

ANALYSIS OF THE DEVELOPMENT OF FISH BONE FLOUR APPLICATION IN INDONESIA

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ABSTRACT

Indonesia's vast fishery production generates significant solid waste, primarily fish bones, which remain largely underutilized and pose environmental issues, despite being rich in protein, collagen, calcium, and phosphorus. Aligning with the circular economy, the innovative solution is Fish Bone Flour (FBF), a fine powder suitable as a functional raw material for the food, feed, pharmaceutical, and cosmetic industries. This study analyzes the shift from simple traditional processing to modern techniques using advanced equipment like controlled dryers and autoclaves to enhance FBF quality, hygiene, and consistency. FBF has been successfully fortified into various popular products (crackers, cookies, donuts, nuggets) to significantly boost their calcium content without compromising consumer acceptability. The market strategy emphasizes a zero-waste principle, high nutritional value differentiation, digital promotion, and modern multilayer packaging for longer shelf life. FBF development delivers integrated positive impacts: empowering MSMEs, offering an affordable natural calcium source for community health, and reducing organic waste volume.

Keyword: Fish Bone Flour, Fishery Waste Utilization, Circular Economy, Processing Technology, Calcium Fortification, Food Application

1. INTRODUCTION

The fisheries sector plays a strategic role in supporting food security, economic growth, and the welfare of Indonesian society. As an archipelagic nation, Indonesia possesses vast marine resources, making this sector one of the main contributors to the national Gross Domestic Product (GDP). According to the Ministry of Marine Affairs and Fisheries (2024), national fishery production has exceeded 24 million tons annually and continues to increase steadily. However, behind this achievement, fish processing activities generate a considerable amount of solid waste, particularly fish bones. Most of this waste remains underutilized, leading to environmental issues and indicating a missed economic opportunity from materials that are actually rich in protein, collagen, and essential minerals such as calcium and phosphorus (Yusrina et al. 2021).

To promote sustainable development, the implementation of a circular economy has become a strategic approach in managing fishery by-products. This concept emphasizes resource efficiency through the principles of *reduce, reuse, and recycle*, aiming to transform waste into materials with new functional and economic value

(Borrello et al. 2017). In the fisheries sector, the circular economy can be realized by utilizing processing by-products such as fish bones to produce value-added products. One promising innovation aligned with this concept is the production of Fish Bone Flour (FBF), a finely processed powder derived from fish bones that is rich in calcium, phosphorus, and collagen. These nutrients make FBF a potential raw material for applications in the food, feed, pharmaceutical, and cosmetic industries (Berghuis et al. 2023).

Efforts to develop FBF in Indonesia have shown significant progress in recent years. In terms of processing technology, several methods have been introduced, including enzymatic hydrolysis to enhance protein and collagen availability, demineralization to reduce the characteristic fishy odor, and low-temperature drying to preserve nutritional content and product quality (Arkananta & Eviana, 2022). Regarding raw materials, fish bones from species such as mackerel and short-bodied mackerel are commonly used due to their high calcium and collagen content. Moreover, product development has expanded toward diverse applications, including food fortification, livestock feed additives, and natural cosmetic ingredients. The packaging and marketing aspects have also

evolved, with the use of eco-friendly packaging materials and digital marketing strategies through e-commerce platforms. At the global level, research by Seo et al. (2024) reinforces this potential, demonstrating that mineral extraction from fish bones can produce hydroxyapatite-structured flour suitable for food and pharmaceutical applications.

This study aims to analyze the development of FBF processing technologies in Indonesia, review the existing product development practices, and examine the raw material processing, production methods, product applications, marketing and packaging strategies, as well as the socio-economic and environmental impacts of FBF development. Furthermore, this research seeks to formulate appropriate strategies for product development and downstream implementation in line with the circular economy principles. Theoretically, this study is expected to enrich the body of knowledge on fishery waste management and product innovation based on processing by-products. Practically, it is expected to provide useful insights for policymakers, industry players, and local communities in optimizing fish bone waste as a competitive and sustainable resource.

2. METHODS

This research employs the Systematic Literature Review (SLR) method with a scientific publication survey approach to review and analyze various relevant studies concerning the development of fish bone meal (FBM) processing technology. This method was chosen because of its structured and systematic nature in identifying, evaluating, and interpreting research results related to the study topic (Kitchenham & Charters, 2007; Rhamadhanty et al. 2025). The data for this study were obtained from various reliable scientific sources, such as journals, research articles, and reference books used as a theoretical basis. Each source was examined deeply and systematically to gain a comprehensive, relevant understanding that supports the research objectives (Andriani, 2021).

