This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773330

Deliverable report for

GAIN

Green Aquaculture Intensification

Grant Agreement Number 773330

Deliverable D2.7

Title: Valorisation of fish by-products

Due date of deliverable: 31/10/2020

Actual submission date: 30/10/2020

Lead beneficiary: University of Stirling

Authors: Wesley Malcorps, Richard Newton, Dave Little, Carmen G.Sotelo

Ethics requirements

Dissemination Level:		
PU	**Public**	**Y**
		Y

Document log

Version	Date	Comments	Author(s)
Version 1	11/9/2020	First draft	Wesley Malcorps
Version 2	10/10/2020	Second draft	Wesley Malcorps, Richard Newton
Version 3	22/10/2020	Third draft	Wesley Malcorps, Richard Newton and David Little
Version 4	23/10/2020	Fourth draft	Wesley Malcorps, Richard Newton and David Little
Version 5	28/10/2020	Fifth draft	Wesley Malcorps, Richard Newton and David Little
Version 6	30/10/2020	Sixth draft	Wesley Malcorps, Richard Newton and David Little

Recommended Citation

Malcorps W, Newton R, Little D. (2020) Valorisation of fish by-products. Deliverable 2.7. GAIN - Green Aquaculture INtensification in Europe. EU Horizon 2020 project grant nº. 77330. 41 pp. INtensification in Europe. EU Horizon 2020 project grant nº. 773330. 41 pp.

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GLOSSARY OF ACRONYMS

Acronym	Definition
BP	By-product
CF	Conversion Factor
EU	European Union
EEA	European Economic Area
FAO	Food and Agriculture Organization
FPH	Fish Protein Hydrolysate
GAIN	Green Aquaculture Intensification in Europe
HOG	Head-On-Gutted
IIM-CSIC	Marine Research Institute (IIM-CSIC)
IoA	Institute of Aquaculture
LW	Live weight
MT	Metric Tonne
UoS	University of Stirling
(G)VCA	(Global) Value Chain Analysis

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Executive summary

The EU funded Green Aquaculture Intensification (GAIN) project seeks to optimise output of aquaculture in terms of product and value while minimising negative environmental and social impacts. A promising strategy is to improve the utilization of aquaculture processing by-products to increase food, feed and economic output. The nutritional value of the individual by-products (heads, frames, trimmings, skin and viscera) of six key farmed finfish species, was analysed as part of T2.2. This deliverable provides a by-product balance to determine available aquaculture by-product volumes on a country level based on production, trade and processing activities. The volumes of potential added edible yield, feed ingredients, collagen and gelatine derived from the available by-products are calculated based on the analysed yields (Annex 2) by Marine Research Institute (IIM-CSIC), as part of T2.2

The most important European aquaculture finfish species in terms of volume are Atlantic salmon (*Salmo salar*), rainbow trout (*Oncorhynchus mykiss*), European seabass (*Dicentrarchus labrax*) and gilt-head seabream (*Sparus aurata*). Common carp (*Cyprinus carpio*) is only of significance in Eastern Europe, whereas turbot (*Scophthalmus maximus*) remains an important niche species. Consumption patterns vary across Europe, leading to different processing strategies for different industries, targeting different markets.

Section 4 provides a detailed methodology on how by-product volumes were calculated from aquaculture processing activities by country and species. A spreadsheet model was used, including production, and commodity trade data from FAO, informed by yield data from earlier lab analysis performed by UoS to estimate by-product fractions for each species (heads, frames, trimmings, skin and viscera). Estimates of the level of fish currently processed were based on FAO production and trade data along with necessary literature guided assumptions on levels of processing. Further modelling provided insight into the potential volumes of derived fish ingredients (protein hydrolysates, peptones, fish oil and gelatines) that could be produced from by-products. The dominance of Atlantic salmon in terms of current production and level of processing is clear compared to the other species. Well established value addition strategies through feed applications were apparent in Norway but full potential through separation has not been realised. Results indicate significant potential for the European seabass and gilthead sea bream industry to add value through utilising viscera to produce fish oil and hydrolysates, but other by-products (heads, frames and trimmings) have low availability because of low levels of secondary processing. The methodology also identifies the potential flesh yield from the individual by-products which is significant in some cases. However, separation technologies are not investigated.

The different parts of Task 2.2 are complementary in providing an industry driven consensus on the necessary improvements needed for the EU aquaculture industry and to highlight opportunities to add value responsibly and sustainably by the use of already available fish by-products.

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1. Introduction

To estimate the volumes of derived by-products from European aquaculture processing, it is imperative to understand trade and consumption characteristics. From the estimated by-product volumes, potential volumes of feed ingredients, separated flesh for human consumption and other products can be extrapolated. Practicality is also indicated by the concentration of available by-products to make utilization economically attractive.

The design of the work within D2.7 was based on a combination of a lab analysis, that provided yield data for each class of by-product across a range of the key farmed finfish species, linked to aquaculture production and seafood commodity trade data from the FAO (FAO, 2020), which allowed estimations of by-product volumes. The lab analysis conducted by Marine Research Institute (IIM-CSIC) on yields of marine ingredients was used to estimate total volumes of ingredients that could be produced from each by-product stream where they occurred.

The GAIN work thus falls into five main parts to assess the role of aquaculture by-products in Eco-intensification:

(i) Deliverable 2.3 provides data on by-products fraction yields and their nutritional profile, which supported the work in to identify the most suitable by-products for feed applications.
(ii) Deliverable 2.7 provides data on European volumes of by-product raw materials and potential applications based on commodity trade of the major European aquaculture producing countries, importers and exporters.
(iii) Deliverable 1.4 provides information on performance of feed ingredients in standardised feed trials including feed ingredients (e.g. FPH and peptones) produced from by-products.
(iv) Deliverable 4.4 gives a sustainability assessment of the performance of GAIN innovations through the EISI, including the use of by-products in feed applications.
(v) Deliverable 4.2 discusses the different applications of by-products from a value chain perspective, considering volumes, logistics and cultural norms.

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2. European aquaculture sector and processing

The UK, France, Greece, Italy and Spain were responsible for 78% of direct value output of the EU 28 from aquaculture in 2012, from which 50% of the value was produced in marine cages, but represented only 28% of the production volume (Bostock et al., 2016). This can be explained by the relatively large bivalve shellfish production, which made up a disproportionate 56% of EU aquaculture production (Ferreira and Bricker, 2015). Norway, although not a member of the EU, is part of the EEA and therefore follows its regulations. It is the largest producer of Atlantic salmon in the world at over a million tonnes, much of which is exported to the EU, "head-on-gutted", for further processing and therefore contributes a significant volume to consumption of aquaculture products in the EU (Table 2.1). Norway supplies around 25% of the total seafood imports into the EU and the largest share of farmed salmon imports. Norwegian farmed salmon made up 35% of the total apparent consumption of aquaculture products and 15% of the volume of all fish and seafood products imported by the EU in 2017 (FAO, 2020). Other important imports into the EU include seabass and sea bream from Turkey. Although Turkish production is not explicitly mentioned within this report (as Turkey is not in the EEA), any volumes of imported product are accounted for within the trade statistics.

