Scaling up of savoury compounds production from mussel cooking side streams

M. Gutierrez*, D. San Martin, J. Ibarruri, C. Bald, J. Zufía and B. Iñarra
AZTI, Food Research, Basque Research and Technology Alliance (BRTA), Astondo Bidea, Edificio 609, 48160 Derio, Bizkaia, Spain
Keywords: Seafood by-products; savoury compounds, preindustrial test, food effluent valorisation
*Presenting author email: mgutierrez@azti.es

Introduction

The population growing concern towards a healthier diet has meant that the seafood sector has experienced a significant increase in recent years. FAO reported that fisheries and aquaculture production rose around 3 % since 2018 [1]. However, the seafood production brings an increase in emissions that causes new impacts that must be considered, such as seafood side streams. Currently, these process waters end up in wastewater, increasing organic matter to the point that the company may fail to comply with the discharge limit values. This fact is especially relevant taking into account that the organic matter is mainly composed by useful proteins that can be used in food, feed or other valuable purposes. The North-West of Spain, with an annual mussel's production of 200 000 tones (35 % of the world), generates between 300-400 litres of wastewater per ton of cooked mussels, that are continuously disposed into the sea without pre-treatment. These effluents, rich in organic matter (25 g COD·L^{-1}), contribute to the progressive deterioration of the marine ecosystem [2].

In this context, the WASEABI project [3] arose to promote a better utilisation of aquatic resources, by testing different technologies that can guarantee an effective, sustainable supply system for seafood processing industries into to a biorefining scheme. This may enable those raw materials to be turned into commercial goods.

In a previous work [4] three technologies were tested to concentrate the high value proteins from mussel cooking waters (steam cooking). In all cases, interesting biomolecules retention and the high content on salt from the water contained in the mussels were the limiting factors. In this work, the scale-up and optimization of the resulting concentration processes for the mussel cooking water (MCW) in real conditions in Pescados Marcelino's factory and the selection of the best conditions for the membrane concentration operation (a combination of nanofiltration and diafiltration steps).

Material and methods

The raw material to carry out the tests came directly from the discharge of the mussel cooking system at 100 ºC. Immediately after collecting, it was passed through a heat exchanger to cool to 40 ºC, the set temperature for biomass concentration processes using membrane technology. Pescados Marcelino (Galicia, Spain) has provided the raw material to carry out the scaling, as well as its facilities for piloting.

The membrane concentration processes consisted of different steps. After the solid removal through a pre-filter (200 µm), the nanofiltration (NF) was carried out in a membrane pilot plant (surface of 7,5 m^2 and molecular weight cut-off of 150-300 Dalton). Diafiltration (DF) consisted in a second step in which the NF concentrate was diluted with water to recover the initial protein concentration and a further DF was performed to reduce the salt content in the final concentration. Filtrations were carried out in the following operating conditions: permeate flow 300-500 l/h, temperature T = 40-50 ºC, and the operating pressure ranged from 15-30 bar.

The volumetric concentration factor (VCF) for NF, was defined as the ratio of the initial volume to the final volume of concentrated mussel cooking water. In case of DF, VCF was defined as the initial volume of the feed plus the accumulated volumes of water added for diafiltration, divided by the final volume of the concentrate.

Table 1: Different assays carried out in the scaling in Pescados Marcelino

Assay	Nanofiltration VCF	Diafiltration VCF
Assay 1	10	10
Assay 2	10	20
Assay 3	20	20

All chemical parameters were determined at least in duplicate. Crude protein and COD (Chemical oxygen demand) of the mussel cooking water were analysed following standardized methods [5].

Results and discussion

The aim of the study was to optimize the performance of protein concentration processes via nanofiltration with the purpose of reducing energy consumption, improving the protein yield, and decreasing the final wastewater pollution and consequently its treatment.