Subsequently, the collected data were analyzed using a descriptive-comparative approach to compare the development of fish bone meal processing technology based on the results of various previous studies. This analysis aims to identify similarities, differences, and trends in

technological innovation, such as the application of processing methods, raw material processes, product application and marketing development, packaging, and the impact of fish bone meal development (Fitriani & Darmawan, 2017; Berghuis et al. 2023).

3. RESULTS

3.1. Product Definition

Fish Bone Meal is a processed product derived from fishery byproducts, specifically fish bones that have undergone processing (such as boiling or hydrolysis, drying, and grinding) to produce a fine powder (Putranto et al. 2015; Thalib, 2009). Fish Bone Meal is recognized as a rich source of minerals, particularly Calcium (Ca) and Phosphorus (P), while also containing protein and collagen (Kaya, 2008).

Within the context of the fishery sector value chain, fish bones are classified as solid waste generated by the fish processing industry, such as in the production of fillets, surimi, or canned fish. The utilization of fish bones to produce Fish Bone Meal constitutes a critical component of the strategy for waste reduction and value addition (valorization) of these byproducts. Fish Bone Meal is subsequently utilized as a functional raw material or nutritional fortifying agent in various food products (e.g., biscuits, doughnuts, noodles, and meat balls) and non-food products (Saputra et al. 2025; Liviawaty et al. 2012).

3.2 Fish Bone Flour Processing Using Traditional And Modern Methods

Flour processing, also known as milling, plays an important role in producing high-quality products. Milling is a physical transformation process of solid materials aimed at reducing their particle size into smaller or finer forms (Azkin, 2021). Flour processing is commonly applied to plant-based materials such as grains; however, the process can also be utilized for animal-based materials. One potential animal-based material that can be converted into flour is fish bone

Fish bones are by-products of fisheries that still contain essential nutrients. According to Yusrina et al. (2021), the process of converting fish bones into flour not only aims to reduce waste but also to produce a natural calcium source that is safer

and more environmentally friendly compared to synthetic calcium. Fish bone flour is widely used as a food ingredient, a raw material for animal or fish feed, and as a base ingredient in the pharmaceutical industry (Putra et al. 2021).

The processing of fish bone flour involves several main stages: washing, boiling, drying, and grinding/milling. These stages can be carried out using either traditional or modern methods. The traditional method is conducted manually and simply, whereas the modern method employs advanced technology (Haryati et al. 2019).

The traditional method of flour processing is carried out without modern equipment or only through simple manual steps. In this process, fish bones are washed with clean water to remove remaining flesh, blood, and impurities that cause unpleasant odors. The cleaned bones are then boiled for 30–60 minutes until they soften. Boiling helps to soften tissues, facilitate drying, and remove fats and odors. The bones are then sun-dried for 1–2 days, depending on weather conditions. Drying reduces the water content in the bones, making them easier to grind and extending the shelf life of the flour. The final stage is grinding or milling, performed by pounding or manually grinding the dried bones into powder. This process facilitates application of the flour in the desired products (Putra et al. 2021).

The traditional method of fish bone flour processing is environmentally friendly since it does not use chemical additives and produces no hazardous waste. Utilizing sunlight for drying also conserves energy and enhances the natural aroma of the raw material (Nurdiani et al. 2018).

However, despite its advantages, the traditional method also has several drawbacks. This technique affects the quality, efficiency, and consistency of the produced fish bone flour. In terms of quality, there is a higher risk of microbial contamination due to open-air drying, which impacts product safety. Regarding efficiency, the process duration is relatively long and highly dependent on weather conditions, leading to inconsistency (Setiawan et al. 2021). Additionally, the water content in the flour is difficult to control, which can result in a less durable product or promote mold growth (Mulyani et al. 2019).

Overall, the application of traditional methods in fish bone flour processing still holds potential for development on a small or household scale. However, the resulting flour generally differs from that produced by modern methods, particularly in terms of color, texture, and shelf life. Therefore, the improvement of critical stages such as drying and grinding is necessary to produce more hygienic and high-value flour (Rizal et al. 2020).