European finfish culture is dominated by production of high value species such as Atlantic salmon (*Salmo salar*), Rainbow Trout (*Oncorhynchus mykiss*), European seabass (*Dicentrarchus labrax*) and gilt-head sea bream (*Sparus aurata*). While there are 70 aquaculture species cultured in the European Union (FAO, 2014), these 4 species, together with common carp (*Cyprinus carpio*) and turbot (*Scophthalmus maximus*), make up more than 90% of cultured finfish volume (Bostock *et al.*, 2016) and are the focus of the GAIN project. EEA major producing countries and regions are provided in Table 2.1. Overall, volumes of Atlantic salmon production have increased by nearly 40% between 2010 and 2018, while rainbow trout production marginally declined in Europe (EU + EEA) in the same time (FAO, 2020). The production of European seabass increased by 30%, while gilthead sea bream production declined from 2010 to 2018 (FAO, 2020). Both seabass and sea bream production have faced challenges regarding high mortality, high costs of production and labour, particularly at the hatchery stage. Turbot is a niche species with low production volumes, which has been declining slightly in the EU (FAO, 2020). Common carp production grew by around 10% from 2010 to 2018. It is a traditional species in Eastern Europe, mainly supplying the Christmas market when carp is often purchased live.

European (EU-28) aquaculture and capture fisheries combined production volumes are not sufficient to meet domestic demand. Consequently, the EU-28 relies on seafood imports (EUMOFA, 2019) and it is important to improve efficiency in the use of raw material supplies to reduce this dependency. A recent paper by Newton and Little (2018) demonstrated that 75% of feed ingredients included in Scottish farmed salmon diets were imported, while Jackson and Newton (2016) showed that 0.6 million MT of EU seafood processing by-products could be made available and channelled into the feed ingredients industry, resulting in less waste and greater efficiencies.

Table 2.1: European (EU and EEA) aquaculture fish species categorized by production volume, system and country (FAO, 2020).

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European species	Production EU+EEA (MT) (2010)	Production EU+EEA (MT) (2018)	Dominant production system / (fresh/salt)	Main European production countries/regions
Atlantic Salmon (*Salmo salar)*	1,111,032	1,474,765	Intensive marine	Norway/Scotland
Rainbow Trout (*Oncorhynchus mykiss*)	251,672	243,498	(semi)-intensive mostly in freshwater ponds	Italy, France, Denmark, Spain, Germany
Gilthead Sea bream (*Sparus aurata*)	93,075	91,964	(semi)-intensive marine	Mediterranean
European Seabass (*Dicentrarchus labrax*)	65,180	84,400	Extensive and semi-intensive , mostly marine cage	Mediterranean
Common Carp (*Cyprinus carpio*)	68,034	75,347	Extensive and intensive freshwater ponds	East-Europe
Turbot (*Scophthalmus maximus)*	9,608	8,395	Extensive and semi-intensive on-shore marine tanks and cages	Portugal, Spain, France, Germany, United Kingdom and Denmark

Availability and utilisation of by-products across producing countries is mixed, however, depending on trade in different commodities which meet local and international markets. While Norway already utilized 89% of the 336 thousand MT available by-products in 2013 (Olafsen et al., 2014), mixing of different by-products is still a common practice. More separation and appropriate strategic redirection of individual by-products could improve the overall value of them, and in doing so enhance sustainability. Stevens *et al.* (2018) calculated better separation of Scottish salmon by-products could double their value compared to current practices. Producers and processors in other countries also have similar opportunities to varying degrees. A continuing preference for purchase of whole fish in some locations (EC, 2018a, 2018b, 2018c, 2018d; Lasner et al., 2020) clearly reduces the possibility for centralised and efficient use of by-products.

Aquaculture by-product utilisation is subject to strict EU laws (eg. EC, 2009, 2011), as described in Deliverable 3.1. Nevertheless, the aquaculture industry shows interesting characteristics compared to capture fisheries in term of its capacity to combine grow-out, slaughter and processing (Little et al., 2018). The aquaculture industry could learn from strategies to use the whole animal, such as in the poultry industry, to improve its overall efficiency (Asche et al. 2018) and support innovation in the industry.

3. Method fish by-product balance and applications

The methods underpinning the by-product balance fall into 2 sections.

i. Data on EU aquaculture production and trade was downloaded from the FAO FishstatJ database (FAO, 2020). Production volumes for the GAIN key species was adjusted for trade in

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processed commodities which allowed by-product volumes to be estimated in each country. Fraction proportions for each by-product were taken from earlier GAIN work within Task 2.2.

ii. Data provided by CSIC from pilot scale work on hydrolysate, peptones and gelatines was used to determine potential volumes of these products from the available by-product quantities.

3.1 By-product fractions and commodity conversion factors.

The FAO provides a list of standardised conversion factors (Table 3.1) for different commodities. However, these conversion factors are averaged and not species specific. For this analysis we calculated species specific conversion factors based on lab analysis (Table 3.2) from Task 2.2 and compared these values with the FAO commodity factors to verify the results. The conversion factor to the initial live weight (LW) volume for each species is calculated as follows; 100/(100 - % of each by-product).

Table 3.1: Seafood commodity conversion factors. Data obtained from lab analysis T2.2 (Malcorps, 2020 in preparation).

FAO commodity groups (FAO, n.d.)	**Conversion factor (CF) based on data from lab analysis (*Malcorps, 2020* in preparation)**							**CF (FAO, n.d.)**
Conversion factor (CF) group for seafood commodities	**Form**	**Atlantic salmon**	**Rainbow Trout**	**European seabass**	**Gilthead sea bream**	**Common carp**	**Turbot**	
Frozen – whole	Whole	1	1	1	1	1	1	1
Dressed - gutted, head on (HOG)	Viscera removed	1.12	1.12	1.09	1.08	1.16	1.06	1.13
Dressed – gutted, head off	Head + Viscera removed	1.26	1.26	1.41	1.54	1.44	1.34	1.3
Fillets, steaks	Heads + Trimmings + Viscera removed	1.40	1.40	1.56	1.69	1.63	1.64	1.6
Skin on (fillets)	Heads + Frames + Trimmings + Viscera removed	1.64	1.64	1.92	2.13	1.92	2.23	2
Skin off	Heads + Frames + Trimmings + Skin + Viscera removed	1.78	1.78	2.22	2.50	2.31	3.28	2
Fish salted, wet or in brine	Heads + Viscera removed	1.26	1.26	1.41	1.54	1.44	1.34	1.5
Fish prepared or preserved, canned	Heads + Trimmings + Viscera removed	1.40	1.40	1.56	1.69	1.63	1.64	1.2
Smoked (skin off)	Heads + Frames + Trimmings + Skin + Viscera removed	1.78	1.78	2.22	2.50	2.31	3.28	1.92

Table 3.2 Share (%) of by-products and flesh yields from whole fish and by-products by mass (WW). Data obtained from lab analysis (Malcorps, 2020 in preparation).

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Species / fraction		BP fraction of whole %	Flesh yield %	BP fraction of whole fish %	Total edible yield from BP %	Total edible yield %
Atlantic Salmon*	**Heads**	9.94	37.22	43.84	20.95	77.11
	Frames	10.41	56.73			
	Trimmings	8.16	80.95			
	Skin (incl. scales)	4.73	100			
	Viscera	10.60	0			
	Fillet	56.16	100			
European Seabass	**Heads**	21.19	40.62	54.96	25.83	70.87
	Frames	11.92	41.78			
	Trimmings	7.11	73.64			
	Skin (incl. scales) **	7.00	100			
	Viscera	7.74	0			
	Fillet	45.04	100			
Gilt-head sea bream	**Heads**	27.55	48.94	59.86	31.21	71.35
	Frames	12.42	46.05			
	Trimmings	5.98	83.85			
	Skin (incl. scales) **	7.00	100			
	Viscera	6.91	0			
	Fillet	40.14	100			
Common carp	**Heads**	17.31	43.54	56.74	28.28	71.54
	Frames	9.26	90.00			
	Trimmings	7.98	45.99			
	Skin (incl. scales)	8.74	100			
	Viscera	13.45	0			
	Fillet	43.26	100			
Turbot	**Heads**	19.65	37.02	69.55	33.35	63.8
	Frames	16.38	49.44			
	Trimmings	13.46	27.33			
	Skin (incl. scales)	14.30	100			
	Viscera	5.76	0			
	Fillet	30.45	100			

**Share (%) of by-products and flesh yields from Atlantic salmon also applied to rainbow trout, as they are both from species group Salmonids.*
***Share (%) of skin for gilt-head seabream and European seabass is based on (Pateiro et al., 2020).*

Aquaculture production statistics in FishStatJ (FAO, 2020) are presented by country as tonnes live weight (LW). On the other hand, data on trade is given on a commodity basis (*e.g. "Atlantic and Dunabe salmons, fresh or chilled", "salmon fillets, frozen", "salmons, salted or in brine" etc.*) in tonnes. The by-product volumes that are available in different countries can be estimated from the trade in different seafood commodities combined with production volumes. This is followed up by multiplying the commodity weight by the conversion factor (Table 3.1) resulting in the LW volume, from which the commodity weight is subtracted to give the available by-product yield derived from the production of a specific commodity.

