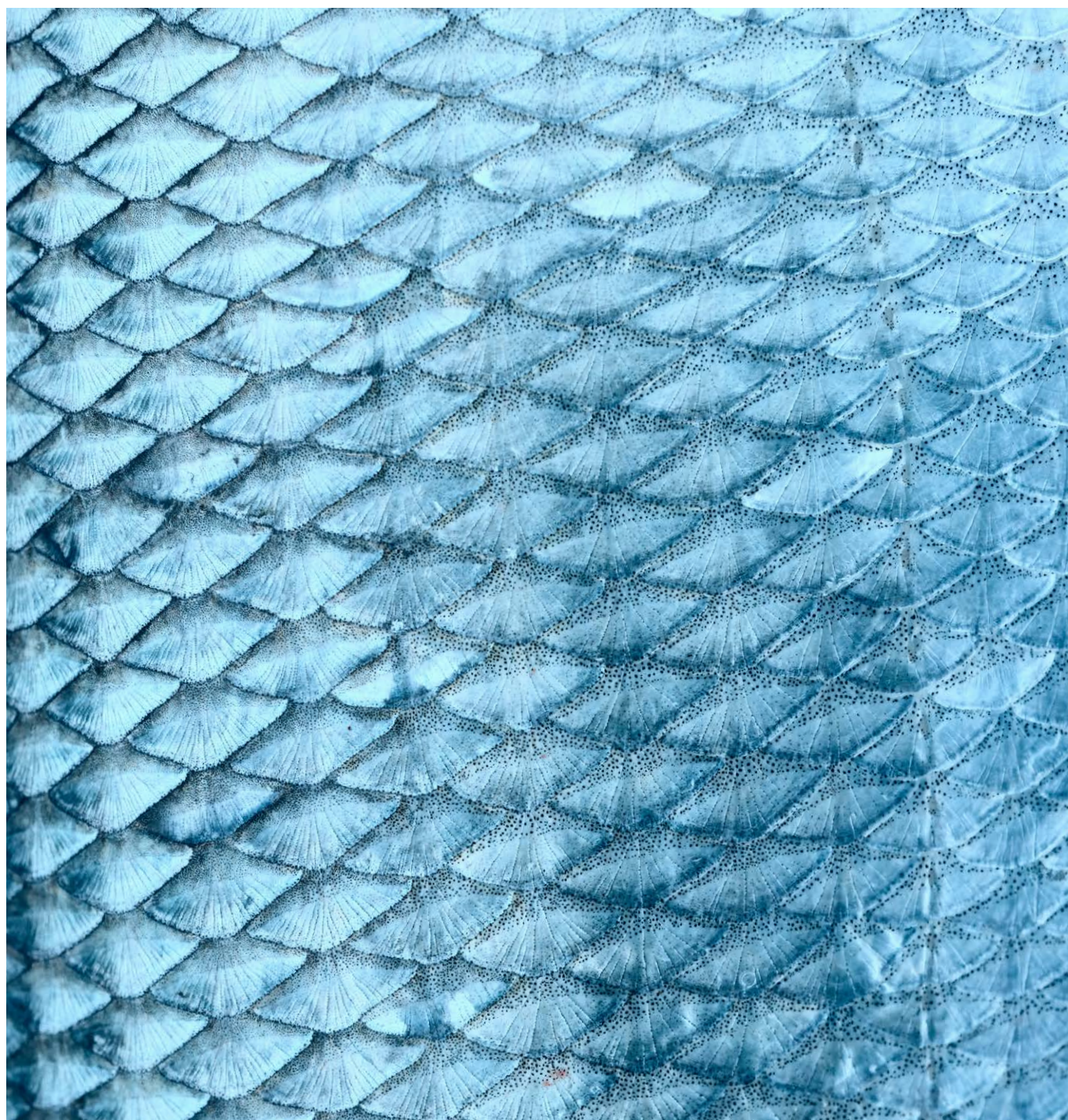


Blue Economy Circular Value Chains

Business case: Morocco

Valorization of fish processing by-products for high-revenue markets



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Each implementing organization contributes specialized experience and tools to partner with the eight beneficiary countries on activities that span policy development, capacity building, business support services, demonstration activities and networking.

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Challenges and opportunities

Morocco's fish industry plays a significant economic role by providing more than 660,000 direct and indirect employment opportunities and 21 billion Dirham (€1.9 billion) in export revenues. According to the World Bank, the sector captures 1.4 million tons of fish annually, making Morocco Africa's largest fish producer.

