Brewers' spent yeast and grain as second-generation feedstuff for aquaculture feed

D. San Martin[1*], M. Orive[1], B. Iñarra[1], A. Estévez[2], R. Fenollosa[3], J.M. Martinez[4], A.M. De Smet[5] & J. Zufía[1]

[1]AZTI, Bizkaia, Spain
[2]IRTA, Tarragona, Spain
[3]RIERA NADEU, Barcelona, Spain
[4]LKS KREAN, Gipuzkoa, Spain
[5]The Brewers of Europe, Brussels, Belgium

*Corresponding author: E-mail: dsanmartin@azti.es; Tel.: +34 667 174 315; Fax: +34 94 657 25 55

Abstract
Aqua feeds are formulated to contain all the essential nutrients that fishes need to keep healthy. They are highly dependent on fish meal (FM) and fish oils (FO). According to IFFO, the global production of FM was 5.13 million tonnes in 2018 (65% goes to aquaculture), while FO was 1.04 million tonnes (83% goes to aquaculture). Thus, alternative ingredients which successfully replace these marine components with non-traditional sources are required to result in sustainable and economical feeds.
European Union is the 2nd largest beer producer in the world (about 400 million Hl in 2017). Breweries employs different batch type operations in processing raw materials to the final beer product that produce large quantities wastes. The largest volume are brewers' spent grains (BSG), with more than 6 million tons of BSG per year, followed by brewers' yeast (BY) with about 1 million tons of BY.
Reducing aquaculture's dependence on marine resources in the future will depend on developing alternative raw materials that substitute away fishmeal and fish oil and improving their feed efficiencies. Life Brewery project (LIFE16ENV/ES/000160) proposes a sustainable solution for producing new feed ingredients from brewers wastes for aquaculture. The process consists of an enzymatical hydrolysis to improve the digestibility of these by-products and increase the assimilation of nutrients by fishes and an innovative drying process to achieve the desired moisture content of less than 10%. Experimental meals are tested in sea bream, senegalese sole and trout, as models of a Mediterranean, Atlantic and freshwater aquaculture, respectively.

Keywords: Valorisation; Brewers´ by-products; Aquaculture feed; Second-generation feedstuff; Sustainability; Circular economy.

Introduction

European Union is the 2nd largest beer producer in the world (400 million Hl in 2016), ahead of USA, Brazil and Russia, with about 8,490 breweries. The brewing industry employs different batch type operations in processing raw materials to the final beer product that produce large quantities of wastewaters and solid wastes. The largest volume of solid wastes are brewers' spent grains (BSG) (80 % of total solid by-products), followed by brewers' yeast (BY) (10 %). So, given EU beer production in 2016, 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) were generated. BY is often mixed with wastewater and discharged for its treatment, while 70 % of BSG is used in fresh for feed, 10 % for biogas production and 20 % is landfilled. This implies the loss of a valuable product. In addition, the use of 70 % of BSG as a direct supply for animal feed without any treatment depends on many factors which can limit significantly their feasibility and, in many cases, can make it unsustainable. The high moisture content together with its high microbial load and the high temperature at which they are generated makes their useful life not more than 48 hours [1]. Furthermore, although the use of these by-products for human consumption or even for pharmaceutical and cosmetic purposes could be a valuable option, a solution able to cope with larger volumes is needed. Furthermore, only regarding greenhouse gases emission, managing BSG in a landfill has an impact of around 513 kg CO2 equivalent by ton of waste disposed, while the treatment of BY together with wastewater is around 83 kg CO2 equivalent by ton of waste treated.
Aqua feeds are specially formulated to contain all the essential nutrients that farmed fishes need to keep healthy. Currently, they are highly dependent on fish meal (FM) and fish oils (FO). Of the global production of FM (about 4.8 million tonnes), approximately 65% is utilized in aquaculture production, while of the global production of FO (about 1 million tonnes), approximately 83% goes to aquaculture production [2]. Alternative ingredients which successfully replace these marine components with non-traditional sources are required to result in sustainable and economical feeds. Reducing aquaculture's dependence on marine resources in the future will depend on improving feed efficiencies and substituting away from fishmeal and fish oil.
Samuel-Fitwi et al. [3] have demonstrated that replacing FM by other alternative ingredients, such as soybean or rapeseed, involves less environmental impact per tonne of aqua-feed in both Acidification potential (AP); Global