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3.2 Assumptions

Processing practices vary between species and location. For the purposes of this report, it is assumed that all aquaculture products are eviscerated at the point of slaughter in the country of production to produce Head-On-Gutted fish (HOG), which is defined as “primary processing”. Further processing of HOG fish may occur within the country of production or after export, to produce fillets, steaks, sides, etc, which is termed “secondary processing”. In some circumstances, the BP generated from secondary processing such as trimmings, heads etc may be further processed into pâtés, soups, ready meals etc, which is termed as “value addition”. The proportion of aquaculture supply that is completely (i.e both primary and secondary) processed in Europe (EU and EEA) is not possible to determine with accuracy from FAO data, although some estimations can be made using production and trade data together with other literature resources. For any single country and species, commodities and derived BP from exported commodities can be calculated as long as there is enough disaggregation within the commodity data. However, of the remaining production and any imports of HOG fish, the proportion that is secondary processed must be assumed. In Northern European countries (Table 3.3), where the preference is for fillets and more processed commodities, it is assumed that the left-over share is fully processed for most species, providing a maximum yield of BP for further utilisation. We assumed that Atlantic salmon is fully processed in all European import countries. However, we assumed European seabass, gilt-head seabream and turbot HOG imports into south European countries (Table 3.3) were not further processed, as consumers prefer to purchase whole fish over fillets, both for home consumption and in the service sector. Common carp is also usually sold whole and often live, therefore imports into east European countries was assumed mostly unprocessed. A full list of the assumptions on levels of processing is given in Table 3.4 and the differences become apparent in the balances given below. Commodities in FAO data sometimes include multiple aggregated species (e.g. “*salmon fillets fresh or chilled”, “salmonoids frozen”, “Carps, eels and snakeheads, fillets, fresh or chilled”*) and sometimes a mixture of wild and aquaculture production. Consequently, individual species data can be very challenging to disaggregate. Therefore, assumptions were made to determine the share of aquaculture vs fisheries and species composition within commodities, based on the proportion of production of those different species. For example, 85% of salmon commodities traded in the UK were estimated to come from UK farmed salmon, which was factored into the balance. Regional processing practices are given in Table 3.4. The assumptions used for processing practices are generalised according to indications given in the literature and from stakeholders interviewed as part of the value chain analysis in WP3. For example, rainbow trout processing is averaged at 60% across Europe for simplicity, although most of it occurs in northern countries associated with production of large sized fish.

Table 3.3; Northern and Southern European countries included within the by-product balance

Northern Europe	Southern Europe
Belgium	France
Bulgaria	Italy
Czech Republic	Spain
Denmark	Portugal
Finland	Croatia
Germany	Greece
Hungary	Malta
Ireland	
Lithuania	
Netherlands	
Norway	
Poland	
Romania	
Sweden	
UK	

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Table 3.4; Quantity of EU and Norway aquaculture production accounted for in model and assumption of level of processing.

Species	Aquaculture production accounted for %	Processing % in Northern Europe	Processing share in Southern Europe
Atlantic salmon	99	100*	100*
Rainbow trout	96	60	60
European seabass	97	100	5
Gilthead sea bream	95	100	5
Common carp	98	15	15
Turbot	100	5	5

* Filleted fish is assumed skin-on, whereas smoked fish is skin-off

3.3 Aquaculture production, trade, and derived by-products

Seafood processing is highly diverse, often geographically displaced from production centres and recorded inconsistently, adding complexity to how the flows are calculated. For example, although Norwegian salmon is all slaughtered and "primary processed" in-country to produce HOG Atlantic salmon with viscera as a BP, only some of the HOG is further processed to fillets or other commodities in Norway. A larger proportion of HOG is exported for further processing across Europe, particularly Eastern Europe such as Poland, which is a major "secondary processing" centre, generating a large proportion of by-products. Therefore, although Norway is the largest producer of salmon, it is not the largest centre for potential value addition to by-products

3.4 Example of By-product balance applied to the UK salmon industry

A detailed example of by-products generated from UK salmon production and trade is given in Figure 3.1, Tables 3.5 to 3.8. The methodology shown in the following section was applied to all species, following the assumptions laid out in section 3.2.

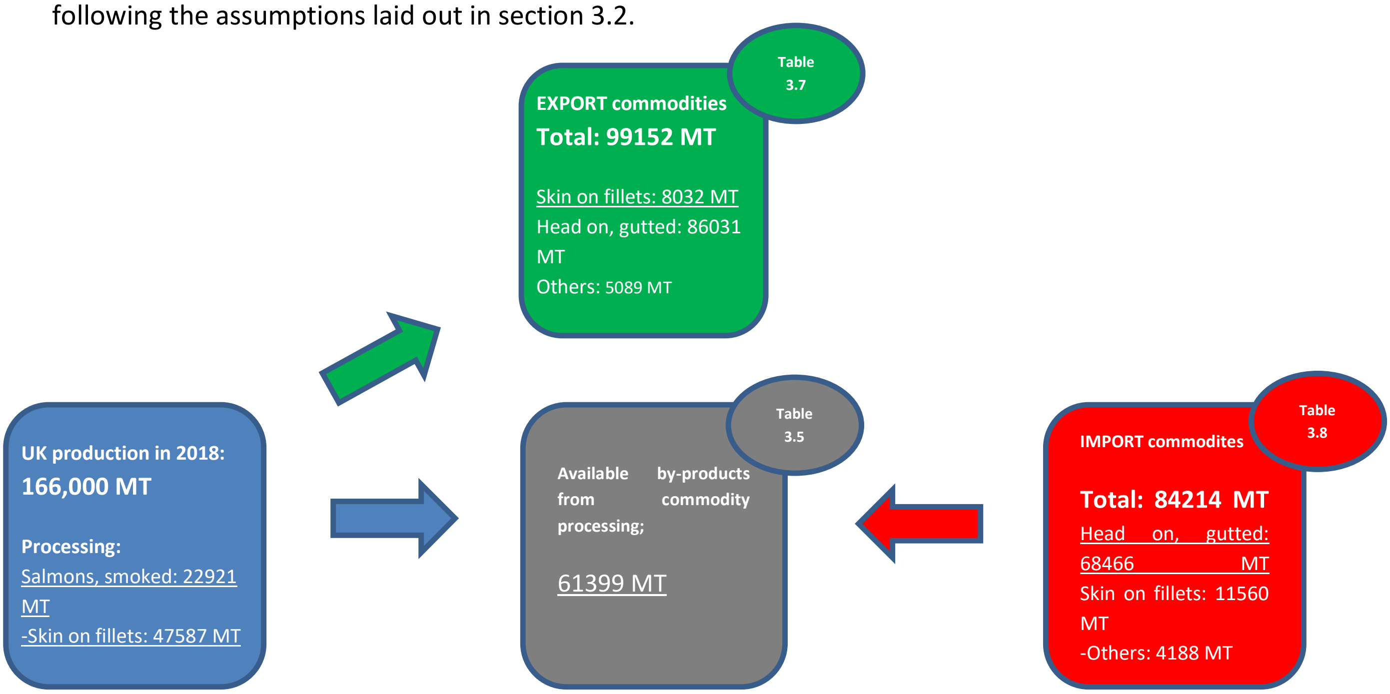

Figure 3.1 Flowchart UK Atlantic salmon, production, trade and derived by-products.

