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Research article

Liquid by-products from fish canning industry as sustainable sources of ω3 lipids

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ABSTRACT

Fish canning industry generates large amounts of liquid wastes, which are discarded, after proper treatment to remove the organic load. However, alternative treatment processes may also be designed in order to target the recovery of valuable compounds; with this procedure, these wastewaters are converted into liquid by-products, becoming an additional source of revenue for the company.

This study evaluated green and economically sustainable methodologies for the extraction of ω3 lipids from fish canning liquid by-products. Lipids were extracted by processes combining physical and chemical parameters (conventional and pressurized extraction processes), as well as chemical and biological parameters. Furthermore, LCA was applied to evaluate the environmental performance and costs indicators for each process. Results indicated that extraction with high hydrostatic pressure provides the highest amounts of ω3 polyunsaturated fatty acids (3331,5 mg L^{-1} effluent), apart from presenting the lowest environmental impact and costs. The studied procedures allow to obtain alternative, sustainable and traceable sources of ω3 lipids for further applications in food, pharmaceutical and cosmetic industries. Additionally, such approach contributes towards the organic depuration of canning liquid effluents, therefore reducing the overall waste treatment costs.

1. Introduction

The growing environmental awareness encourages the use of sustainable feedstocks and minimization of wastes during the production of consumer goods. Although the term "waste" refers to any substance that the holder discards, this term does not exclude substances with potential economic re-utilization. Therefore, a substance resulting from a production process whose primary objective is not its own production may be regarded as a by-product (instead of a waste), as long as a certain number of conditions are verified (Directive, 2008/98/EC).

Food industry generates considerable amounts of processing by-products, which have been identified as particularly appealing for reuse due to the high volumes produced and the interesting variety of chemical compounds presented. The reutilization of such by-products presents the additional advantage of being subjected to traceability, a key parameter for consumer safety and acceptance regarding products from alternative sources.

Among food industry, fish canning is an important economic sector in Galicia (NW Spain) and the North of Portugal, processing mainly oily fish, such as tuna, sardine, sardine-type species and mackerel (Bugallo et al., 2013; Ferraro et al., 2013). One of the major concerns of this industry is related with the wastes generated: both solid and liquid wastes may create a serious environmental problem if discarded without proper treatment, due to their very rich organic load (mainly proteins and lipids). Therefore, the removal of these compounds is crucial, in order to decrease their environmental hazard. On the other hand, instead of being merely removed and discarded, these nutritional (and bioactive) compounds may be recovered, thus becoming a relevant source of revenue to the companies, counterbalancing the (obligatory) costs related to the treatment of wastes before discard, and even allow the creation of new jobs (Blanco et al., 2007).

Although several studies have been undertaken in order to

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predict potential new and more profitable applications for fish processing by-products, very few value-added compounds were able to reach the market and be sold in large quantities. In fact, solid fractions from fish canning are usually sold (at very low prices) to produce animal feed, fishmeal or flour (Ferraro et al., 2013; Penven et al., 2013), while liquid fractions are discarded. Possible explanations rely on overestimation of market possibilities, too small amounts of high quality by-products being available on a regular basis, and very high costs to isolate specific components (Olsen et al., 2014). Nevertheless, some of these limitations may be overcome, e.g. by focusing on the recovery of bioactive compounds with an already existent (and high-valued) market, such as lipids rich in ω3 polyunsaturated fatty acids (PUFA), known to prevent cardiovascular and inflammatory autoimmune diseases, as well as having important roles on brain and retina (Agh et al., 2014). These bioactive lipids are mainly found in fish oil, reaching ca. 30% of the total fatty acid content, although this value is dependent on environmental and genetic parameters.

