausage production, and are then applied to fish. Autochthonous starters, in contrast, are isolated directly from the fish species, the traditional fermented fish product or the specific processing environment that the final product will come from, and are subsequently reintroduced into the same or a similar matrix as a defined inoculum (Speranza et al., 2020). Because autochthonous strains have already adapted to the salt concentration, nutrient composition, temperature range and competing microbiota typical of fish substrates, they are generally expected to perform more reliably as fish fermentation starters than strains borrowed from other food systems.

Concept and Rationale of Autochthonous Starter Cultures

An autochthonous starter culture is typically obtained through a multistep screening procedure. Researchers first collect samples from spontaneously fermented fish products or from the intestinal microbiota of the target fish species, then isolate candidate bacterial colonies on selective media. Isolates are subsequently evaluated for technological traits such as acid production rate, salt tolerance, proteolytic and lipolytic activity and the ability to inhibit undesirable organisms, together with safety traits such as the absence of antibiotic resistance genes and the inability to produce biogenic amines (Speranza et al., 2020). Only strains that combine strong technological performance with an acceptable safety profile are selected as candidate starters, after which they are propagated and reintroduced into the fish matrix at a defined inoculum level, commonly in the order of 10 to the power of 7 colony forming units per gram.

The underlying rationale is ecological fitness. A strain that has already survived and competed successfully within the fish tissue, brine or traditional starter carrier is more likely to dominate the microbial community once reintroduced, out competing the spoilage flora and pathogens that would otherwise proliferate during uncontrolled fermentation. This is different from simply adding a generic commercial LAB strain, which may be well adapted to a meat or dairy substrate but poorly adapted to the salt levels, low carbohydrate content and characteristic amino acid pool of fish flesh.

Effect on Acidification and Fermentation Time

One of the most consistently reported benefits of autochthonous starters is a faster and more predictable drop in pH. Speranza et al. (2020) optimized a fermented fish sausage resembling salami using autochthonous *Lactiplantibacillus plantarum* strains isolated from fish and found that the fermentation time needed to reach a stable pH of about 4.4 could be reduced considerably when sucrose content, nitrite level and incubation temperature were properly combined with the native starter. A related study on lactic acid bacteria with probiotic aptitude, again isolated from fish intestinal microbiota, reported that the selected native strains reduced fermentation time to only two days while maintaining good microbiological quality of the final sausage.

Similar results have been obtained with plaa som, a traditional Thai fermented fish product. Saithong et al. (2010) used two native lactic acid bacteria strains, *Lactobacillus plantarum* IFRPD P15 and *Lactobacillus reuteri* IFRPD P17, isolated from natural plaa som fermentation, as a mixed starter culture. The inoculated batches produced high acidity within twenty-four hours and maintained dominance of lactic acid bacteria throughout fermentation, resulting in a faster and more controlled decrease in pH compared with spontaneous fermentation. In the case of pla ra, another traditional fermented fish paste from Thailand, Vichasilp et al. (2017) isolated proteolytic strains of *Lactobacillus plantarum* and *Lactobacillus brevis* directly from marketed pla ra samples and showed that reintroducing these native isolates as starters accelerated the fermentation process while still producing a product accepted by sensory panelists.

Effect on Biogenic Amine and Nitrosamine Control

Uncontrolled fermentation of fish is a well-documented source of biogenic amines such as histamine, putrescine, cadaverine and tyramine, which accumulate when decarboxylase positive bacteria act on free amino acids released by proteolysis. These compounds are not only responsible for off flavors but are also linked to food poisoning incidents when consumed in excessive amounts (Biji et al., 2016). Autochthonous starter cultures selected specifically for a lack of decarboxylase activity and, in some cases, for an active amine degrading capacity have proven effective in limiting this problem.

Zaman et al. (2011) screened novel starter cultures for fish sauce fermentation and demonstrated that inoculation with selected halotolerant strains significantly inhibited the accumulation of biogenic amines compared with uninoculated controls, without negatively affecting the desirable flavor compounds of the sauce. Likewise, Lee et al. (2016) applied *Bacillus polymyxa* as a starter culture during the fermentation of salted fish and observed that after one hundred and twenty days of fermentation the histamine content and the overall biogenic amine content of inoculated samples were reduced by about thirty four percent and thirty percent respectively when compared with non inoculated control samples. In reduced salt fermented rainbow trout sausages, Öztürk et al. (2024) reported that starter cultures composed of *Lactobacillus sakei* subsp. *sakei*, *Staphylococcus xylosus* and *Pediococcus pentosaceus*, used singly or in combination, lowered pH faster and suppressed the formation of histamine, putrescine, cadaverine, spermine and spermidine, with the *Pediococcus pentosaceus* treatment producing the strongest suppression.

More recent work on Chinese traditional

fermented fish products has extended this line of research to nitrosamines, compounds of greater toxicological concern than biogenic amines alone. Inoculation with autochthonous starter cultures was shown to lower nitrite accumulation and to influence the fate of nitrosamine precursors during simulated human digestion, indicating that the protective effect of native starters may continue beyond the fermentation vessel and into the digestive process itself. Collectively, these findings support the idea that carefully selected autochthonous strains function not merely as acidifying agents but as active barriers against the accumulation of hazardous nitrogenous compounds during fish fermentation.