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Table 3.5: Available by-product volumes from production, import and export associated processing 2018.

Available by-products from commodities	Aquaculture production*	Import**	Export***	Total BP generated
Heads	7426	5751	1520	14697
Frames	7784	6028	1593	15405
Trimmings	6099	4723	1247	12069
Skin	1633	-	-	1633
Viscera	17595	-	-	17595
Total	**40537**	**16502**	**4360**	61399

** By-products from UK production not traded but assumed to be fully processed.*
*** Resulting from processing of HOG salmon imported to UK.*
**** Resulting from processing of fish in the UK to produce fillets and other products for export.*

The United Kingdom produced 166000 MT, live weight (LW) of Atlantic salmon in 2018. Due to the nature of FAO reporting, all calculations are made in reference to LW production, whereas in reality, all of the production is primary processed to HOG and then either further processed or exported. Therefore, care must be taken when converting between LW and HOG that the volumes of viscera are not double counted, especially when dealing with traded products. The steps in the calculation are as follows:

- i) Calculate the quantity of viscera generated from primary processing by applying the conversion factor (CF) for HOG to UK production.
- ii) Calculate the quantity of by-products generated from secondary processing of commodities exported from the UK according to CFs
- iii) Calculate the quantity of by-products generated from imported commodities to the UK (HOG) according to CFs
- iv) Calculate by-products from secondary processing for UK domestic consumption according to CFs and assumptions from literature (and VCA work)
- v) Make adjustments for viscera not produced within the UK from imports and for double counting errors associated with LW/HOG CFs.
- vi) Calculate extra by-product potential if processing was optimised

For example, for UK Atlantic salmon, domestic processing by-products were calculated as a proportion of LW according to the CFs to produce smoked salmon, fillets and other commodities (Table 3.1). The resulting by-product volume from processing was divided between viscera, heads, trimmings, frames and skin as shown in Table 3.5. Imports of “whole fish” (HOG) were assumed to be fully processed into commodities and by-products, calculated according to their conversion factors and various fractions given in Table 3.6. The viscera from imported HOG remains in the country of primary processing/ production whereas secondary processed commodities exported from the UK have associated volumes of by-products which are left within the UK. However, the CFs for commodities processed from imported fish are based on LW and not HOG. Therefore, after all the commodities were calculated, including post trade, an adjustment, was made to prevent double counting of viscera volumes from traded products. The extra potential by-product volumes are estimated from the difference between the extrapolated volumes and those if all EU and Norway processing was at 100%. The traded

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commodities for Atlantic salmon according to the FishStatJ database (FAO, 2020) are shown in Tables 3.7 and 3.8. The different commodities traded per species and selected countries based on production, import and export are listed in Annex 1.

Table 3.6: By-product fractions from UK smoked salmon production (2018) as a proportion of LW and of total by-product.

Origin – By-products from processed production (smoked salmon)	Fraction of Live weight	Fraction of total by-product	MT in 2018
Heads	10%	23%	3447
Frames	10%	24%	3613
Trimmings	8%	19%	2831
Skin (incl. scales)	5%	11%	1641
Viscera	11%	24%	4326
Total	**44%**	**100%**	**15858**

Table 3.7; Conversion factors, export commodity weights and extrapolated live weight equivalents for Atlantic salmon.

Processing	CF	Commodity (Commodity)	Commodity weight (2018)	Live weight (2018)
Gutted, head on (HOG)	**1.12**	**Atlantic and Danube salmons, fresh or chilled**	**74816**	**83686**
Gutted, head on (HOG)	**1.12**	**Atlantic salmon and Danube salmon, frozen**	**6158**	**6888**
Skin on	1.64	Salmon fillets, dried, salted or in brine	113	186
Skin on	1.64	Salmon fillets, fresh or chilled	6595	10831
Skin on	1.64	Salmon fillets, frozen	1324	2174
Fish prepared or preserved, canned	1.40	Salmon minced, prepared or preserved	156	219
Gutted, head on (HOG)	**1.12**	**Salmon nei, not minced, prepared or preserved**	**1394**	**1559**
Gutted, head on (HOG)	**1.12**	**Salmonoids meat, fresh or chilled, nei**	**226**	**253**
Fish prepared or preserved, canned	**1.40**	**Salmonoids nei, minced, prepared or preserved**	**6**	**8**
Gutted, head on (HOG)	**1.12**	**Salmonoids, fresh or chilled, nei**	**1978**	**2213**
Gutted, head on (HOG)	**1.12**	**Salmonoids, frozen**	**1422**	**1591**
Gutted, head on (HOG)	**1.12**	**Salmonoids, not minced, prepared or preserved**	**37**	**41**
Whole fish	1.00	Salmons, live	11	11
Smoked	1.78	Salmons, smoked	4916	8753

Note: CFs presented here are rounded to 2 decimal points but those used to calculate the model were not rounded

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Results were verified by calculating the share of each by-product (MT) as part of the total aquaculture production (MT) (Table 3.4). This share was then compared with all the by-product fractions obtained during laboratory work as part of Task 2.2. (Table 3.2).

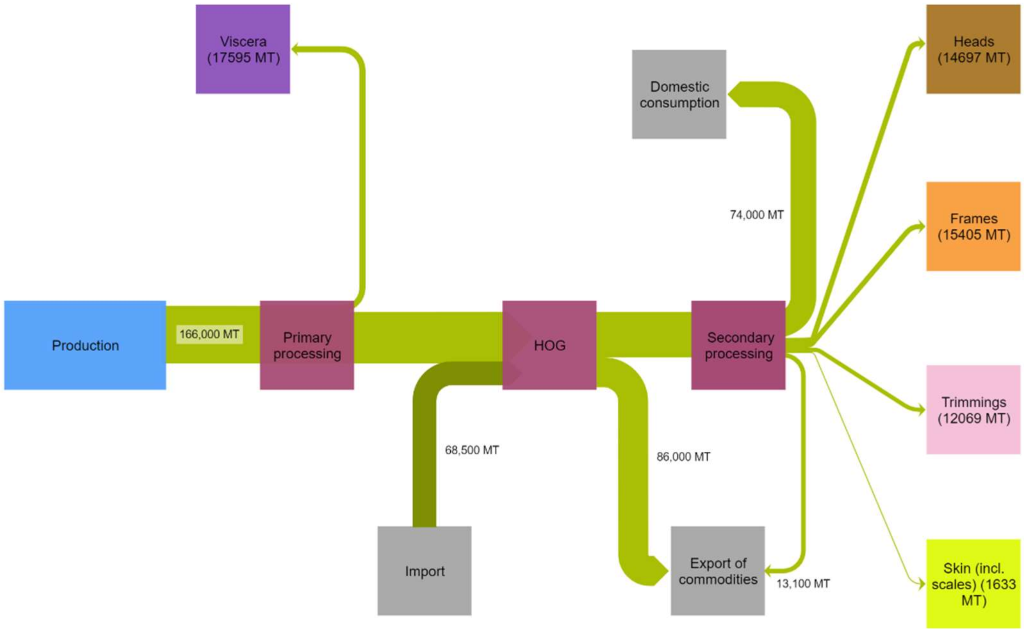

Figure 3.2 Sankey diagram showing material flows of coproducts from UK farmed salmon production and processing

