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A Circular Economy Blueprint: A Revolutionary Model for Fish Waste Utilisation and Economic Valuation

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Overview

At a time when the world is increasingly concerned about waste generation, environmental pollution, resource depletion, and declining farm incomes, a revolutionary model for fish waste utilisation, this innovative model demonstrated how scientific valorisation of fish waste can contribute to sustainability, circular economy, and enhanced income generation within the fisheries and allied agricultural sectors (FAO, 2020).

A noteworthy sustainable model titled **"Fish Waste Solution with Economic Valuation and Product Development"** was presented, addressing environmental challenges while simultaneously generating new income opportunities for fishers, smallholder farmers, and rural entrepreneurs. The model strongly advocates the institutionalization of agro-pharmaceutical initiatives within the agricultural sector to ensure value retention and sectoral growth. What makes the initiative particularly inspiring is that it began as a classroom exercise and evolved into a comprehensive, scientifically grounded business model, demonstrating how innovation in agriculture can promote sustainability, circular economy principles, and income generation within the agri-allied sectors.

The proposed model holds significant national relevance, as India is among the world's leading fish-producing countries, yet an estimated 30–40 per cent of total fish biomass is lost as non-consumption waste (UNEP, 2021). This results not only in substantial economic losses but also in serious environmental challenges, particularly in coastal and riverine ecosystems. The model offers a scalable, low-cost solution that can be implemented across fish markets, cooperatives, self-help groups, coastal villages, small-scale industries, and fisheries training centres. With widespread adoption, it has the potential to catalyse thousands of rural micro-enterprises while substantially reducing waste disposal and environmental pollution at the national level.

What this means for the future of agriculture

By integrating economics, technology, environmental science, skill development, and social impact, the model illustrates how agricultural education can align with national development priorities. If implemented on a larger scale, the model could enhance income stability in fisheries, strengthen food processing industries, reduce environmental hazards, create new opportunities for rural youth, and contribute to the growth of India's rural bioeconomy (Government of India, 2020).

A Vision Rooted in Rural Realities

India’s fisheries sector is expanding at a rapid pace, contributing significantly to food security, employment, and rural livelihoods. However, alongside this growth, the volume of waste generated by consumers, fish markets and processing units has also increased sharply. Every day, tonnes of fish scales, skin, bones, and viscera are discarded, often dumped in open areas or nearby water bodies. This unmanaged disposal leads to foul odour, spread of disease-causing pathogens, and severe water pollution, posing serious environmental and public health challenges.

Despite being treated as waste, these by-products possess immense economic potential. Scientific research has shown that fish scales and skin are rich sources of collagen and gelatin, which are widely used in cosmetics, nutraceuticals, and pharmaceutical industries. Similarly, fish bones can be processed into hydroxyapatite, a critical raw material for orthopedic implants and bone tissue engineering. What is commonly seen as refuse is, in reality, a valuable industrial resource.

In addition, fish viscera can be converted into fish oil and fish silage (Rout, 2025), both of which serve as cost-effective alternatives to conventional livestock and poultry feed. Fish oil also finds application in nutraceuticals and biofuel production, while silage supports sustainable animal nutrition. Furthermore, fish skin is increasingly being used to manufacture fish leather, an eco-friendly and high-value product gaining popularity in the global fashion and handicraft markets most importantly fish water also can be used as a nutrient and n minerals rich manure for the crops.

The central challenge, however, lies not in the availability of raw material, but in the absence of awareness, processing facilities, and integrated economic models at the grassroots level. Most fishing communities and small entrepreneurs lack access to simple, scalable technologies that can transform waste into income-generating products.

Core Components of the Model

At the foundation of the model lies the input section, which displays samples of raw fish waste such as scales, skin, bones, viscera, and wash or meltwater. By presenting these materials in their original form, the model challenges the conventional perception of “garbage” and highlights their potential as valuable industrial raw materials when handled scientifically.

The processing component of the model is presented through a mini demonstration unit and clear flow diagrams. It illustrates five interconnected stages: collection and sorting, cleaning and drying, extraction and processing, product development, and finally packaging and marketing. This integrated and sequential design closely mirrors real industrial workflows, making the model practical, realistic.

