

## Natural Fish Oil from Fishery Biowaste via a Circular Economy Process

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Consumption of omega-3 long chain polyunsaturated fatty acids (PUFAs) abundant in oily fish, krill, shrimp, and algae is critical for the physical and mental health of adults and children [1]. Called by Winkler the most hidden of all the hidden hungers [2], the populations of most world's countries share an insufficient daily intake of both eicosapentaenoic acid (EPA) and docosahexenoic acid (DHA). This diet deficiency led national health authorities to recommend daily intakes of both PUFAs either by increasing consumption of fish and crustaceans or by intake of omega-3 dietary supplements. Besides a minor share of the industry using omega-3 lipids extracted from algae, the large and growing omega-3 food supplement industry uses refined fish or krill oil as raw material. Increasing demand of fish oil adds to the overfishing pressure threatening many species, including anchovies, menhaden and krill [3]. The conventional fish oil extraction involves a multi-step, energy-intensive process starting on board of the shipping vessel where once caught anchovies are cooked and pressed giving an oil in water suspension. After reaching the industrial site, the oily mixture undergoes centrifugation and subsequent chemical refinement eventually affording EPA and DHA in ethyl ester form [4]. Besides contributing to overfishing, the process removes from the refined oil important antioxidant compounds such as carotenoids and biophenols that protect chemically labile PUFAs from oxidation and autooxidation [5]. We recently introduced a circular and green method for the production of fish oil rich in omega-3 from the leftovers of anchovy fillets based on solid-liquid extraction using *d*-limonene as biosolvent [6]. The resulting fish oil contains both EPA and DHA in their natural (triglyceride) form, along with significant levels of vitamin D<sub>3</sub> [7]. The use of fishery byproducts, as raw materials for the production of fish oil omega-3 extracts is highly desirable. Renewably obtained from waste orange peel, the biosolvent limonene is nearly entirely recovered after the extraction whereas its antimicrobial, antifungal, and antioxidant properties protect the PUFAs during the extraction ensuring high recovery rate also of the natural antioxidant zeaxanthin abundant in anchovies [8]. The method closes the materials cycle and establishes a circular economy process to obtain high quality fish oil from bio-based waste available worldwide in several million t/year amount. The extraction of omega-3 lipids from anchovy discards using *d*-limonene as only solvent, indeed, is economically and technically feasible on large scale [8].

### References

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