Table 3.8: Volume of UK salmon import commodities

Processing	**Commodity (Commodity)**	**MT in 2018**
Gutted, head on (HOG)	**Atlantic and Danube salmons, fresh or chilled**	**57543**
Gutted, head on (HOG)	**Atlantic salmon and Danube salmon, frozen**	**178**
Skin on	Salmon fillets, fresh or chilled	3568
Skin on	Salmon fillets, frozen	7992
Fish prepared or preserved, canned	Salmon minced, prepared or preserved	636
Gutted, head on (HOG)	**Salmon nei, not minced, prepared or preserved**	**10621**
Gutted, head on (HOG)	**Salmonoids, fresh or chilled, nei**	**14**
Gutted, head on (HOG)	**Salmonoids, frozen**	**110**
	Salmons, salted or in brine	344
Smoked	Salmons, smoked	3208

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In the case of the UK total salmon, the assumption was that there was 100% processing across the EU and no further potential for increasing by-product volumes within the EU. However, aquaculture production was 166000 MT in 2018, while available by-products volumes from current processing activities were estimated at 61399 MT, representing a share of 37%. Around 4% availability could be added from deskinning fillets and non-EU/ Norway trade accounts for the other remaining by-product fractions, equalling the expected 44% from Table 3.2.

3.5 By-product processing volumes and applications

The available by-product volumes were assessed for the quantities of flesh that could be obtained for human consumption (assuming total efficiency of removal) and their application in GAIN innovations in Tasks 2.2, e.g. fish protein hydrolysate (FPH) and peptones, amongst others. The flesh yields are given in Table 3.2 whereas yields of GAIN innovations are in Annex 2. Some products were produced from a single by-product fraction, e.g. sea bass heads, while others were produced from a mix of by-products such as frames and trimmings, but not in the proportions generated from whole fish. In that case, one of the by-products becomes a limiting factor for the process. Although, the remaining by-product could be applied elsewhere, this was not calculated because of the many different options. For example; Atlantic salmon frames and trimmings are produced in volumes of 16537 MT and 12956 MT respectively. The salmon FPH production process applied in GAIN T2.2 used a mix of 80% frames and 20% trimmings leaving a remainder of 8822 MT salmon trimmings from the process.

4. Results fish by-product balance

4.1 Processing, business as usual and additional potential

Available by-product volumes are dependent on the level of processing and fish production volumes, which differs according to species, in combination with the fraction of each fish by-product in relation to its total body weight. Processing potential indicates the additional potential that can be realized if full processing is implemented. Earlier results within Task 2.2 indicated that Atlantic salmon have the largest fillet yield of the species studied, at 56.16% down to turbot with only 30.45% fillet yield.

Figure 4.1 indicates potential to increase the level of processing and hence, the availability of by-products. Salmon showed the highest level of processing, with only limited extra volumes of heads, frames, trimmings and viscera possible, linked to non-EU traded products (Figure 4.1). More skin could be made available by an increase in smoked salmon production compared to skin-on fillet commodities. Consumer preference for skin on or off was not assessed. Rainbow trout was assumed to have similar fillet yields to Atlantic salmon. Availability of viscera was at full potential for all species except carp because it is the only species sold live, while skin showed greatest potential for separation, assuming consumer preferences for skin-off fillets.

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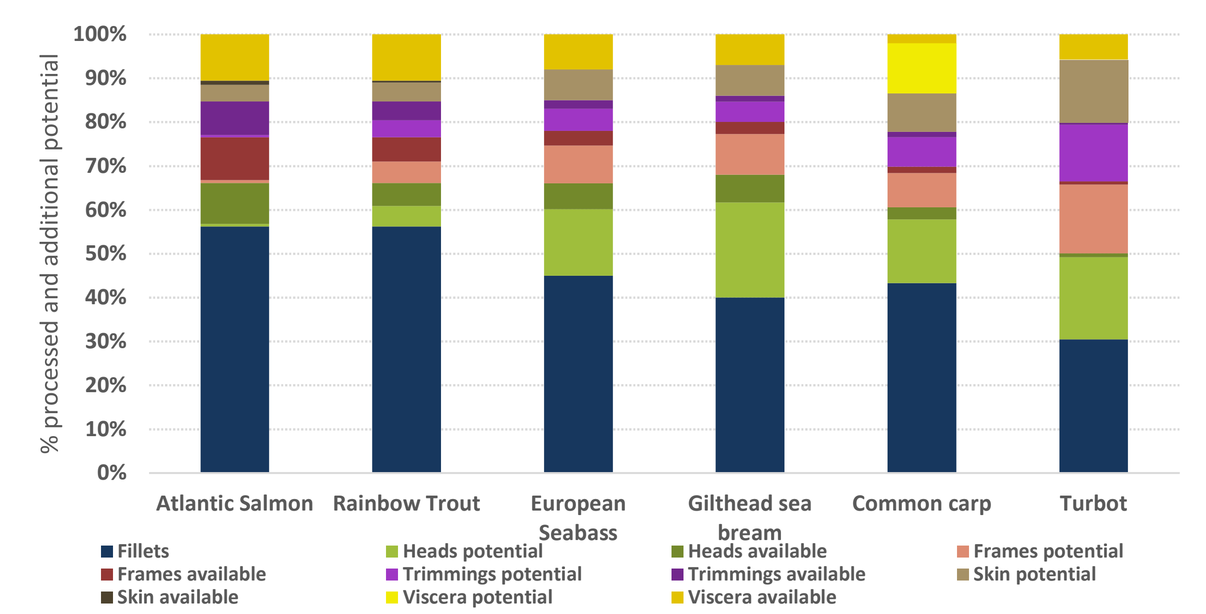

Figure 4.1: Available by-products and potential additional availability from processing for major European aquaculture species in 2018.

However, consumer preferences for whole fish (HOG) in the south of Europe was assumed to result in low levels of secondary processing of seabass, sea bream and turbot, and therefore lower volumes of by-products of those species were available for strategic utilization. Increase in processing could result in an increase of total yield to live weight ranging between 0.64% and 21.62% for heads, 0.67% and 15.65% for frames, 0.52% and 12.85% for trimmings, 3.80% and 14.30% for skin and 0% up to 11.44% for viscera (Figure 4.1).

4.2 Available by-product volumes based on business as usual processing and trade

The following section highlights the main results from the by-product balance and the potential feed ingredients that could be produced from this supply.

4.2.1 Atlantic salmon (*Salmo salar*)

There are large volumes of viscera from primary processing at the point of slaughter within Norway, but secondary processing is decentralised to countries with large fish processing industries such as Poland and Lithuania that are not large producers of salmon (Figure 4.2). This explains why there is no viscera available in Poland (Denmark, France and Germany), but are large volumes of heads, frames and trimmings. Poland also shows the largest proportion of fish skin availability from smoked salmon processing. The United Kingdom imports around the same volume of HOG salmon as it exports, so the proportions of by-products are close to those given in Table3.5.