A key highlight of the model is its focus on scientific transformation processes, showcased through four specialised conversion pathways. Each pathway targets a different component of fish waste and converts it into a high-value product with established market demand.

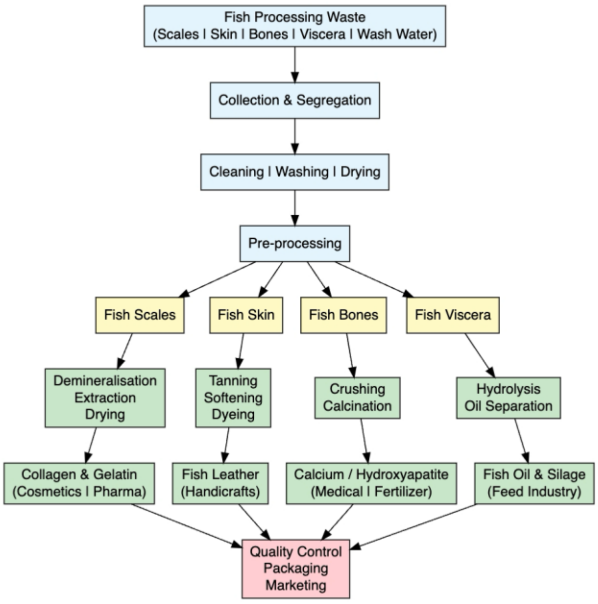

Fig. 1: Flowchart showing the process of product development from waste materials. Source: Self-authored with the help of R Studio

In the first pathway, fish scales are transformed into collagen and gelatin (Jafari, et al. 2020) through a multi-step process involving demineralisation, neutralisation, extraction, and drying(fig.1). These bioproducts are widely used in cosmetics, medical wound dressings, and nutritional supplements. What begins as a zero-value waste material is converted into one of the most expensive bio-inputs in the pharmaceutical and cosmetic industries (Karayannakidis, & Zotos, 2016).

The second pathway focuses on fish skin, which is processed through washing, tanning, softening, and dyeing to produce fish leather. The final products include wallets, belts, bookmarks, and handicrafts. This process not only adds value to waste but also creates new livelihood opportunities, particularly for rural women and artisan groups engaged in small-scale manufacturing.

The third pathway utilises fish bones to produce high-purity calcium powder and hydroxyapatite. Through crushing, boiling, drying, and pulverisation, can be demonstrated the conversion of bones into materials that are essential for orthopedic implants, bone tissue engineering, agricultural fertilisers, and animal feed supplements. This pathway effectively links agricultural innovation with the growing demands of the healthcare sector.

The fourth and final pathway addresses fish viscera, often considered the most problematic form of waste. Using grinding followed by enzymatic or acidic treatment, the viscera are converted into high-quality fish oil and nutrient-rich silage. These products support poultry, aquaculture, and livestock farming by reducing dependence on costly commercial feed, thereby lowering production costs for farmers.

