Ecodesign of new circular economy scheme for Brewer’s side streams

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Introduction

European Union is one of the largest beer producers in the world with 406 million Hl and about 10,154 breweries in 2019. The brewing process produces a large amounts of side streams, being the largest volume of wastes the brewers’ spent grains (BSG) (80% of total solid by-products), followed by brewers’ yeast (BY) (10%). In this scenario more than 6 million tons of BSG (15-20 kg of BSG per 1 Hl of beer) and 1 million tons of BY (1.5-3 kg of BY per 1 Hl of beer) are annually generated in Europe. The management of these side streams is variable among brewers, but BY is generally mixed and treated with wastewater, while BSG is used in fresh for animal feed (70%), landfilled (20%) or used for biogas production (10%). This implies an important environmental impact that, only regarding greenhouse gases emission, accounts 513 kg CO2 equivalent by ton of waste landfilled and 83 kg CO2 equivalent by ton of wastewater treated.

One of the potentials uses of these by-products is the productions of ingredients for the formulation of animal feeds. Life BREWERY project (https://lifebrewery.azti.es/) has designed a new circular economy scheme based on a sustainable solution for valorising brewery by-products as a second-generation feedstuff to produce new feed ingredients for aquaculture.

Aquaculture is one of the pillars of the EU’s Blue Growth Strategy and its development can contribute to the Europe 2020 Strategy. However, aquafeeds are highly dependent on fish meal (FM) and fish oils (FO), consuming about 65 % of the FM and 83 % of the FO annually produced (Tacon et al. 2008). Alternative ingredients to reducing aquaculture’s dependence on marine resources are needed (Turchini et al. 2012). Furthermore, the use of alternative ingredients, such as soybean or rapeseed have demonstrated to reduce the environmental impact per tonne of aqua-feed up to 43 % in Global Warming potential (GWP) related to GHG (Samuel-Fitiwi et al. 2013b; Stone et al. 2007).

Current results of LIFE-BREWERY project have demonstrated that brewers’ by-products stand as a valuable alternative for replacing fish meal in aquaculture feed, due to their availability in Europe, their nutritional characteristics and the validation of the proposed valorisation process and products. The proposed scheme includes the steps to transform brewer’s by-products in aquaculture feed ingredients. In short, the process consists in an enzymatical hydrolysis, to improve the ingredients digestibility, and an innovative and low energy demanding drying process (San Martin et al. 2020).

The resulting products have been tested and validated with three fish aquaculture species: Sea bream, as a model of a Mediterranean aquaculture specie; Senegalese sole, as a model of Atlantic specie; and Trout, as a model of a freshwater specie (Nazzaro et al. 2021).

Several studies have promoted the consumption of aquaculture products as one of the animal-protein products with less environmental impact, having a climate change potential impact significantly lower than other sources of animal protein (Lamb: 20.44 kg CO2 eq/kg product > Beef: 15.23 kg CO2 eq/kg product > Pork: 4.62 kg CO2 eq/kg product > Gilthead seabass: 4.4 kg CO2 eq/kg product > Salmon: 4.14 kg CO2 eq/kg product > Broiler: 2.33 kg CO2 eq/kg product > Rainbow trout: 1.36 kg CO2 eq/kg product) (Aguado-Giménez et al., 2016; Hamerschlag and Venkat, 2011; Samuel-Fitiwi et al., 2013a).

Thus, the use of an Ecodesign approach is of paramount importance to maximize the reduction of the environmental impact of the proposed valorisation scheme to assure the best integration of the processes.
Material and methods

Ecodesign methodology is focused on increasing the efficiency and reducing the environmental impact of those aspects related to operational and investment requirements, such as energy, water and material requirements and outputs such as wastes, wastewater and other emissions.

Based on the requirements established by the valorisation process, an Ecodesign of a Model Recovery Plant (MRP) has been carried out by integrating all the functional and operational needs, taking into account the European environmental requirements and following Ecodesign criteria for the whole life cycle of the plant "from cradle to grave" (San Martin et al. 2019).

The use of Ecodesign criteria means that environmental impact will be considered in the same level as those which traditionally have been considered (cost, time & quality) with the aim of reducing the environmental impact of the plant throughout its whole life cycle.