Fish canning processing may be briefly summarized through the following sequential steps: the preliminary operations (fish reception, washing, brining and cutting), processing (cooking, canning and trimming), and final operations (sealing and sterilization). Auxiliary operations also take place, such as solid waste management and wastewater treatment processes (Bugallo et al., 2013). One of the factors with large environmental impact in the process is the use of water: this natural resource is used in brining, cooking, in distinct washing steps and even in cases where steam generation is required (Table 1). Therefore, liquid effluents are extremely variable in qualitative and quantitative composition. Studies concerning valorisation of liquid effluents from fish processing are extremely scarce, and strongly focused on the wastewater treatment (Cristóvão et al., 2015; Rio et al., 2018). In this paper we exploited the use of alternative physical-chemical and biological-chemical methods for the extraction of ω3-rich lipids from liquid by-products, as they link the efficient utilization of (food grade) organic solvents with temperature, pressure or enzymes, in an improved and more environmentally-friendly solution. Furthermore, the alternatives proposed for lipid extraction were evaluated through a Life Cycle Assessment (LCA), in order to assess their environmental and economic impacts. The selected procedures may simultaneously provide an alternative source of functional ingredients (ω3-PUFA) to incorporate in food, pharmaceutical and cosmetic products, and substantially reduce costs in the management of the remaining liquid waste streams.

2. Material and methods

2.1. Samples

The raw material used in this study was the liquid effluent resulting from the cooking step of mackerel (*Scomber japonicus*), kindly provided by La Gondola company (Matosinhos, Portugal). The abovementioned processing step is performed in steam driers, after brining and evisceration of fish. The raw fish was firstly disposed in large metal trays, which are then placed inside the steam-cooking equipment, operated at 100 °C for a few minutes. Afterwards, the trays were removed from the steam drier, the cooked fish continued its processing along the process chain, and the liquid by-product (condensate) generated during the steam processing was collected from the bottom of the metal trays. Then, the liquid was filtered with cotton cheesecloth (in order to remove eventual solid particles in suspension) and stored at −20 °C until use.

2.2. Extraction processes

2.2.1. Physical-chemical methods

2.2.1.1. Conventional extraction. Conventional extraction was hereby described as the process employing solvents and temperature, with mechanical agitation. Lipids from liquid effluent were extracted according to the procedure described by Hara and Radin (1978), with modifications (Alonso et al., 2003), using a mixture of isopropanol and hexane at 50 °C, 70 °C and 90 °C, under continuous mixing at 1500 rpm in a heating magnetic stirrer (AREC.X, Velp Scientifica), for 30 min. Phase separation was achieved by centrifugation at 12000 rpm (Heraus Megafuge 16R, Thermo Scientific). Next, the organic phase was collected and the solvent was evaporated under low pressure (Buchi Rotavapor R-200, with Vacuum Controller V-850), for gravimetric quantification of total lipids. Assays were performed in triplicate. Due to a problem occurred during storage, it was not possible to perform further analysis with these extracts.

2.2.1.2. Pressurized liquid extraction

2.2.1.2.1. High hydrostatic pressure extraction (HHPE). Assays were conducted in a Hydrostatic press (FPG7100, Stanstead Fluid Power, Stanstead, United Kingdom), equipped with a pressure vessel of 100 mm inner diameter and 250 mm height, and surrounded by an external jacket to control the temperature (kept at 20 °C). Since different solvents and proportions were used, the polarity index (PI) was employed to enable a simplification of data.

Table 1
Main process steps involving the generation of wastewaters during fish canning processing.

Process step	Purpose	% of total process wastewater	Compounds present in wastewater
Brining	provide flavour	10	Blood, salt, scales
Washing during heading & eviscerating	avoid the presence of non-desired solids	35	Blood, salt
Cooking (the prepared fish is placed on perforated trays that facilitate the spillage of oil and water, followed by a thermal treatment with steam at approximately 100 °C and atmospheric pressure)	(i) eliminate part of the water in the meat, so that it is not liberated inside the can during the sterilization; (ii) remove part of the oil/grease. which may provide strong flavours to the final product; (iii) coagulate proteins, facilitating the later removal of the skin and spine; (iv) provide colour, texture and flavour characteristics to the product.	15	Oil, protein
Can washing before sterilization	remove residues from the process	40	oil

Adapted from Ferraro et al., 2013.