The limitations of the traditional method have driven the development of modern methods that utilize technology to enhance efficiency, hygiene, and product quality. The use of equipment such as drying ovens, autoclaves, and high-pressure grinders provides solutions to the main challenges of the traditional process.

The modern method of fish bone flour processing represents an innovation aimed at improving efficiency, quality, and safety of the final product. This process employs various equipment and technologies to optimize each stage — from washing and boiling to drying and grinding (Wulandari et al. 2020).

The initial stage in the modern method begins with the separation of bones from meat using a *meat-bone separator* or *deboning machine*. This device functions to efficiently remove residual meat, skin, and blood from bones without damaging their structure. The use of this equipment results in cleaner, more hygienic bones that are ready for the subsequent washing stage (Suryani et al. 2022).

Next, the washing process is performed using a high-pressure *washing drum*, which effectively removes remaining organic residues compared to manual washing. Boiling is carried out using an *autoclave* or high-pressure cooking system to accelerate the process and significantly reduce fishy odors. In some studies, a mild alkaline solution (1–3% NaOH) is also used to help dissolve residual proteins and fats, resulting in whiter, odorless, and mineral-rich fish bone flour (Haryanti et al. 2019).

The drying stage is conducted using a temperature-controlled *oven* (60–80°C) or *freeze dryer*. This method maintains the moisture content below 10%, thereby producing a more durable product that is resistant to mold and has a uniform color. Furthermore, modern drying

techniques help preserve the calcium and phosphorus content within the bones (Rizal et al. 2020).

The final stage is grinding using a *high-speed grinder* or *ball mill*, which produces finer, more homogeneous particles than manual grinding. The resulting flour is easier to apply in the food, feed, and pharmaceutical industries due to its uniform texture and low moisture content (Wulandari et al. 2020).

This modern method offers various advantages, including hygienic products, long shelf life, bright color, and high calcium content. However, it also presents certain disadvantages, such as high equipment investment costs, substantial electricity consumption, and the need for skilled operators (Suryani et al. 2022).



Figure 1 Tools and Machines for Fish Bone Meal Processing

3.3 Analysis Of Raw Material Source Diversification Development

3.3.1 Utilization of General Waste

The fish processing industry produces large amounts of waste, especially fish heads, bones, tails, and fins, which are not yet optimally utilized. This waste has the potential to cause environmental pollution if not handled properly. Research shows that fish bone waste has a high calcium content that can be used as a mineral

source in food products. The utilization of fish bone waste has evolved from the use of abundant and easily available fish species to more specific development based on the calcium content and characteristics of each fish species.

Tuna fish bones can be made into flour, which is currently widely used in various processed foods. In a previous study, Maulid developed tuna fish bone flour into a new type of cake that has the highest calcium content of 42.84% with the addition of 150 mg of tuna fish bone flour (Maulid, 2023). However, the study showed that the resulting taste was not quite right, because cakes generally have a sweet taste and a fragrant aroma, while tuna fish bone flour tends to have a fishy smell. Another study by Meiyasa developed seaweed sticks as a savory snack with the addition of tuna bone flour, which produced a calcium content of 2.04% with the addition of 6% tuna bone flour. This product was considered more suitable in terms of sensory characteristics because its savory taste and aroma were in line with the characteristics of tuna bone flour (Meiyasa, 2020).

Tongkol fish bones are a fishery by-product that mainly consists of protein and calcium. Tongkol fish bones contain 9.45% protein and the highest amount of calcium. In addition, fish bones also contain collagen, which is good for the skin. Fish bones are a by-product of fish processing that is rarely utilized. However, fish bones can be processed into fish bone meal, which can be used as a food ingredient. Fish bones have the potential for diversification by processing them into flour, which can then be applied to food products to increase their nutritional value and benefits for the body. Tongkol fish bone flour contains 49.4% minerals, 4.2% calcium, and 3.7% moisture (Yanti et al. 2024).

Patin fish bones can be used as raw material for flour production, thus having economic value while also addressing the problem of waste that is harmful to the environment. Fish bone flour can be used as an additional flour ingredient in the manufacture of processed foods, so that the food produced is high in calcium. Calcium and phosphorus are minerals needed for bone formation (Murniyati & Sunarman, 2000). Patin fish bone meal has a high calcium content of 61238.66 mg/kg. Not only calcium, patin fish bone

meal also contains several other minerals such as iron, zinc, and phosphorus (Oktaviani, 2021).