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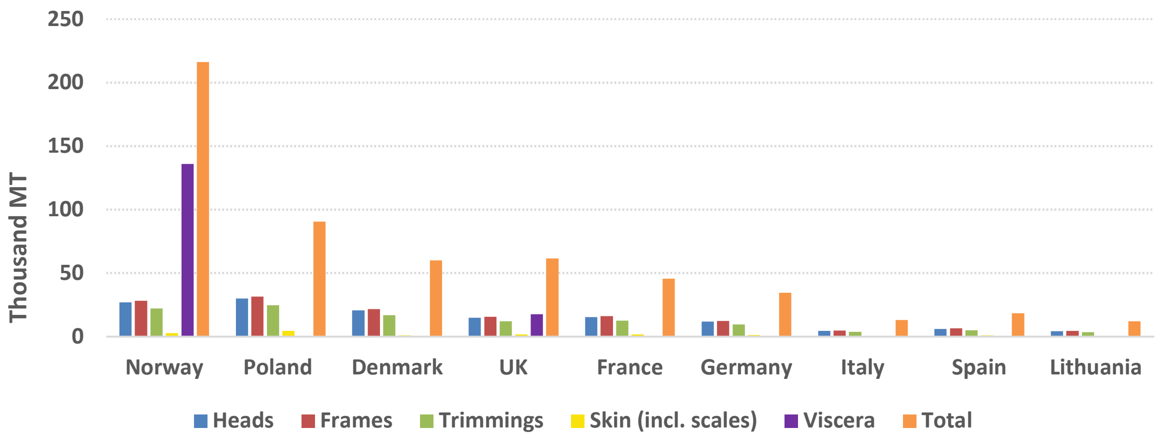

Figure 4.2.: Atlantic salmon by-products by country (2018)

4.2.2 Rainbow trout

Rainbow trout is produced across Europe. Norway was the largest producer with 68216 MT in 2018. resulting in the largest proportion of viscera from primary processing (Figure 4.3), followed by Italy, Denmark and France. However, while Norway is the largest producer, France has a larger volume of secondary processing by-product volume available due to the processing of HOG imports. The volumes of rainbow trout skin in Denmark and France are the direct result of smoking in those countries.

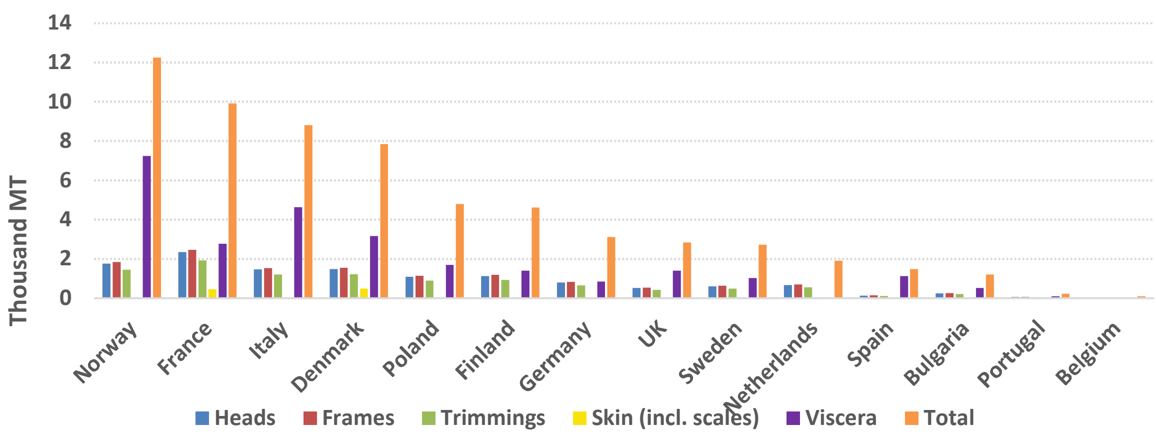

Figure 4.3: Rainbow trout by-products by country (2018)

4.2.3 European seabass

Greece is the largest producer of European seabass in the EU, followed up by Spain resulting in the highest viscera volumes from primary processing (Figure 4.4), but the preference for consuming whole (gutted) fish in southern European countries means there is little or no secondary processing by-products from domestic processing. Conversely, exports of HOG seabass to northern European countries are assumed to be fully processed to fillets resulting in their respective available by-products volumes. However, the FAO data contains no reference to seabass fillet exports which must be aggregated within another commodity, which was not possible to determine. Therefore, there are no

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secondary by-products resulting from filleting in Southern European countries for export, according to the model.

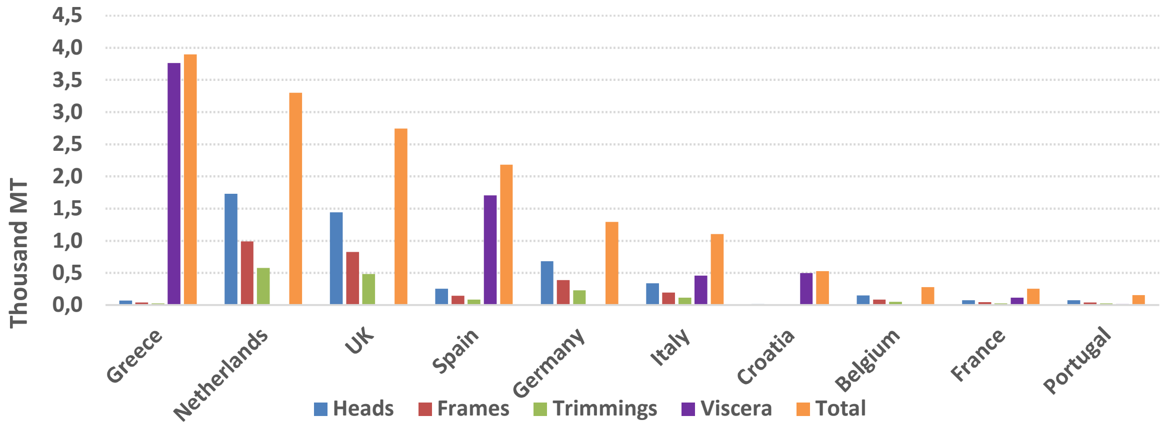

Figure 4.4: European seabass by-products by country (2018)

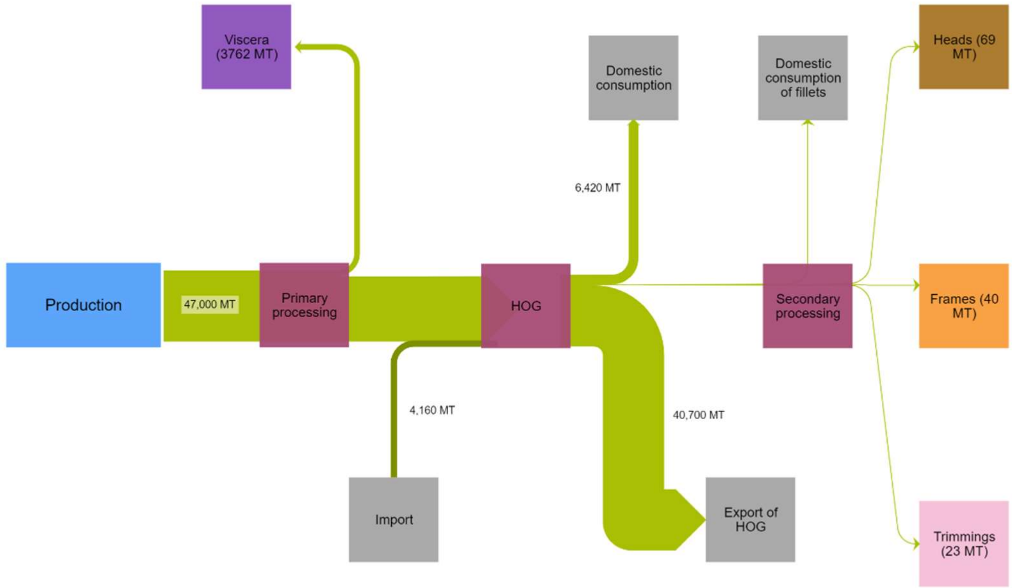

Figure 4.5 Sankey diagram showing material flows from Greek seabass production and processing

