



Abstract

Natural Fish Oil from Fishery Biowaste via a Circular Economy Process [†]

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The consumption of omega-3 long-chain polyunsaturated fatty acids (PUFAs), which are 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 the consumption of fish and crustaceans or by intake of omega-3 dietary supplements. Aside from 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 the demand of fish oil adds to the overfishing pressure that threatens many species, including anchovies, menhaden and krill [3]. Conventional fish oil extraction involves a multi-step, energy-intensive process that starts on board a shipping vessel, where caught anchovies are cooked and pressed using 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]. Aside from contributing to overfishing, this process removes important antioxidant compounds from the refined oil, such as carotenoids and biophenols, which protect chemically labile PUFAs from oxidation and auto-oxidation [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 recyclable biosolvent [6]. The resulting fish oil contains both EPA and DHA in their natural (triglyceride) forms, along with significant levels of vitamin D in its most bioavailable form (vitamin D₃) [7]. The use of fishery by-products in place of fish as raw materials for the production of fish oil using biobased limonene as sole extraction solvent is highly desirable. Renewably obtained from waste orange peel, limonene is almost entirely recovered after extraction, whereas its antimicrobial, antifungal, and antioxidant properties protect the PUFAs during extraction, ensuring a high recovery rate also of the natural antioxidant zeaxanthin abundant in anchovies. Besides being economically and technically feasible on large scale, this method closes the materials cycle and establishes a circular economy process to obtain high-quality fish oil from bio-based waste, of which several million t/year is available worldwide [8].

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/Foods2021-11071/s1>, Presentation: Natural Fish Oil from Fishery Biowaste via a Circular Economy Process.



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