The fish industry is mainly oriented towards small pelagic fish, particularly canned sardines, of which Morocco is the leading producer and exporter worldwide. However, these industrial canning operations generate a significant amount of waste. During the SwitchMed project in 2020-2021, a value chain mapping showed that up to 40-50% of small pelagic fish are discarded during industrial processing. These unutilized fractions of fish either end up in the sewage, leading to environmental degradation, or are diverted to fish meal and oil processing. The fish meal industry uses the by-products to produce animal feed ingredients (aquaculture, livestock, pet food), however, only with a limited added value to the final product.

These by-products are rich in proteins, oils, and minerals so that they can be repurposed for various high-value applications for food, pharmaceuticals, nutraceuticals, cosmetics, and agriculture markets. Extracting more value out of fish catches to produce new products is a sustainable strategy for developing a circular blue bio-economy and new job opportunities, while increasing the overall profitability of Morocco's fish sector.

The scope of the project

Beginning in 2021, the United Nations Industrial Development Organization (UNIDO) has, within the regional EU-funded SwitchMed Programme, explored options that can improve the sustainability and circularity of Morocco's fish processing sector. UNIDO has partnered with industry federations, government institutions, and sector experts to demonstrate how resource-efficient business models can benefit the industry from an environmental and economic perspective.

A pilot project was initiated in collaboration with a consortium of national and international experts led by Procidys, the Specialized Center for Seafood Valorization of the National Institute of Halieutic Research (INRH), and Complex Industriel Belhassan (CIBEL), a vertically integrated group located in Agadir, Morocco. The demo site for the pilot project was the production facilities of CIBEL, which involves fish canning, fish freezing, fishmeal and fish oil industrial units.

The objective of the pilot project was to undertake lab-scale and industry-scale trials to assess the technical and economic feasibility of producing high-value end products from fish processing by-products in Morocco. The trials focused on high-value end products that can develop Morocco's export capacity and pave the way to shift its fish processing industry, aligning with the growing blue bio-economy global market.

The pilot actions

In the first phase, a comprehensive market study was conducted to assess potential new markets for by-products, considering the raw material volumes, availability, technology, process complexity, market size and barriers to entry within the global blue bio-economy dynamics.

By-products from fish processing include heads, collars, skin, bones, scales and viscera. Each part contains distinct inherent constituents with significant value when appropriately segregated, handled, and processed. Several trials were undertaken throughout the pilot project initiative, employing a rigorous methodological approach to ensure thorough evaluation and validation of each trial.

During the second phase, laboratory trials were conducted to develop the process further. These trials occurred either in Agadir at CIBEL in the production lab, at the INRH seafood valorization platform or in France at the Procidys lab. These experiments aimed to fine-tune the operational parameters required by each process, calculate the yields and assess the quality of the finished products.

The final phase comprised trials in the CIBEL production units, wherein different processes were tested on segregated and preserved by-products on a pilot scale. The pilot-scale trial objectives were to obtain diverse samples and confirm production steps, yields, quality, and process parameters compared to lab-scale results, thus validating industrial-scale technologies tailored to the process.

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The CIBEL Group is keen to implement innovative approaches, such as the SwitchMed Blue Economy project, to make better use of our products and by-products. The SwitchMed Blue Economy project has demonstrated the opportunities for energy savings, the development of new products and the sustainable use of our marine resources for better development of the circular economy and the blue bioeconomy.

Sara El Baissi
CEO, CIBEL

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Market analysis for high-value products derived from fish processing by-products

A variety of marketable products can be produced from pelagic fish by-products, including hydrolysates, collagen, peptides and food ingredients within the rapidly expanding marine-based products market.

Hydrolysates market

Various fish hydrolysates are available and have distinct characteristics depending on the industrial process used. They find promising market potential in animal feed, pet food and the agricultural sector. Fish hydrolysates, which can be made of any fish by-product, hold the potential to absorb large quantities of by-products and provide higher profit margins than fishmeal. The market size for fish hydrolysates is about €600 million in 2023, projected to grow at a 5% per year rate.

Concerning feed applications, fish hydrolysates are particularly relevant for aquaculture and can improve fish feed performance, digestibility, immune response and the Feed Conversion Ratio. Hydrolysates from pelagics are already being produced in Spain, Asia and South America.