Warming potential (GWP); Eutrophication potential (EP) or Land competition (LC) than fish meal based standard aqua-feed. Thus, in case of the GWP, the fish meal standard trout feed has an impact of 1,797 kg CO2 equivalent per ton while the soybean meal and rapeseed meal based aqua-feeds has 1,019.65 and 1,037.13 kg CO2, respectively. The maximum level of substitution of FM and FO depends on the species [4-5]. In the case of sea bream, it can reach up to 100% FM and 70% FO replacement followed by a refeeding period to recover the levels of omega 3 fatty acids in the fillet.

Material and methods

Within this framework, Life BREWERY project (LIFE16ENV/ES/000160) proposes a sustainable solution for reusing brewery by-products as new feed ingredients for aquaculture through the application of an innovative process to obtain low-moisture meal prototypes.

This process consists, firstly, in an enzymatical hydrolysis to improve as much as possible the digestibility of these by-products with the aim of increasing the assimilation of nutrients by fishes and, therefore, the percentage of inclusion of these ingredients in aquafeed. In case of BY, the aim is a protein hydrolysate whereas in the case of BSG is a fibre hydrolysate.

Then, an innovative drying process is applied to both by-products consisting, firstly, in a mechanical dewatering that consumes a low amount of energy to reduce the water content as much as possible before applying a higher energy consuming thermal drying technology to achieve the desired moisture content of less than 10%.

Experimental meals are tested in three fish species in aquaculture systems: 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. Firstly, a digestibility test is carried out with the aim of determining the maximum level of inclusion of each ingredient and, secondly, a specific growth trial with each specie is applied with the aim of quantifying the nutritional efficiency of each experimental ingredient for each fish species aimed of study.

Finally, a sensory quality of produced fishes has been carried out by an expert panel of consumers.

The methodology to achieve these goals has been divided in five technical actions:

1. Pre-Industrial optimization of processes for obtaining brewers´ by-products-based meal & aquafeed prototypes: An optimized drying process at semi-industrial scale will be developed obtaining 2 meal prototypes. Experimental aqua-feed diets including developed 2 meals will be formulated till optimum level of inclusion.

2. Design of a valorisation scheme for brewers' by-products including all stages of the value chain: The valorisation scheme will address the technical and administrative actions for each stage. It will be contrasted with Stakeholders.

3. Demonstration trial of the valorisation scheme applied to the case study: north-east region of Spain. A demonstration trial at a semi-industrial scale and in real operational conditions will be carried out. By-products will be taken from the most important breweries of Spain. They will be adapted and stabilized by an optimized drying process. Fish growth trial with developed aqua feed will be carried out. Finally, the sensory quality of produced fish will be assessed.

4. Feasibility assessment of the implementation of the valorisation scheme in an industrial reference scenario: The valorisation scheme will be assessed from the technical, economic, social and environmental points of view, as well as the eco-design of the valorisation plant at full scale.

5. Replicability and transferability of the valorisation scheme at European Level: The valorisation scheme will be replicated and transferred to EU. A comprehensive analysis of the replicability to 2 European areas will be carried out. A replicability and transferability plan will be performed in each of them.

Results and discussion

The production of alternative ingredients for aquaculture feed based on brewers´ by-products (Figure 1) has been validated from the technical, environmental and economic point of view. Four ingredient prototypes have been obtained through the combination of hydrolysis and drying process: brewer´s spent grain and hydrolysed spent grain & brewers´ spent yeast and hydrolysed spent yeast.

The enzymatic hydrolysis as pre-processing prior to dehydration has been studied with the aim of assessing the increasing of the digestibility of ingredients. Then, an innovative and efficient drying process has been validated to stabilize by-products over time and to ensure their applicability in aqua feeds. Developed drying process consists of two steps: a low energy demanding dewatering process and, once the moisture has been reduced till 55 %, a highly efficient thermal drying process to achieve a moisture content of less than 10 %.

