Oceans of waste

Fishing industry wastes are being increasingly tapped as a valuable source of proteins and other bioactive ingredients, reports Suzanne Elvidge

The world's fishing industry generates a lot of waste. In 2012, the Norwegian salmon fishing industry alone was left with 250,000t of waste after filleting and processing, said Kjartan Sandnes, head of research at Skogsvåg, Norway-based Biomega, speaking at the BIOPROSP meeting in Tromsø, Norway, in February 2013. Add to this 180,000t from herring, and 300,000t from white fish, and the net result is a lot of fish skin, bones, flesh and guts.

But rather than viewing this simply as a waste problem, a number of companies and research institutions in Norway, and across Europe, are now looking to use fish wastes as a sustainable resource from which to create valuable products from animal feed to enzymes.

Cosmetics and cosmeceuticals is one high-value end market benefiting from the trend. Oslo-based Regenics, for example, develops and supplies active ingredients based on salmon eggs for use in cosmetic and therapeutic wound healing applications. The company takes surplus eggs from local salmon hatcheries and fisheries, and removes the shell and fatty acids to leave behind a protein-rich extract, including vitamins, peptides, minerals, DNA, RNA and free amino acids, used in skin products.

'We looked at the activity of egg extracts from different species on collagen production and cell proliferation in skin cells, and found that the salmon egg extract had the same or better effect, and was easily available in Norway,' says Regenics ceo, Camilla Haglerød.

Regenics' lead active ingredient is LEX, is used in skin products to reduce the appearance of fine lines and wrinkles, by boosting collagen and elastin production, as well as increasing hydration. Papers on its clinical and *in vitro* data are in the pipeline.

The company is also developing *VERNEX,* which triggers skin cell regeneration to improve wound healing. This is in preclinical development. Regenics is developing its cosmetic and wound healing products in parallel, as the route to market for cosmetics is quicker, and will fund the R&D for wound healing products.

Another Arctic skincare company, Tromsø-based ScandiDerma, is developing cosmeceuticals through collaborations. Its *Skin Science* brand includes Regenics' active ingredient *LEX*. 'We are testing biomass waste from fisheries to find bioactive peptides. This is a highly diverse resource that is freely available, and we can create something of high value from it,' says Ragnhild Dragøy Whitaker, senior scientist at ScandiDerma.

Aqua Bio Technology is also working with salmon eggs, but focusing on proteins and proteases found in the hatching water. *Aquabeautine XL*, used in topical skincare, tackles signs of aging. The research sprang from feedback from salmon hatchery workers, who said that their hands were softer after sorting salmon eggs, despite prolonged exposure to cold water.

Increasing value

Around three-quarters of the fish 'leftovers' are already used in human food and animal and fish feed, nutrients, supplements, enzymes and bioactives, but much of this is relatively low value. However, some researchers are looking to boost the value, for example, by enriching fish oils. Farmed salmon, for example, are increasingly being fed a diet of vegetable oil rather than fish oil and fish meal, because of pressures on fish stocks, variability of supply and rising costs. However, fish fed with vegetable oils, particularly soya bean oil, have lower levels of polyunsaturated fatty acids (PUFAs), including EPA (eicosapentaenoic acid) and docosahexaenoic acid (DHA).[1,2]

Gudmundur Haraldsson of the Science Institute, University of Iceland, is working on the use of lipases to augment fish oils with PUFAs and essential fatty acids, including EPA and DHA, to increase their value. He uses *Mucor miehei* lipase in the presence of excess PUFAs to catalyse a transesterification reaction to produce triglycerides with 70% EPA and DHA content.

Haraldsson is using *Candida antarctica* lipase, followed by a coupling reaction to add medium chain fatty acids (MCFAs), EPA and DHA to predetermined positions on the glycerol backbone of triglycerides from fish oils. These could have potential as enriched sources of PUFA and essential fatty acids in nutritional supplements, and would be higher value that the original fish oils.

Biomega uses enzymes to extract products from the heads, backbones and intestines of fish waste from local salmon fisheries. This separates the waste into higher value oils (phospholipids), and water-soluble proteins (bioactive peptides, peptones and flavours), while the remaining residue is processed into lower-value products. For example, the insoluble protein goes into salmon meal for pet food, and the bones are a source of marine minerals, glucosamines, chondroitin and bioactive peptides.