Fish hydrolysates are highly effective additives or fertilizers for composting as plant bio-stimulants, contributing to soil microbial growth. These hydrolysates are rich in nitrogenous compounds, which enable rapid plant growth by serving as foliar fertilizers and soil treatments. In 2017, the global agricultural application of fish hydrolysates reached 10,500 tons, with a projected growth of 15,000 tons by 2024, reflecting a 4% market increase. This trend attracts various manufacturers to produce hydrolysates for agricultural applications.

For the nutraceutical market, the Moroccan sardine, known as *Sardina Pilchardus Walbum*, has, in combination with its high levels of Omega-3 fatty acids, the potential to be recognized as one of the best sources of marine hydrolysates for the production of marine peptides.

Marine peptide market

Marine peptides, applied in nutritional formulations, are derived from hydrolysates with advanced transformation processes, rendering them odourless, colourless and with bioactive properties, such as antiviral, antimicrobial, anti-diabetic, or cardiovascular prevention. Peptides from sardines are already being produced in France and Japan, and their medical properties make them popular in the dietary supplement industry. The global market for marine peptides is valued at €85 million, with an expected annual growth rate of 6%. Nevertheless, penetrating this market niche necessitates substantial research and development investments and demonstrating functional and clinical efficiencies.

Collagen market

Sardine scales and skins contain a significant amount of collagen, which can be used for products that support tissue regeneration, moisturizing effects, antioxidants and anti-aging benefits. The global collagen market comprises various forms of collagen, such as native, gelatin/gel and peptides, from different sources. This market is estimated to surpass €5 billion by 2023. The global market for marine collagen is growing rapidly, with prices ranging from €10,000 to €40,000 per ton depending on the applications and properties; this market segment has a compound annual growth rate of over 7%. The main demand for marine collagen comes from cosmetic, medical, and pharmaceutical companies, with Asia (40%), Europe (29%), and North America (23%) being the primary markets. Despite the potential of this lucrative market segment, the Moroccan fish processing industry has yet to tap into it.

Marine minerals

The market for marine minerals, such as hydroxyapatite extracted from fish bones, was valued at €2.2 billion in 2020 and is projected to reach €3.1 billion by 2025, with a cumulative annual growth of 6.8%. This market includes products for dental care, orthopedics, plastic surgeries, and applications in food and pharmaceuticals, with key markets in North America and Europe. Similar to marine peptides, penetrating this market niche remains demanding, with R&D and clinical tests required to demonstrate functional properties.

Results from the laboratory and industry trials

Based on the outcomes of the market analysis conducted, the pilot project undertook trial processes to determine yields and product quality. This was done to see if the products could meet market expectations and to conduct pre-feasibility studies that can provide evidence-based information on investment requirements, operational expenditures and turnover potential for the Moroccan industry.

Fishmeal enriched with proteins

Pilot tests were conducted to recover the drainage juices from the cannery, which are currently wasted in sewage in CIBEL's factory. These were incorporated into fishmeal, resulting in an additional protein content in fishmeal. This increased the quality and market value of the fishmeal from 58-60% to a fish meal with 65% protein-rich content, in line with international benchmarks on commodities markets.

Bringing these results on a full industrial scale will require investment in a dry-transport system, which has an effective payback period of 1.5 years in the case of CIBEL. Implementing the valorization improvements would enhance the quality of the end product and lead to an annual 7% production increase.

Marine hydrolysates

Trials conducted on whole sardines and a mix of heads, viscera, and tails, utilizing various commercial enzymes, demonstrated promising benefits, such as rapid solubilization, increased protein efficiency, reduced peptide size, and improved oil separation. The processing yielded marine hydrolysate between 15% and 21% with a protein content between 75% and 85%, which is in line with international benchmarks. In the case of CIBEL, with a payback period of less than three years for an initial investment of €8.2 million, venturing into producing marine hydrolysates emerges as a robust avenue for Moroccan industries. The successful hydrolysate pilot test validated its applicability within the Moroccan context.

Bioactive peptides

It is possible to obtain bioactive peptides from sardine hydrolysates via extraction and purification steps. Specific needed equipment that was not available on the CIBEL facility, nor at the INRH platform, restricted the trials for bio-active peptides to lab tests at Procidys, which was equipped with a lab-scale membranes pilot unit. These trials demonstrated the technical feasibility of producing bioactive peptides in Morocco that are compatible with industry production rates.