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4.2.4 Gilthead sea bream

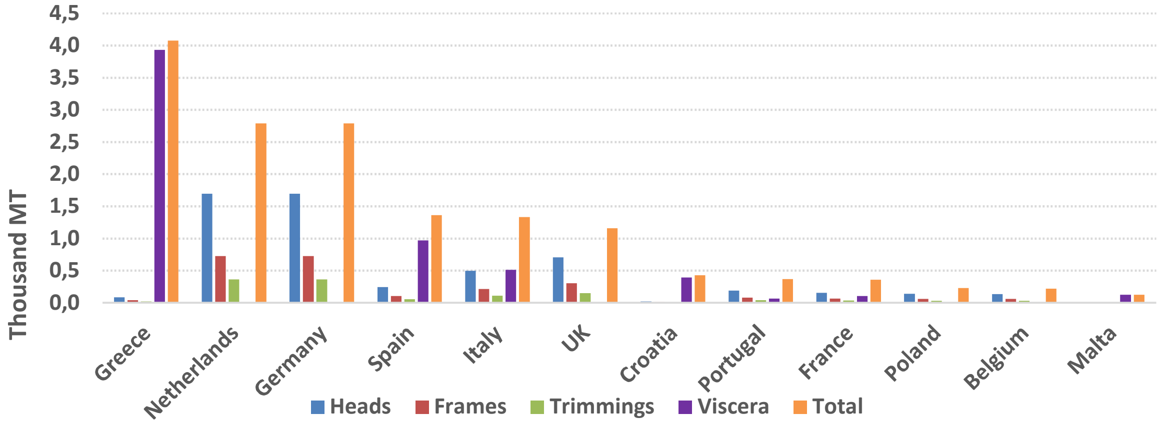

Figure 4.6: Gilt-head sea bream by-products by country (2018)

Greece is the largest producer of sea bream in Europe, leading to high volumes of viscera from primary processing. Greek exports are higher than production, explained by its significant import volumes (particularly from Turkey), that are re-exported with no further processing. However, similar to seabass, producing countries have little secondary processing, so most heads, frames and trimmings are generated within importing countries where consumers prefer fillets according to the assumptions in the model.

4.2.5 Common carp

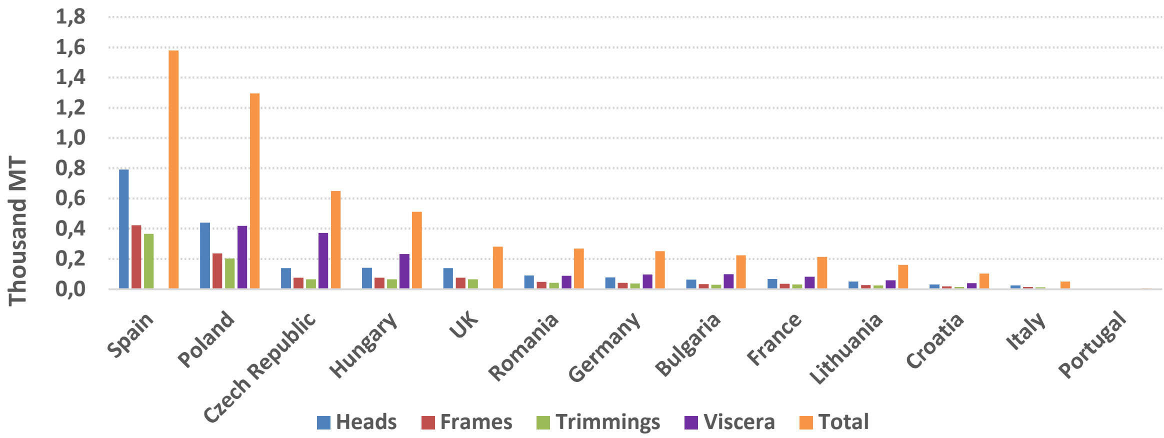

Figure 4.7: Common carp by-products by-country (2018)

Total common carp production was 74554 MT in the EU in 2018, but processing is not a common practice due to consumer preferences for whole fish (Figure 4.7), even across northern Europe, where sales are often to satisfy eastern European diaspora. Preference for live fish in producer countries explains the relatively low available volumes of viscera. However, there is a small but growing movement towards more processed commodities, away from live sales due to welfare concerns amongst some consumers. According to FAO (2020), 2796 MT of carp fillets were exported from Spain in 2018, from which the by-product supply is extrapolated, whereas Poland exports less processed

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products and most of the heads, frames and trimmings are extrapolated from domestic consumption, assumed to be secondary processed at 15% according to Table 3.4.

4.2.6 Turbot

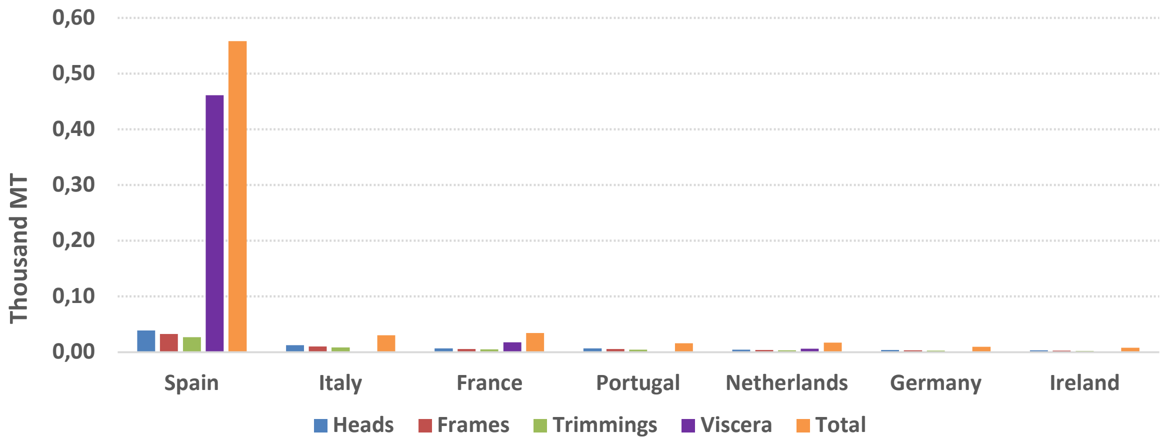

Figure 4.8: MT turbot by-products by country (2018)

Turbot is a niche species with low production volumes in the south of Europe. The majority is sold whole, sometimes without gutting and consequently by-product volumes are very low (Figure 4.8). The available by-product volumes in northern European countries are related to the imports of HOG turbot, from which small volumes are processed into fillets. It is assumed that much of the imports are unprocessed, going mainly to service sectors rather than retail.

5. Value addition potential from EU aquaculture by-products

Available by-product volumes per species and country were calculated based on the yields of FPH, peptones and gelatines from data provided by CSIC. The quality of the products, value and economic implications of redirecting by-products are not discussed in detail in this deliverable because those aspects will be investigated in deliverable 4.2.

