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Circular Valorisation of Freshwater Fish Processing Side-Streams into Child- and Adult-Accepted Food Products: From School Catering to Retail Markets

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Abstract

Freshwater fish processing generates substantial by-products, such as frames after filleting, belly portions, and other underutilised fractions, which are often directed to low-value pathways, such as rendering or biogas production, despite their high nutritional potential. In land-locked Central European countries, fish consumption remains critically low, and blood levels of long-chain omega-3 fatty acids (EPA and DHA) are among the lowest in Europe (Jia et al., 2025). This study presents a circular, practice-oriented model that upgrades freshwater fish processing by-products into safe, nutritionally valuable, and economically viable food products for both preschool children and adult consumers. Side-stream-derived raw materials, including mechanically separated fish meat ("baader") recovered from frames and low-market-value belly portions of African catfish (Clarias gariepinus), were incorporated in varying proportions into newly developed formulations. Products were designed to ensure boneless structure, technological stability, and suitability for institutional catering and retail distribution. Comprehensive evaluation included sensory testing (including preschool panels), chemical composition analysis, microbiological assessment, and economic evaluation. Sensory trials demonstrated high acceptance among preschool children when products were presented in familiar formats (e.g., sausages, kebab-like shapes, balls) with moderate salinity (approximately 1.4–1.6 %) and mild seasoning; positive contextual factors, particularly teacher encouragement, significantly increased tasting rates and overall acceptance. Nutritional analyses confirmed balanced protein levels (approximately 14–17 g 100 g^{-1}), moderate fat content depending on formulation, and reduced salt levels (approximately 1.5–1.7 g 100 g^{-1}). EPA + DHA concentrations ranged from approximately 265 to 1067 mg 100 g^{-1}, contributing substantially to recommended intake levels. Microbiological testing confirmed compliance with safety criteria throughout chilled storage, including the absence of Listeria monocytogenes prior to product release and levels below regulatory limits throughout shelf life. Economic analysis showed that increasing the inclusion of mechanically separated fish meat significantly reduced production costs while maintaining quality and safety standards, supporting affordability in school catering systems operating under strict budget constraints. Beyond preschool catering, the same circular formulations were successfully transferred to the adult retail segment, demonstrating scalability and improving overall raw material valorisation efficiency; products are currently supplied to approximately 200 schools and kindergartens,

while adult-oriented products are commercially available in retail markets. This case study demonstrates that circular upcycling of freshwater fish side-streams into human food can simultaneously reduce post-harvest losses, increase resource efficiency, improve population nutrition, and create economically sustainable market opportunities across institutional and retail sectors.

Keywords: circular economy, fish side-streams, food loss prevention, school catering, omega-3 fatty acids

References

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