The production of peptides reduces yield compared to hydrolysates, yet the product is tailored for a higher value-added market. The increased selling price of peptides (around €50,000 per ton) is expected to optimize value and offset the investment and operational costs of additional separation steps, with a payback period of five years in the case of CIBEL. Despite the proven technical feasibility and economic viability, marine bioactive peptide production appears to be a lower-priority endeavour due to the complexity of processes and the relatively small market compared to other products such as fish hydrolysates.

Collagen (fish skin and fish scale) and marine minerals

Fish by-products include two collagen-rich materials: scales and skins. Three collagen variants can be extracted:

- native collagen, a high-molecular-weight triple-helix collagen;
- collagen gel, a partially depolymerized collagen;
- and hydrolyzed collagen.

Experiments focused on producing collagen gel and hydrolyzed collagen using fish scale and fish skin at lab and pilot scales. Collagen extracted from sardine skin yielded less than 4 to 7%, significantly lower than collagen extracted from other species such as tuna, cod or tilapia skin. Despite several positive trials with manual and machine-peeling methods to recover the skin, the trials have shown that collagen from sardine skin can hardly compete with other conventional species utilized for marine collagen production.

On the other hand, the extraction of collagen from fish scales showed promising results. The lab tests yielded 30% collagen gel, 13% hydrolyzed collagen powder and 56 to 48% hydroxyapatite-rich powder. Lower yields were obtained at a pilot scale, 22%, 2%, and 48%, respectively, due to the absence of an appropriate bioreactor in situ. On a larger scale and with appropriate equipment, it is obvious that higher yields and higher quality collagen could be obtained in line with international benchmarks.

Overall, the pilot demonstrated that collagen production from fish by-products, particularly fish scales, has great potential for the Moroccan fish processing industry. In the case of CIBEL, establishing a dedicated collagen production unit to valorize fish scales could produce 35 to 50 tons of collagen annually, with a payback period of 3.4 years. Additionally, the facility could yield, as a side-stream, 30 to 45 tons of hydroxyapatite for the pet food market with a price range between €2,000 to €5,000 per ton and 5 to 10 tons of purified hydroxyapatite with a price range between €10,000 to €20,000 per ton for the nutraceutical market.

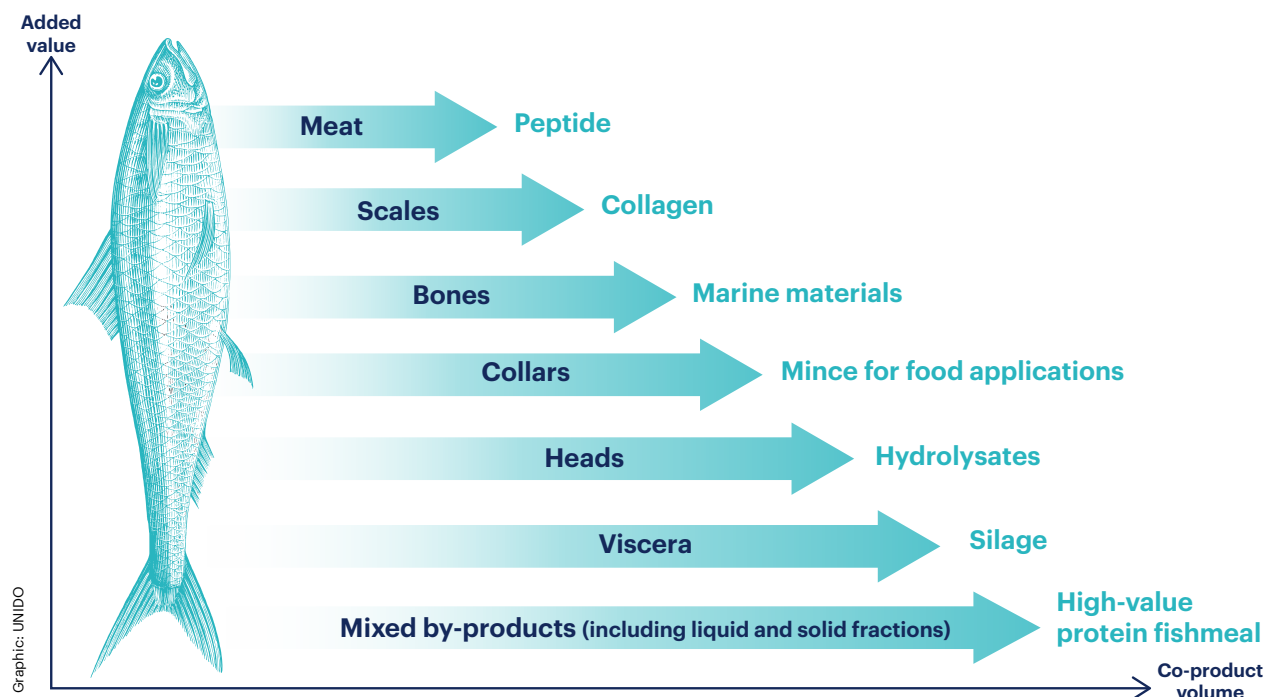
Food applications (collars valorization)