The base of this methodology is to include the environmental attribute from the beginning of the ideation of the valorisation process and the MRP, when the degrees of freedom are sufficient enough to include improvement actions or strategies with high potential to reduce the overall environmental impact. The environmental assessment is performed with the internationally recognized Life Cycle Assessment (LCA) methodology, that consists in identifying all the inputs and outputs with higher environmental impact and their quantification of a process encompassing the whole value chain (cradle to grave). It is regulated by the ISO 14040 and involves 4 steps, which are not simply sequential:

- The definition of the Goal and Scope
- The Life Cycle inventory analysis
- The Life Cycle Impact Characterisation
- The interpretation

LCA is an iterative technique that allows to be increased the level of detail in successive iterations.

The Ecodesign of the MRP also includes the identification of the location, applying GIS methodology to identify the specific and optimize the location and context in which the MRP will be implemented.

Furthermore, the Ecodesign also introduces advance concepts about: Integrating Value Engineering, Life-Cycle Costing, and Sustainable Development, from conceptual stage till detailed design completion and execution.

Results and discussion

The ecodesign of the new circular economy scheme proposed by the LIFE-BREWERY projects includes different steps from the sourcing to the final use (Figure 1):

- Ecodesign of an optimized logistics for the management of by-products from brewery.
- Ecodesign of a highly efficient process to valorise the brewery by-products and transform them in sustainable ingredients for aquaculture feeds.
- Ecodesign of an efficient facility.
- Use in an appropriate sector substituting non-sustainable ingredients and avoiding their import with local sourcing.

Figure 1: LIFE-BREWERY new circular economy scheme proposed.
As far as the main environmental impact of food waste recovery is related to the energy consumption and wastewater generation of the processing plant (Salemdeeb et al., 2017), the reduction of the impact within the solution could lead to great improvement of the whole final feed ingredient, and thus also of the final aquaculture product. After the assessment of the global solution the main environmental impacts evaluated are: Climate change, Acidification, Eutrophication terrestrial or Land use, which have been selected following the International reference Life Cycle Data system (ILCD) methodology.

![Main environmental impacts](image)

**Figure 2:** Main environmental impact characterization of the 4 different management alternatives of 1 ton of BSG: Landfill, Incineration, Valorisation for livestock animals feeding, and Valorisation for aquafeeds. Climate change (kg CO₂ eq.), acidification (mol H+ eq.), Eutrophication terrestrial (mol N eq.) and Land use (Pt).

Considering that certain feed ingredients are avoided, the valorisation of brewers’ by-product spent grains potentially reduces the overall environmental impacts. Indeed, regarding climate change impact category, 274 kg of CO₂ eq. are avoided when choosing this management option. The management itself consumed high amounts of energy which has a significant impact on the environment (+ 200 kg CO₂ eq.). However, due to the avoidance of fishmeal and soymeal cultivation and production (- 474 kg CO₂ eq.), the overall environmental impact obtains a negative value.

Moreover, with the proposed solution, the valorisation of brewers’ by-product spent grains, would lead to a potential saving on greenhouse emissions of about 1000, 300 and 150 kg of CO₂ equivalents per ton related to current management options landfill, incineration and valorisation for livestock animal feeding, respectively.

Furthermore, the implementation of the ecodesign approach in the facility design allows the reduction of energy demand by the integration of flows and energy uses, as well as the implementation of high thermal efficient systems and thermal and electric power generation in site.

On the other hand, the use of brewer’s by products will also contribute to reduce the environmental impact related to aquaculture feed production, by substituting FM or edible crops. In example, considering the production of feed ingredients and their transport to feed mill, the aquafeeds obtained with LIFE BREWERY ingredients show significant benefits comparing with commercial aquafeed, such as the reduction of 6 % of climate change, among others. Moreover, almost the 80 % of the impact related to the aquaculture product is related to aqua-feed, and thus, within the inclusion of environmentally improved feeds, the impact of the final product could be also reduced.

The Ecodesign of the MRP reduces the impact of the valorisation process evaluating not only the avoided impact, but also leading to a more sustainable design of the process, the facilities and the logistics related to this new circular economy scheme.
Conclusions

The valorisation of Brewers’ by-products as an ingredient for the formulation of aquafeed has an important favourable effect both in brewers and aquaculture environmental impact. The use of an Ecodesign methodology has improved the preliminary environmental advantages of the scenario leading to a more sustainable circular economy scheme exceeding initial expectations.

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