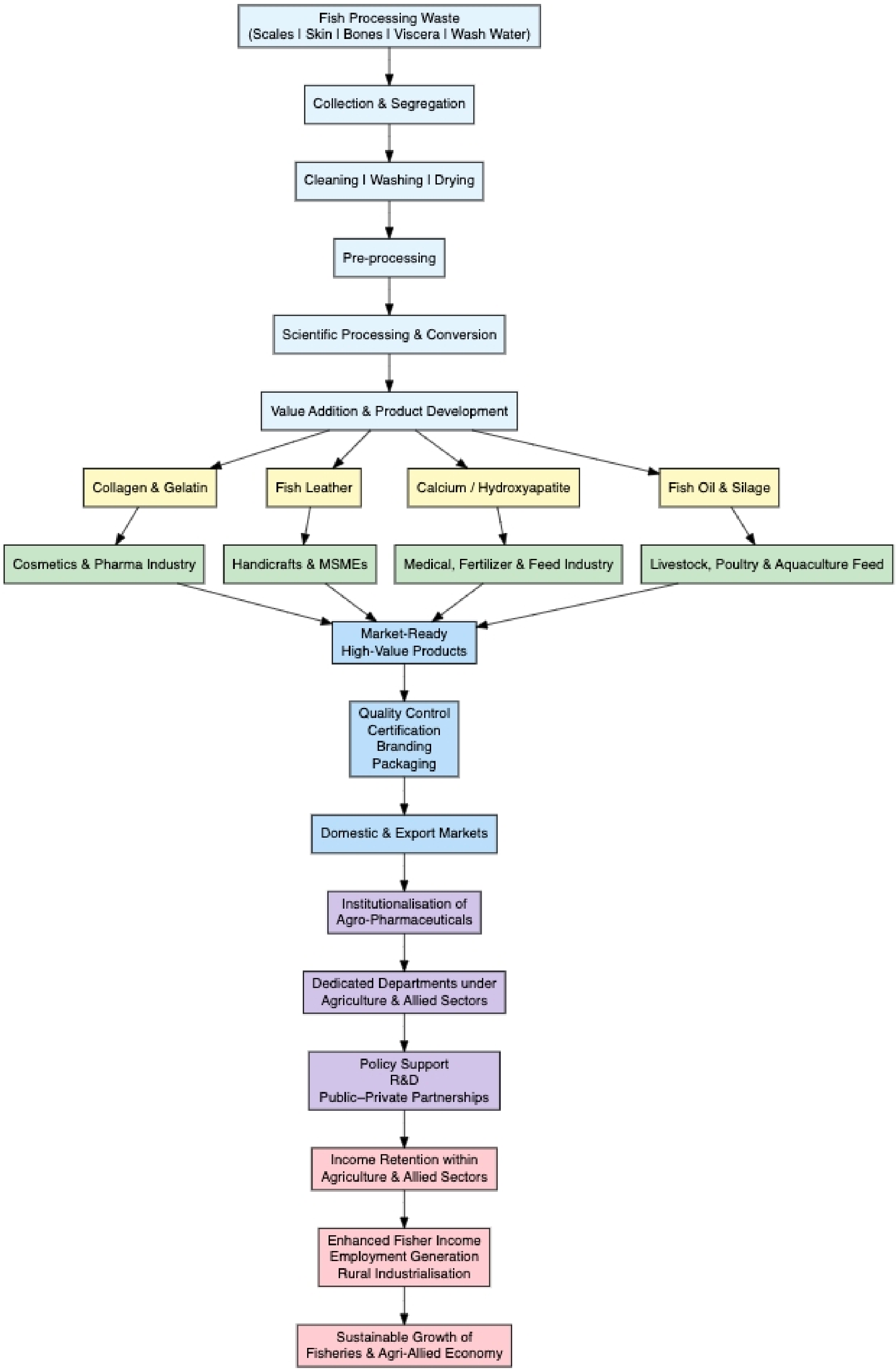

Fig. 2: Flowchart depicting the conversion of fish waste into market-ready products and their institutionalization within the agri-allied sector. Source: Self-authored with the help of R studio

A Solution with Economic, Clean and Green Approach

The true strength of this model lies not only in its scientific design but also in its economic transparency and environmental relevance. The students prepared a clear income-based assessment highlighting the market value of each output product. By using low-cost or freely available inputs, the model demonstrates how waste can be converted into multiple revenue streams, enhancing income while simultaneously reducing environmental pollution. With almost zero-cost inputs, a fisher or rural entrepreneur can multiply their income 3 to 4 times, while reducing environmental pollution. This aligns perfectly with India's goals of:

- doubling farmers' income,
- creating green industries,
- reducing waste, and
- promoting circular economy models.

One of the most striking strengths of this initiative is its clear potential for institutional and industrial adoption (fig 2). Unlike many academic exercises that remain confined to classrooms, this model bridges the gap between theory and real-world application. By integrating biochemical extraction with value-added product development, the model aligns closely with current industrial and developmental needs. Its relevance extends across multiple sectors, including pharmaceutical departments, food technology units, start-up incubators, rural livelihood programmes, and skill development initiatives. This model demonstrates how agricultural universities can transcend traditional academic boundaries and emerge as centres of practical innovation that directly serve rural communities and emerging industries.

The model strongly supports India's environmental and sustainability objectives. By scientifically processing fish waste, it prevents the dumping of organic refuse near water bodies, thereby reducing water pollution and health risks. Its emphasis on complete utilisation ensures high resource efficiency, embodying the true spirit of a circular economy.