Based on seasonal variations and supply conditions, as much as 50% of sardines may require trimming to fit within the can dimensions. In this process, a fillet segment remains attached to the head and is diverted as a by-product for fish meal and fish oil processing. This constitutes a substantial fraction of high-quality fish flesh, offering market opportunities for other food applications.

A set of trials was conducted at the INRH Seafood valorization platform, equipped with a refiner, yielding 70% in mince that can be further processed into patés, terrines, frozen fish balls or fish burgers for human consumption. Incorporating natural ingredients such as tomatoes, lemons, aromas, etc., opens many flavouring options. Recipe elaboration and consumer sensory testing are essential for any company interested in creating a product range.

For CIBEL, an investment estimated at €450,000, with a payback period of less than a year, would be required. Scaling up the valorization of collars to industrial food production can generate an additional turnover estimated at more than €800,000 per year, presenting a very promising outlook for export and national markets.

Added value of fish processing by-products



Overview of by-product valorization potential and new product development opportunities from the Moroccan fish processing industry

	APPLICATION	BY-PRODUCT AVAILABILITY	TECHNOLOGY COMPLEXITY
		Criteria: Quantities on-premises, easiness of segregation, handling and preservation	Criteria: Level of complexity to integrate and operate
		Range: LOW / MEDIUM / HIGH AVAILABILITY	Range: LOW / MEDIUM / HIGH COMPLEXITY
Hydrolysate	Animal Feed (incl. aquaculture) Petfood Agriculture	HIGH	MEDIUM
Marine peptides	Healthcare Nutraceuticals	HIGH	HIGH
Collagen	Nutraceuticals Cosmetics Pharmaceuticals	MEDIUM	HIGH
Marine minerals	Food supplements Pharmaceuticals	MEDIUM	HIGH
Mince (flesh from collars)	Food applications	MEDIUM	LOW
Fish oil	Feed grade: animal feeding Food grade: Nutraceutical	HIGH	MEDIUM

The way forward

Morocco's fish processing industry can transform and become a global actor in the blue bioeconomy. Uniquely positioned with abundant and high-quality raw materials, Morocco can diversify its revenue streams and decouple economic growth from fish catches.

However, the regulatory framework of fish by-products in Morocco must be updated to meet the standards of target markets. For example, the European Union has set a range of regulations when it comes to Cosmetic (CE 1223/2009), Food (CE 853/20054), Feed (CE 1069/2009) and Bio-stimulants (UE 1009/2019). Currently, the Moroccan regulatory framework prevents fish processing by-products from being used in human food, nutraceuticals and cosmetics, limiting their application to producing fishmeal and fish oil. The regulatory framework needs to evolve in line with international standards that can encourage economic efficiency and capitalize on the value of high-end marine-based products in the global blue bio-economy.

Short-term business opportunities are in the feed and food markets, with the potential for expansion into nutraceuticals, cosmetics, and pharmaceuticals in the medium to long term. As the global population ages and becomes more focused on their well-being, the healthcare market is experiencing significant growth. In addition, changing consumer preferences towards sustainably sourced ingredients and their capacity to be positioned in Halal or alternative market segments can give marine-based products a comparative advantage over other land-based sources.

The aquaculture value chain seeks alternative feeding sources from fish meal/fish oil or cereal such as soya or wheat and is looking for new formulations with bioactive properties to increase aquaculture productivity. Fish hydrolysates have already proven their potential in new fish feed formulations. Another promising application for fish hydrolysates lies within agro-value chains, which could be an interesting strategic development for Morocco, as bio-stimulant properties can help crops resist water scarcity and better adapt to the effects of climate change.

The pilots demonstrated the technical feasibility of the different fish by-product valorization routes with payback ranging from a few months to five years. The economic dimension is promising, offering a pathway to maximize returns from marine resources at export and national levels.