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material's processing, thereby solving the disposal issue,' says Richard Walsh of the Irish Seaweed Research Group, National University of Ireland.

Biomega is adding further value to its products by creating a nanoencapsulation system that has a charged surface and incorporates an antioxidant derived from the hydrolysate. This improves both the stability and bioavailability of the encapsulated peptides or fish oils.

Nofima (Norwegian Institute of Food, Fishery and Aquaculture), based in Tromsø, is looking at herring as a source of high value bioactives, by extracting value from the whole fish rather than just cherry-picking the most valuable parts. 'It would be good to be able to extract the valuable enzymes and bioactives first and then process the bulk of the waste,' says Diana Lindberg at Nofima. 'Even once you have taken out these valuable products there is still a lot left!'

Lindberg is working on extracting enzymes from herring waste after filleting (*C&I*, 2013, **4**, 14), while other Nofima researchers are looking at marine byproducts, from potential drugs to high molecular weight polymers, such as chitosan and DNA. Ongoing projects include high quality phospholipids as food supplements and nutraceuticals, and small molecule protease inhibitors with potential in viral and fungal infections or the growing market of Alzheimer's disease.[3]

On the menu at the National Food Institute in Denmark is pickled herring, as it generates large quantities of waste brine containing valuable fish proteins. The brines, which contain up to 5kg protein for every 100kg of processed herring, have antioxidant potential and show reducing and iron chelating capabilities, which could be useful in the food, feed and nutraceutical sectors, according to Institute researcher Nina Gringer.

Tromsø-based Marealis, meanwhile, has created the food supplement *Tensiotin* from the shells of Arctic coldwater shrimps. This cocktail of peptides inhibits angiotensin-converting-enzyme (ACE) activity and so has the potential to regulate high blood pressure in patients with high-normal blood pressure. The product completed a Phase 2 clinical trial in December 2012 and could be on the market later in 2013.

Much of the current research into creating added value from marine byproducts is focused on Scandinavia. However, research elsewhere includes the EU's MARMED project looking at the potential marine resources in the biomedical industry. Ten research groups from France, Portugal, Spain, the UK and Ireland have received over €2m through MARMED, to find economic and societal value from marine resources, sub-products and by-products. This research will focus on developing biomaterials for human tissue engineering, drug delivery applications, dental and bone fillers and wound dressings. Specific areas include marine by-products as an alternative source for collagen; and hydroxyapatite and bone proteins from fish bones.[4]

Marine bioactives

Marine-derived products can also be used as part of a process to create higher value products, or a stepping-stone to a more convenient form of product. Biomega, for example, is working with the UK's Centre for Process Innovation (CPI) to investigate sustainable marine-derived peptones in the production of high-value chemicals via fermentation. The peptones are extracted from salmon residue, and work well as a growth medium for industrial biotechnology organisms, including yeasts.[4]

In another shrimp waste project, shrimp-derived alkaline phosphatase, a DNA modifying enzyme completely inactivated at 65°C, was developed from marine sources by a small Tromsø-based company later acquired by Biotec Pharmacon. The enzyme is found in glands in the heads of shrimp, and is extracted from the water released when the shrimp are thawed. Biotec Pharmacon refined the purification process to produce molecular grade alkaline phosphatase, and the product passed to ArcticZymes in a 2009 spinout.

'We used to buy the waste thawing water from the seafood factories on Tromsø Island and extract the enzyme. However, when the factories moved further away it was no longer practical. So we moved to a recombinant technology in 2010,' says Gerd Nilsen, head of customer operations at ArcticZymes.

Assuming that robust supply processes are in place to guarantee a constant supply of the marine waste, the 'leftovers' from the fishing industry promise to provide a sustainable and readily available source for high-value by-products for the health, nutrition, cosmeceutical and biotechnology industries.This will improve the sustainability of the industry by cutting waste, and could have the advantage of providing a source of funding for further R&D, particularly early-stage research.

However, as some fish waste is dumped out at sea and 'recycled' by seabirds, not everyone will be pleased by this development!

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Richard Walsh
National University of Ireland

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