The use of low-energy techniques, such as sun drying, helps minimise the carbon footprint, while eco-friendly income generation contributes to long-term rural stability. Equally important, the model instils a waste-to-wealth mindset among young learners, fostering environmental responsibility and scientific awareness.

Policy Suggestions

1. **Institutionalization of Agro-Pharmaceuticals within Agriculture & Allied Sectors (**FAO & World Fish 2019**)** Governments should formally recognise fish waste–based bio-products (collagen, gelatin, hydroxyapatite, fish oil, silage) under an **Agro-Pharmaceutical or Bio-Input sub-sector**, ensuring that their economic value remains within fisheries and allied agricultural systems rather than migrating to external industrial sectors.
2. **Creation of Dedicated Departments/Cells** Establish **dedicated departments or cells for Fish Waste Valorisation and Agro-Pharmaceuticals** under State Agriculture/Fisheries Departments to coordinate R&D, standardisation, licensing, and market development.
3. **Strengthening Policy Support and Regulatory Frameworks** Introduce clear regulatory guidelines for quality control, certification, and safety standards for fish waste–derived products to facilitate domestic marketing and exports while ensuring consumer confidence.

4. **Promotion of Public–Private Partnerships (PPP)** Encourage PPP models involving universities, fisheries cooperatives, MSMEs, startups, and pharmaceutical/cosmetic industries to scale up technologies from laboratory to commercial level(OECD, 2019).
5. **Integration with National Missions and Schemes** Align fish waste valorisation initiatives with schemes such as PMMSY, Startup India, MSME promotion, and circular economy missions to ensure financial, technical, and institutional backing.
6. **Export Promotion and Branding Support** Develop export-oriented policies, branding strategies, and geographical indications (where applicable) for high-value fish waste products to enhance global market access.

Recommendations

1. **Capacity Building and Skill Development** Train fishers, SHGs, women entrepreneurs, and rural youth in scientific processing, value addition, quality assurance, and enterprise management related to fish waste utilisation (ICAR, 2019).
2. **Decentralised Processing Units** Promote small-scale, decentralised processing units near fish landing centres to reduce waste, transportation losses, and environmental pollution while generating local employment.
3. **Market-Ready Product Development** Focus on transforming fish waste into **market-ready, high-value products** with assured demand in pharmaceuticals, cosmetics, healthcare, fertilisers, and feed industries.
4. **Research and Innovation Support** Increase investment in applied research for cost-effective extraction technologies, improved shelf life, and diversified product portfolios through agricultural universities and research institutes (OECD, 2019).
5. **Income Retention within Fisheries and Allied Sectors** Ensure that the value generated from fish waste processing benefits fishers and farming communities directly, strengthening income security and reducing dependence on volatile primary produce markets (Ghaly, et al. 2013).
6. **Sustainability and Circular Economy Orientation** Promote fish waste utilisation as a core component of the **circular economy**, reducing environmental burden while enhancing resource efficiency and long-term sustainability (FAO, 2018).

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Under the continuous guidance and mentorship of **Sh. Sachin Rathour,** Assistant Professor (Contractual), Department of Agricultural Economics, RVSKVV, Gwalior, a newly admitted cohort of eleven B.Sc. Agriculture students—**Sukhdevi Ahirvar, Navneet Uikey, Chandrika Parte, Rajkumar Jajnme, Manish Karjhare, Atendra Batham, Pooja Ahirwar, Yogesh Dhurve, Anil Parmar, Priyanshu Singram, and Shalini Admachi**—successfully conceptualised and developed this model.

A brief author biography: Sachin Rathour is an ICSSR Doctoral Fellow and an Agricultural Economist associated with Banaras Hindu University (BHU), Varanasi, and currently serving as Assistant Professor (CT) in the Department of Agricultural Economics at Rajmata Vijayaraje Scindia Krishi Vishwavidyalaya (RVSKVV), Gwalior. His academic and research interests focus on food security, farmer welfare economics, climate change, circular economy, and sustainable agricultural development. He has published extensively in UGC-CARE, Scopus, and Impact factors, NAAS-rated journals and has received several prestigious fellowships and awards for academic excellence. He has been visted as an advanced reserch scholar to Brazil and UAE with full funded fellowship. He actively engages in mentoring students, policy research, and interdisciplinary innovation in agriculture and allied sectors.

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