3.3.2 Development Type

Fish bones are a type of waste from the fish processing industry that contain the highest amount of calcium among other parts of the fish, because the main elements of fish bones are calcium, phosphorus, and carbonate. However, fish bone waste is always abundant and wasted without being properly processed. Research by Bechtel (2019) found that catfish bones contain 6.33% calcium, 3.27% phosphorus, 0.27% sodium, and 0.13% magnesium. The calcium content in catfish bone flour reaches 13.48% (Sari, 2013). Research by Suprihartini and Puspita 2025 on brownies with catfish bone flour substitution found that the calcium content varied, depending on the proportion of catfish bone flour. The calcium content of brownies increases with the addition of catfish bone flour. Fish bones contain minerals and calcium, which affect the calcium nutritional value of products made with catfish bone flour substitution. The higher the substitution of catfish bone flour added to the product, the higher the calcium content will be (Salitus et al. 2017). Based on Regulation of the Indonesian Food and Drug Administration Number 1 of 2022 concerning Supervision of Claims on Labels and Advertisements of Processed Foods, a source of calcium must contain at least 30% ALG per 100 g. Thus, browntule with a 5% substitution treatment already meets the claim as a calcium source product for infants, and the 10% substitution treatment meets the claim as a calcium source product for pregnant women and the general public.

Treatment	Bone Meal Substitution	Calcium Content (mg)
0	0%	51,56
1	5%	259,27
2	10%	467

Table 1. Calcium Content in Brownies (mg/100 g)

The research by Kusumaningrum and Asikin (2016) applied belida fish bone flour as a calcium fortifier in fish crackers. The bone flour was made using the alkali (NaOH) method with a 3-hour pressure cooking process and 4 boilings, resulting in a calcium content of 31.31%. This study aimed to determine the chemical characteristics of fish

crackers fortified with varying concentrations of bone meal (0%, 5%, 10%, 15%, and 20%). Fortification of belida fish bone meal in fish crackers was proven to be very effective in increasing the calcium content of the product. The optimal treatment was 15% fortification, which produced a calcium content of 5.64%, an increase of 59.8% from the control (3.53%). This calcium content was the highest compared to other similar fortified products. With a calcium content of 5,640 mg per 100 grams, fortified crackers can contribute significantly to meeting daily calcium requirements (56.4% RDA for a consumption of 10 grams). This study proves that belida fish bone waste can be converted into a high-value ingredient as a calcium source for food fortification, providing an innovative solution to address calcium deficiency in the community while supporting the optimal utilization of fishery industry waste.

Treatment	Bone Meal Substitution	Calcium Content (mg)
K0	0%	3,53
K1	5%	4,19
K2	10%	4,76
K3	15%	5,64
K4	20%	6,57

Table 2. Calcium Content Of Belida Fish Crackers (mg/100 g)

3.4 Analysis Of Product Application And Market Development

3.4.1 Application of Fish Bone Meal Products

The development of fish bone meal products as calcium supplements and animal feed shows significant potential in utilizing fishery waste to improve animal nutrition. One prominent innovation is the GO-CORI mineral block formulation that uses fish bone waste to meet the calcium needs of ruminant livestock in an effort to prevent hypocalcemia (Parmelina et al. 2024). This product has been proven to have a very high calcium content, reaching 30.74%, making it an eco-friendly and economical solution with strong market competitiveness (Parmelina et al. 2024). Meanwhile, another application focuses on the use of skipjack tuna (*Katsuwonus pelamis*) bone waste as a raw material for poultry feed, which serves as a vital source of calcium and phosphorus to support skeletal growth and egg quality (Tukan

et al. 2025). The main potential of these two developments lies in transforming abundant fishery waste into nutritious products that can reduce the challenges of feed costs, dependence on imports, and while opening new business opportunities in the livestock sector (Tukan et al. 2025).