INVESTMENT	RETURN ON INVESTMENT	MARKET ACCESS	MARKET POTENTIAL
Criteria: Capital Expenditures	Criteria: Payback period	Criteria: Barriers to entry, current regulation, R&D efforts	Criteria: Size, growth, margin
Range: AFFORDABLE (<100k€), AVERAGE (100k€ to 2M€), MAJOR (>2M€)	Range: SHORT (<1yr), MEDIUM (1 to 5yr), LONG (>5yr)	Range: LARGE, SELECTIVE, CHALLENGING, NICHE	Range: ESTABLISHED (CAGR<3%), LUCRATIVE(3%<CAGR<6%), HIGH PROSPECT (CAGR>6%)
MAJOR	MEDIUM	SELECTIVE	LUCRATIVE
MAJOR	LONG	NICHE	HIGH PROSPECT
AVERAGE	MEDIUM	CHALLENGING	HIGH PROSPECT
AVERAGE	LONG	NICHE	HIGH PROSPECT
AFFORDABLE	SHORT	LARGE	LUCRATIVE
AVERAGE	SHORT	LARGE	LUCRATIVE

Besides economic and regulatory considerations, changing the perceptions of the fish processing industry of by-products is essential. Currently, these are perceived as waste; by-products must be considered premium raw materials for creating high-value-added products. A change in mindset is required to align proper segregation, handling, storage, and conservation of by-products with the same quality standards applied to conventional end-products. By-products hold unique properties that can only be revealed with an appropriate logistic infrastructure.

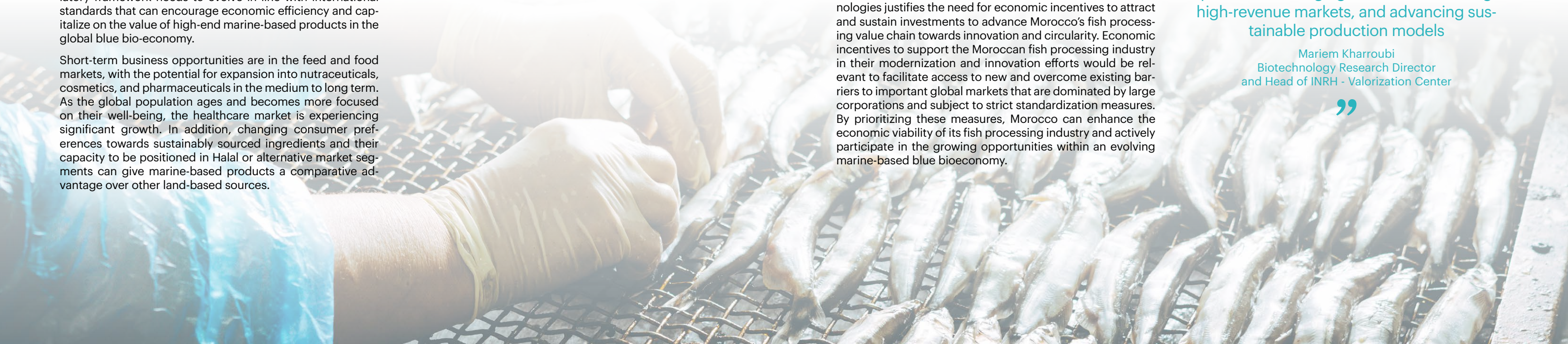
Reinforcing the bridge between national R&D and the industry is also essential for developing pre-series and tailoring production unit design to each company willing to engage in the outlined new markets for fish by-products. Acknowledging the financial risks of installing new valorization technologies justifies the need for economic incentives to attract and sustain investments to advance Morocco's fish processing value chain towards innovation and circularity. Economic incentives to support the Moroccan fish processing industry in their modernization and innovation efforts would be relevant to facilitate access to new and overcome existing barriers to important global markets that are dominated by large corporations and subject to strict standardization measures. By prioritizing these measures, Morocco can enhance the economic viability of its fish processing industry and actively participate in the growing opportunities within an evolving marine-based blue bioeconomy.

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Catalyzing innovation and sustainability, the SwitchMed Blue Economy initiative has played a pivotal role in showcasing the significant potential of valorizing pelagic by-products in an industrial setting. From R&D to industrial pre-series, the INRH-Valorization Center, is aiming at upscaling these achievements to other Moroccan companies, encouraging innovation, entering high-revenue markets, and advancing sustainable production models

Mariem Kharroubi
Biotechnology Research Director
and Head of INRH - Valorization Center

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