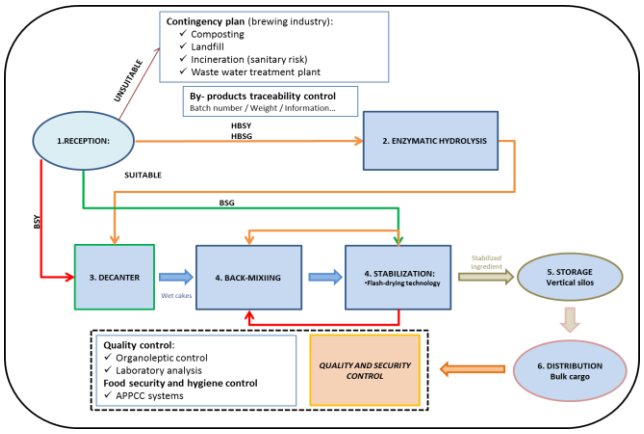

Fig. 1 Proposed flow chart for the brewers´ by-products processing plant

The obtained four ingredient prototypes have been analysed in order to know their nutritional potential for aquafeed production (Table 1).

Table 1 Basic nutritional composition of four experimental ingredients

Experimental ingredients	Crude protein (%)	Ether extract (%)
Spent grain	22.73	7.75
Hydrolysed spent grain	21.38	11.46
Spent yeast	45.07	0.35
Hydrolysed spent grain	41.24	0.45

Experimental diets have been formulated to be iso-protein and iso-caloric with the aim of comparing the obtained results (Table 2).

Table 2 Experimental diets composition

	Control	Yeast 30%	H-Yeast 30%	Spent grain 20%	H-Spent grain 20%
Dry matter (DM, g/Kg)	978,30	979,20	976,60	980,50	978,10
Ash (g/Kg DM)	98,80	83,20	78,70	93,60	100,60
Crude protein (g/Kg DM)	419,80	413,30	418,20	417,70	392,80
Crude fat (g/Kg DM)	218,42	223,94	234,04	219,83	221,40
Carbohydrates (g/Kg DM)	215,10	218,50	197,00	130,20	166,20
Gross energy (MJ/Kg DM)	18,65	18,89	19,04	17,25	17,53

They have been tested in two fish species in RAS aquaculture systems: Sea bream (*Sparus aurata*), as a model of a Mediterranean aquaculture specie, and Rainbow trout (*Oncorhynchus mykiss*), as a model of a freshwater specie. Obtained results have shown acceptable digestibility between 53,97 % to 90,74 % (Table 3).

Table 3 Digestibility of experimental diets including brewer´s by-products

Rainbow trout Diet	Protein diet			ADC
Control	419,80	±	3,39	84,23
D-Yeast 30%	413,30	±	1,16	74,81
H-Yeast 30%	418,20	±	2,49	78,05
D- Spent grain 20%	417,70	±	3,51	80,37
H-Spent grain 20%	392,80	±	0,70	84,23

Sea bream Diet	Protein diet	ADC
Control	419,80 ± 3,39	90,34
D-Yeast 30%	413,30 ± 1,16	53,97
H-Yeast 30%	418,20 ± 2,49	70,58
D- Spent grain 20%	417,70 ± 3,51	86,27
H-Spent grain 20%	392,80 ± 0,70	90,74

Regarding greenhouse gases emission, it is estimated that, with the proposed solution, the greenhouse gases emissions which are potentially avoidable are about 615.6 million kg of CO_2 equivalent, in case of BSG, and 66.4 million kg CO_2 equivalent, in case of BY.

Conclusions

Brewers´ by-products stand as a potential alternative for replacing fish meal in aquaculture feed, due to their availability in Europe (about 9 million tons of BSG and more than 1,2 million tons of BY), their nutritional characteristics (high content of protein) and the results obtained in the trials with fishes (acceptable digestibility in fishes).

Their availability will also contribute to reduce the environmental impact related to fish meal based aqua feed by reducing the greenhouse gases emission (more than 600 million kg of CO_2 equivalent) and preserving marine resources.

In addition, proposed solution involves an increase of the sustainability of aquaculture by providing two new, economically advantageous, protein sources that could replace fish meal. Thus, the reduction of aquaculture production costs will contribute to achieve the objectives established by the new European Common Fisheries Policy and the replacement of marine origin ingredients (fishmeal) will contribute to reduce significantly wild catches, contributing to achieve the goals defined in the Marine Strategy Framework Directive.

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