The development of fish bone meal as a calcium fortification ingredient in bakery products demonstrates a positive trend in converting waste into functional foods. A prominent innovation is the addition of catfish (*Clarias* sp.) bone meal to yellow sweet potato cookies, which aims to increase the nutritional value of the final product, particularly its calcium content (Mutmainah et al. 2024). A sustainability analysis of this technology indicates that the development of this fortified cookie business is categorized as quite sustainable, indicating the technology's feasibility and long-term potential at the MSME level (Mutmainah et al. 2024). Furthermore, processed catfish bone meal, processed into high-calcium flour, has also proven effective for cookie production, as part of a program to improve community skills in processing fishery waste into marketable products (Oktaviani Rz et al. 2021). Popular fortifications, such as white bread, use milkfish (*Chanos chanos*) bone meal, which significantly increases calcium content, although care must be taken not to compromise consumer acceptability (Mahfiroh et al. 2025). The addition of tuna (*Euthynnus affinis*) bone meal is also recommended for baked donuts to improve nutritional content (Yanti et al. 2024). In general, adding fish bone meal is an effective way to transform fast food or everyday snacks into high-calcium functional foods.

Fish bone meal has also been successfully implemented effectively in modern processed products such as nuggets to create accessible, functional food alternatives. A case in point is the development of gluten-free fish nuggets with the addition of milkfish (*Chanos chanos*) bone meal, whose organoleptic test results showed that the product was acceptable to the public, with one formulation selected as the best (Fadillah et al. 2024). The successful consumer acceptance of the nugget product indicates that the snack's organoleptic properties can be maintained even when fortified with fish bone meal (Fadillah et al. 2024). Other research also shows that swanggi fish (*Priacanthus tayenus*) bone waste can be used

to increase the protein nutritional content of instant noodles, which often have low nutritional content (Anasri et al. 2022). Similarly, mackerel (*Scomberomorus commerson*) bone meal has been successfully fortified into wet noodles to add minerals, especially calcium, which plays an important role in bone and tooth formation (Nurfina et al. 2022). The use of fish bones for this snack product effectively solves the waste problem and adds nutritional value, where the discarded bone waste is converted into calcium and phosphorus-rich flour (Oktaviani et al. 2021).

The traditional product sector, particularly crackers, is a primary channel for the application of fish bone meal, which is based on the concept of zero waste and increasing economic added value. A feasibility study of a catfish bone cracker business shows very strong business potential with a R/C ratio of 2.02, indicating the product is feasible for development at the MSME level (Mahayani et al. 2024). This model emphasizes the role of fish bone meal in realizing a zero-waste process, transforming fish processing waste into a marketable commodity (Mahayani et al. 2024). Furthermore, processing mackerel bone waste into fish bone crackers has also been shown to provide substantial added value, with a significant profit margin of 79.30% per production, demonstrating its positive impact on household income (Yulihartika et al. 2023). Its application to traditional products such as Kue Kembang Goyang using milkfish bone meal demonstrates that fortification can be carried out without reducing hedonic acceptability, making it an efficient means of providing high calcium through a popular snack (Alisa et al. 2023). Furthermore, the substitution of fish bone meal in processed products such as patin fish meatballs (*Pangasius* sp) successfully increased the calcium content of the product significantly, from initially low to higher, while maintaining panelist acceptance (Sunarma et al. 2025). This also applies to fish sempol with the addition of tilapia fish bone meal (*Oreochromis* sp.), where fish bone meal serves as an effective source of calcium without drastically affecting the chemical and sensory characteristics of the product (Irfani et al. 2025).

Overall, the development of fish bone meal applications in functional foods and traditional products represents an innovative solution to two key challenges: fisheries waste management and improving community nutrition. The

transformation of calcium-rich bone waste into meal has successfully created high-value products, supported by strong consumer acceptance and strong technical and financial feasibility (Mahayani et al. 2024). This initiative not only supports a circular economy and reduces environmental impact but also empowers local MSMEs through training and product innovation, making it a model for sustainable development in the fisheries sector (Mutmainah et al. 2024).



Figure 2 Examples of Fish Bone Meal Product Applications

3.4.2 Market Development Strategy

The market development strategy for processed fish bone meal products is firmly rooted in creating a competitive advantage through cost efficiency and added value. The primary approach is the implementation of a zero-waste process concept, which converts fishery waste into a marketable commodity, thereby reducing disposal costs while creating new raw materials (Purwanti et al. 2023). The financial feasibility of this strategy has proven to be very strong, as demonstrated by the analysis of the catfish bone cracker business, which obtained a R/C ratio of 2.02, indicating that the business is highly feasible to develop (Mahayani et al. 2024). Furthermore, this waste processing adds substantial added value to traditional products, with mackerel bone crackers capable of generating high profit margins, ensuring strong market competitiveness and offering an economical solution for consumers (Yulihartika et al. 2023).