Starting from the results on previous work in WASEABI project [3], the scale-up assays was designed into 3 trials (Table 1), taking into account the volume concentration factor (VCF) achieved in each membrane concentration stage: nanofiltration and diafiltration. The assays carried out were designed to study the best strategy for higher concentration and lower resources (energy/water/reagents) use.

Table 2: Comparison between different performance parameters in treated side stream

NF (VCF) – DF (VCF)	**Assay 1** NF 10x - DF 10x	**Assay 2** NF 10x - DF 20x	**Assay 3** NF 20x - DF 20x
Protein recovery (%)	0.53	**0.67**	0.56
Volume of protein concentrate l/m^3 MCW)	10	5	**2.50**
Energy consumption (kWh/m^3 MCW)	21.42	**17.12**	21.51
Volume of final effluent (m^3/m^3 MCW)	1.98	1.95	**1.49**
COD in final effluent (mg O_2/l)	1013	**856**	**854**
CIP Reagents (€/ m^3 MCW)	128	**121**	136

In **bold** the better results in each analysed category related to the resource´s use

Table 2 shows the results of the comparison between the main outputs of the performance of MCW protein recovery. The best VCF strategy for lower energy consumption, protein recovery and lower use of reagents was a first step of 10 times NF concentration followed by a diafiltration with 20 times (Assay 2). Operational parameters tested on assay 2 allow the factory to reduce the final volume of concentrate with the consequent reduction in the cost of handling the protein concentrate as a secondary raw material for sale or waste management. The reduction on organic pollution in the MCW effluent showed that assays 2 and 3 get around 90 % of the COD reduction in the permeate (the final effluent of MCW), with a final average COD around 850 mgO_2/l.

Conclusions

The tests carried out have made it possible to verify that it is possible to achieve a higher concentration of organic matter, thus reducing the volume of concentrate to be managed. The organic load of the permeate continues to be higher than the parameters required by legislation. As it is a sterile stream due to the action of nanofiltration membranes, it is recommended to look for internal uses for reuse. The rest that cannot be reused is recommended to be laminated with cleaning water from other company processes to reduce final COD effluent.

The state of the initial sample is very important, so the use a good cooling system of the MCW side stream as a pre-conditioning is a key factor in the whole process to recover valuable compounds from MCW. The inadequate treatment of raw material causes an increase in the degradation of the organic components causing the acceleration of the membrane fouling and consequently, the energy use of the operation increases, as well as the needs for reagents, water and energy for its cleaning.

Acknowledge

This project has received funding from the Bio Based Industries Joint Undertaking (JU) under grant agreement No 837726. The JU receives support from the European Union's Horizon 2020 research and innovation programme and the Bio Based Industries Consortium. This communication reflects only the author's view and that the JU is not responsible for any use that may be made of the information it contains.

References

[1] FAO. 2022. The State of World Fisheries and Aquaculture 2022. Towards Blue Transformation. Rome, FAO. https://doi.org/10.4060/cc0461en

[2] Prieto M.A., Prieto I., Vázquez J.A. and Ferreira I. C.F.R. (2015). An environmental management industrial solution for the treatment and reuse of mussel wastewaters. Science of the Total Environment 538, 117–128. https://doi.org/10.1016 / j.scitotenv.2015.07.041

[3] WaSeaBi: Optimal utilization of seafood side-streams through the design of new holistic process lines project. BBI-JU funded project No 837726. https://www.waseabi.eu/

[4] Gutiérrez M., Iñarra B., San Martin D., Bald C., Orive M., Zufía J. (2022) Recovery of biomolecules from liquid side-streams from mussel processing. 8th International Conference on Sustainable Solid Waste Management, 23-26 June 2021, THESSALONIKI, Greece

[5] APHA; AWWA; WEF. (2012) Standard Methods for the Examination of Water and Wastewater, 19th ed.; Rice, E., Baird, R., Eaton, A., Clesceri, L., Eds.; American Public Health Association: Washington, DC, USA, 2012.