Effect on Sensory Quality and Consistency

Flavor development in fermented fish depends on a complex network of proteolysis, lipolysis and subsequent generation of volatile compounds, free amino acids and peptides. Because spontaneous fermentation is driven by an unpredictable mixture of environmental organisms, the resulting flavor, color and texture of traditionally fermented fish can vary widely between batches and even within the same production facility. Introducing a defined autochthonous starter culture narrows this variability and allows processors to reproduce a target sensory profile more reliably.

In the fermented fish sausage study by Speranza et al. (2020), sensory evaluation covering odor, texture, color and overall acceptability was carried out over twenty one days of storage at four degrees Celsius, confirming that products inoculated with autochthonous *Lactiplantibacillus plantarum* maintained acceptable sensory quality throughout the assessed period. Similarly, in the study on Hukuti, a traditional fermented fish product, comparison between traditional spontaneous methods and controlled value added fermentation revealed that controlled fermentation produced more consistent proximate composition and improved fatty acid stability while traditional methods yielded more variable, though nutritionally diverse, results. In rainbow trout sausages, the addition of native or well characterized starter cultures, particularly *Pediococcus pentosaceus* and its combination with other strains, also improved aroma attributes and overall acceptability scores relative to uninoculated reduced salt controls (Öztürk et al., 2024).

Effect on Safety and Shelf Life

Beyond biogenic amine control, autochthonous starters influence the general microbiological safety of fermented fish by rapidly lowering pH and competing with pathogenic and spoilage organisms for nutrients and space. Saithong et al. (2010) reported that the native mixed starter culture used in plaa som fermentation was able to suppress and eliminate *Escherichia coli* within twenty four hours, whereas the use of a single strain alone resulted in incomplete suppression of pathogenic bacteria. This finding highlights an important nuance in starter culture design, namely that a combination of two or more complementary autochthonous strains often performs better than a single isolate because different strains may contribute different antimicrobial mechanisms such as organic acid production, bacteriocin synthesis or nutrient competition. Vichasilp et al. (2017) similarly noted that pathogenic bacteria could not be detected in pla ra samples prepared with the selected native starter combination, supporting the conclusion that appropriately chosen autochthonous cultures can materially improve the hygienic quality of the final product while simultaneously shortening the time needed to reach a microbiologically stable state.

Comparative Advantage over Non Native Starters

Several authors emphasize that lactic acid bacteria which perform well as starters for meat, dairy or vegetable fermentation do not automatically translate into good performance in fish, because the chemical environment of fish muscle, characterized by high non protein nitrogen content, different amino acid profiles and often high salt concentration, imposes selective pressures that only fish adapted strains have already encountered (Speranza et al., 2020). Reviews on the broader topic of fermented fish safety and quality point out that although starter cultures are widely used and well studied in meat and dairy technology, dedicated starters specifically developed for fish remain comparatively rare, and no universal commercial starter yet exists for fish fermentation (Li et al., 2025; Cai et al., 2024). This gap reinforces the argument for continued isolation and characterization of autochthonous strains directly from the fish species and traditional products that a given industry intends to standardize, rather than relying solely on generic commercial cultures developed for other food matrices.

Challenges and Future Prospects

Despite promising laboratory and pilot scale results, several challenges limit the industrial adoption of autochthonous fish starters. First, strain stability during long term storage and scale up fermentation needs further validation, since performance demonstrated in small batches does not always translate directly to larger production volumes. Second, regulatory frameworks for novel microbial starters in traditional fermented foods are still developing in many producing countries, which can slow commercial approval. Third, the diversity of traditional fermented fish products across different regions means that a starter optimized for one product, such as plaa som, may not be directly transferable to another, such as Hukuti or Chinese salted fish, requiring product specific screening programs. Finally, consumer acceptance of a standardized product that departs even slightly from the traditional spontaneously fermented flavor profile must be carefully managed, since the cultural value of many fermented fish products is closely tied to the particular flavor produced by uncontrolled fermentation.

Future research directions include the use of combined or multiple strain autochthonous starters that pair acidifying lactic acid bacteria with amine degrading or proteolytic organisms, the application of genomic tools to rapidly screen large numbers of fish associated isolates for desirable and undesirable traits and the integration of starter culture technology with complementary interventions such as reduced salt formulations and improved packaging to address the wider health and sustainability goals identified in recent reviews of fermented fish processing (Li et al., 2025).

Conclusion

The evidence reviewed in this article indicates that autochthonous starter cultures, meaning lactic acid bacteria and related organisms isolated directly from fish or from traditional fermented fish products, exert a clear and largely positive influence on the fermentation process. Compared with spontaneous fermentation and with generic non native starters, well selected native strains accelerate acidification, shorten fermentation time, suppress spoilage and pathogenic microorganisms, reduce the accumulation of biogenic amines and nitrosamine precursors and improve the consistency of sensory attributes such as odor, texture and overall acceptability. Case studies from plaa som, pla ra, fermented fish sausage, salted fish, rainbow trout sausage and Hukuti collectively support the conclusion that ecological adaptation of the starter strain to the fish matrix is a key determinant of successful fermentation outcomes. Nevertheless, the field remains relatively young compared with starter culture technology for meat and dairy fermentation, and continued screening, strain characterization, scale up validation and regulatory development will be necessary before autochthonous starters can be adopted broadly across the global fermented fish industry.

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