For market penetration, the implemented strategy focuses on diversification of functional products

and digital promotion to reach a wider consumer segment. Fish bone meal products are fortified into popular everyday foods such as cookies and nuggets, making them practical and affordable functional foods, designed to be enjoyed by all segments of society (Himast et al. 2024). Digital promotion is key to expanding market reach for MSMEs, with training explicitly covering both online and offline strategies (Firmansyah et al. 2024). Overall, the combination of technological innovation in nutritional enhancement, affordable pricing, and digital marketing strategies makes this business model categorized as quite sustainable from a technological perspective (Mutmainah et al. 2024).

The market development strategy for products fortified with fish bone meal focuses heavily on product differentiation through increased nutritional value, particularly calcium and protein content (Bakhtiar et al. 2019). The primary target market is health-conscious consumers, such as children (to address stunting) and adults who require high calcium intake. This strategy utilizes fishery waste in the form of fish bones to create value-added products, such as donuts, biscuits, or cookies, representing a product innovation. Therefore, the development follows the concept of existing product development in the market by adding specific health benefits. Furthermore, a market penetration strategy is implemented by ensuring that the addition of fish bone meal does not reduce the sensory acceptability (taste, texture, aroma) of the final product (Husna et al. 2020), enabling the product to compete in the broader snack market. Economic feasibility and broad market potential (including for export) are also important considerations in this development (Saputra 2025).

The product marketing process begins with the processing of raw materials, solid waste (fish bones) from the fishing industry, into fish bone meal, which is high in calcium and phosphorus (Pangestika et al. 2021). This fish bone meal then serves as a fortification ingredient and is added to food products (e.g., cookies, donuts, or meatballs) during the production process by MSMEs or food processing industries (Bakhtiar et al. 2019). The next stage is distribution, where the calcium-rich final product is marketed through sales channels relevant to the product type, such as retail stores, markets, or through digital marketing to reach consumers (Disyacitta et al. 2024). Marketing also

often involves educating consumers about the health benefits of fish bone meal, which is a key step in attracting consumers and generating demand (Saputra, 2025). This process emphasizes offering high nutritional value that differentiates the snack market, from waste to a consumer product with health benefits.

3.5 Analysis Of Product Packaging Development

Packaging is an area of visual communication design whose function interacts with consumers, encompassing technical, creative, communicative, and marketing aspects articulated in visual language (Azhari 2016). Packaging has two functions: protective and promotional. The protective aspect concerns product protection, transportation infrastructure, and ensuring consumers receive the product undamaged or defect-free. Conversely, the promotional aspect is utilized as a means of promotion, considering consumer preferences regarding color, size, and appearance. Therefore, the best and most appealing packaging is necessary for a product to captivate consumers and win fierce competition (Apriyanti 2018).

Development can be carried out across aspects such as technology, processing, packaging, and marketing. Innovative and creative idea generation can cultivate product uniqueness, thereby offering an opportunity to increase consumer purchasing power (Imani et al. 2022). In terms of packaging design development, efforts can involve refining the design, brand, logo, packaging labels, and consulting on packaging materials, providing additional and new information to consumers considering the product (Sayatman et al. 2018).

Advanced technological progress impacts packaging, involving methods such as vacuum packaging or Modified Atmosphere Packaging (MAP). The principle of the MAP method is to use a specific gas mixture to replace the air inside the packaging. This packaging technique utilizes Carbon Dioxide (CO₂), Nitrogen (N₂), and Oxygen (O₂) gases. High oxygen content is required for red meat products to maintain their color and delay discoloration processes caused by metmyoglobin production (Hauzoukim et al. 2020). Vacuum packaging is proven to extend the shelf life of food products compared to non-vacuum packaging (Mulyawan et al. 2019).

The development of packaging technology for fish bone meal, a product fortified with calcium and phosphorus from fishery waste, has undergone a significant shift from traditional methods to modern systems to maintain quality stability and expand market reach. Traditionally, fish bone meal, particularly for the animal feed segment, is generally packaged using plastic sacks (woven bags) lined internally with simple plastic bags. While effective for accommodating large volumes and keeping costs low, this packaging exhibits relatively high water vapor and gas permeability, making it susceptible to hydrolytic and oxidative damage during long-term storage (Pangestika et al. 2021). Therefore, packaging innovation is crucial, especially when fish bone meal is intended for human consumption. Modern packaging development involves utilizing multilayer materials, such as (standing pouch) (aluminium foil) High Density Polyethylene (HDPE) multilayer packaging (Istini 2020). The use (aluminium foil) proves superior due to its barrier properties against oxygen, water vapor, and light, which significantly inhibits fat oxidation and microbial growth, thereby extending the product's overall shelf life (Hartanti et al. 2022). Thus, the transformation from traditional packaging focused on volume to modern packaging emphasizing protective function and visual aesthetics has been key to increasing the sales value and competitiveness of fish bone meal in both domestic and international markets.



Figure 3 Packaging and Products of Fish Bone Meal

3.6 Analysis Of The Impact Of Fish Bone Flour Development

The development of Fish Bone Flour (FBF) represents an important innovation in enhancing the economic value of fishery products while promoting sustainable waste management. As a maritime nation, Indonesia generates a considerable volume of fish bone waste every year, much of which remains underutilized. Through a circular economy approach, such waste

can be reprocessed into value-added products that generate positive economic, social, and environmental impacts. The utilization of fish bones, which were previously considered waste, now provides new business opportunities, particularly for Micro, Small, and Medium Enterprises (MSMEs) in the fish processing sector. Berghuis et al. (2023) reported that the use of mackerel (*Rastrelliger kanagurta*) bones can produce high-calcium flour suitable for both food and feed industries. By applying simple technologies such as enzymatic hydrolysis and low-temperature drying, the production process of fish bone flour can be carried out efficiently without compromising the quality of the final product.

From an economic perspective, the development of fish bone flour contributes to the establishment of a new value chain that connects fishers, processing industries, and local MSMEs. Yusrina et al. (2021) explained that fish bone flour production serves as a form of product diversification based on waste utilization, increasing industrial efficiency and reducing disposal costs. Furthermore, Kusumaningtyas and Djafar (2022) highlighted that fish bone waste processing activities in coastal communities can enhance local income and strengthen regional economic resilience. Hence, the development of fish bone flour aligns with the zero-waste industry principle, where every part of fish catch possesses economic value.

From a health perspective, fish bone flour serves as a natural source of calcium and phosphorus, which are essential for maintaining bone and dental health and preventing metabolic disorders such as osteoporosis. Ashila et al. (2022) demonstrated that the fortification of red tilapia bone flour in doughnut products significantly increases calcium content without reducing consumer acceptance levels. These findings indicate the great potential of fish bone flour as an affordable and nutrient-rich food fortification ingredient. Moreover, the collagen content in fish bones adds functional value, allowing its utilization in the development of natural cosmetic and nutraceutical products.

From an environmental perspective, the utilization of fish bone waste for FBF production plays a significant role in reducing organic waste volumes in coastal areas. Probowati et al. (2024) found that the processing of fish bone and

seaweed flour in the food industry can reduce organic waste by up to 30% while improving production chain efficiency. This approach not only helps maintain marine environmental quality but also strengthens the image of a sustainable and eco-friendly fishery industry.

Overall, the development of fish bone flour provides integrated economic, health, and environmental benefits. This innovation serves as a practical example of circular economy implementation in the fisheries sector, transforming waste into valuable resources. Government support through technological advancement, MSME capacity building, and promotion of FBF-based derivative products is crucial to strengthen downstream development and realize a competitive and sustainable fishery industry in Indonesia.

4. CONCLUSION

The development of Fish Bone Flour (FBF) application in Indonesia is a significant implementation of the circular economy concept in the fisheries sector, aiming to transform abundant fish bone waste into high-economic-value products. FBF is rich in essential minerals such as calcium and phosphorus, as well as protein and collagen, making it a functional raw material for food, feed, pharmaceutical, and cosmetic industries. While traditional, simple processing methods are still employed, the trend is shifting towards modern techniques utilizing equipment like autoclaves and controlled dryers to enhance product quality, hygiene, and consistency. FBF has been successfully fortified into various popular products, including crackers, cookies, donuts, and nuggets, significantly boosting their calcium content without compromising consumer acceptability. The marketing strategy is underpinned by the zero-waste principle, high nutritional value differentiation, and digital promotion, while modern packaging development employs multilayer materials like aluminum foil to ensure a longer shelf life and improve competitiveness. This innovation delivers integrated positive impacts: enhancing the economy of MSMEs, providing an affordable natural calcium source for community health, and reducing the volume of organic waste in coastal areas.

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