5.1 Flesh recovery for direct human consumption

Table3.2 shows the flesh yields which can be obtained from individual by-products according to work conducted by UoS as part of Task 2.2. Whether flesh recovery is a feasible option from by-products is likely to be determined by the quantity of by-products, their quality, and consistency of production. Skin is assumed to be 100% edible, whereas viscera are assumed to have no edible fraction. How flesh could be obtained from by-products is open to debate according to processing practices and consumption patterns. Where, fish is bought whole and prepared within the home, it may be argued that all of the edible parts may be consumed directly, although this may be considered unlikely if some is particularly difficult to separate, such as in heads of some of the smaller fish species. The bones, eyes and other soft tissues are also not likely to be consumed, whereas if directed to marine ingredients, more nutrition and value could perhaps be obtained. Mechanised flesh recovery from processed by-

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products may also be challenging, especially from smaller species. Typically, recovered flesh may be used for value added products. Processed salmon heads are commonly exported to Vietnam and other East Asia countries for use in their local cuisine, but heads of other species are not, perhaps due to their smaller size as well as their availability. Processing can, in some circumstance, allow for better use of by-product resources, but in other circumstances more direct flesh consumption may be achieved through leaving the fish whole. The relative efficiencies have not been assessed, but it is likely that with better separation and targeting of by-product resources, more efficiency can be achieved as discussed by Stevens et al (2018). The following graphs show the total edible flesh yields from each by-product fraction in each country.

5.1.1 Atlantic salmon

Atlantic salmon has the highest fillet yield of any farmed European fish at around 56%. There is also a lot of capacity across Europe to increase the flesh yield from by-products at over 220 thousand tonnes, outstripping UK production. However, much of this is already done through reclamation from trimmings, export of heads and to a lesser extent, frames. Nevertheless, Stevens *et al* (2018) estimated that around 50% of by-products remain mixed and are destined for rendering and hydrolysis in the marine ingredients industry, which could be separated and used for human consumption with potential value addition.

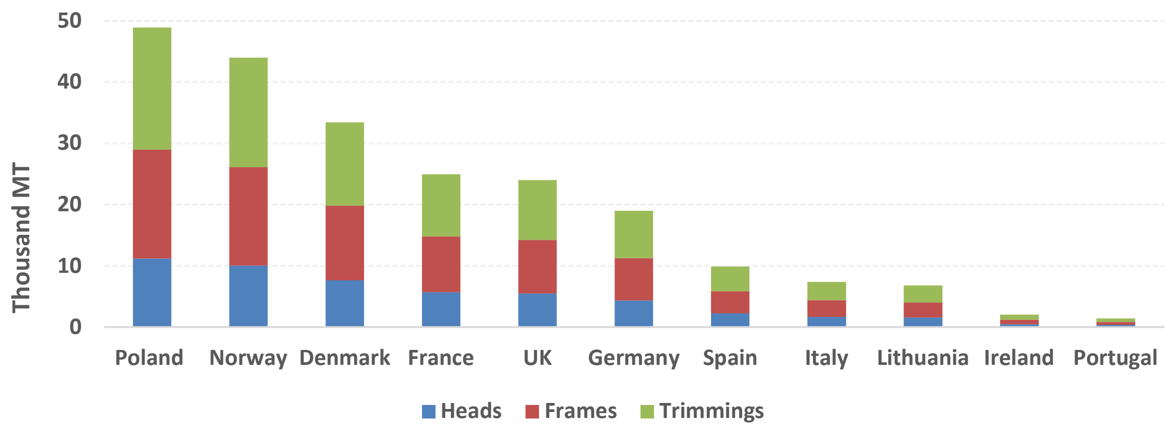

Figure 5.1 Potential flesh yield from EEA Salmon processing by-products

5.1.2 Rainbow trout

Despite being a widely produced species, the potential for more flesh yield from Rainbow trout is quite low, owing to low processing levels and sale of HOG fish. The major processors in France, Norway and Italy have the highest potential for reclaiming flesh although processing is much more geographically dispersed, with several countries producing modest quantities of by-products. However, feasibility of reclamation may depend on the size of fish. Trout are produced in a much wider range of sizes compared to salmon, from 500 g to several kilos and smaller fish may be too difficult to obtain meaningful quantities of flesh and better directed to marine ingredients production. According to EUMOFA (2017), around 40% of trout production is large sized and processed to fillets and other

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products, with the majority of production occurring in Northern European countries. However, the model assumed 60% processing across all countries because of problems disaggregating the data.

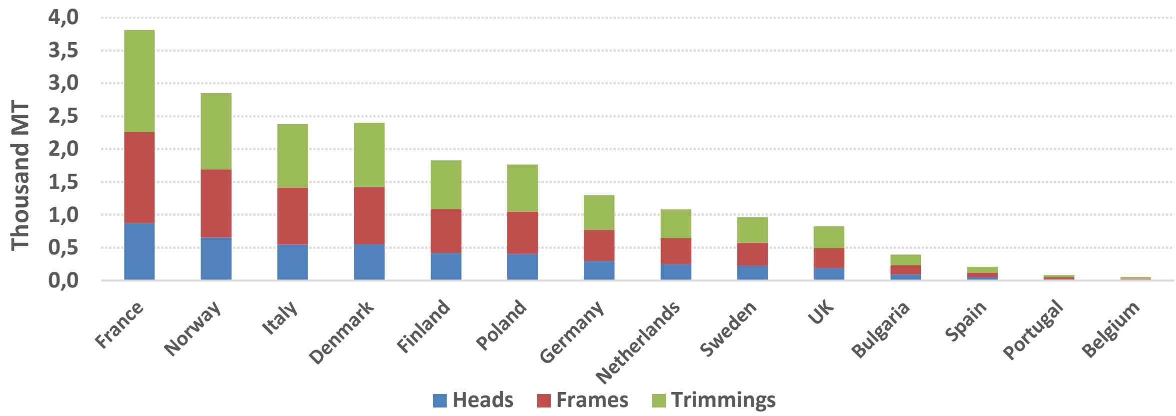

Figure 5.2 Potential flesh yield from EEA rainbow trout processing by-products

5.1.3 Seabass and seabream

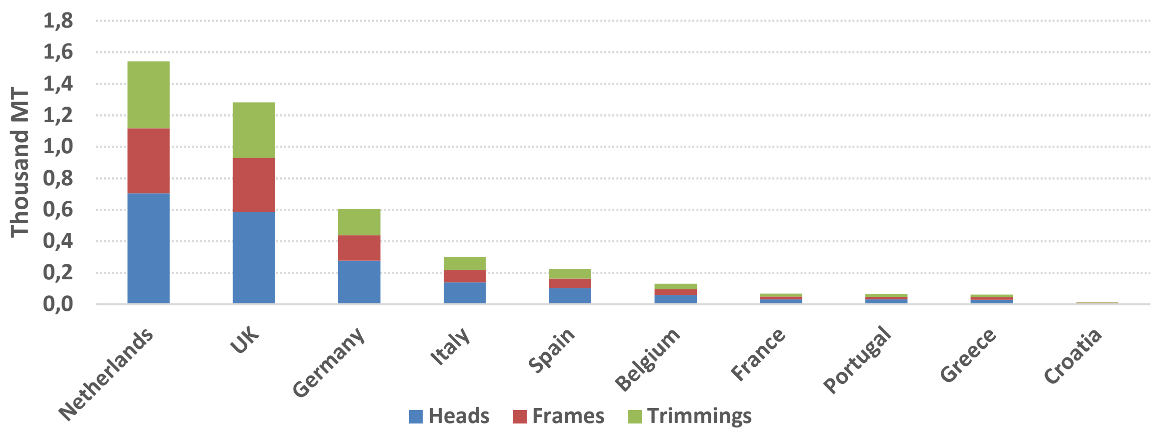

Figure 5.3 Potential flesh yield from EEA sea bass production and processing

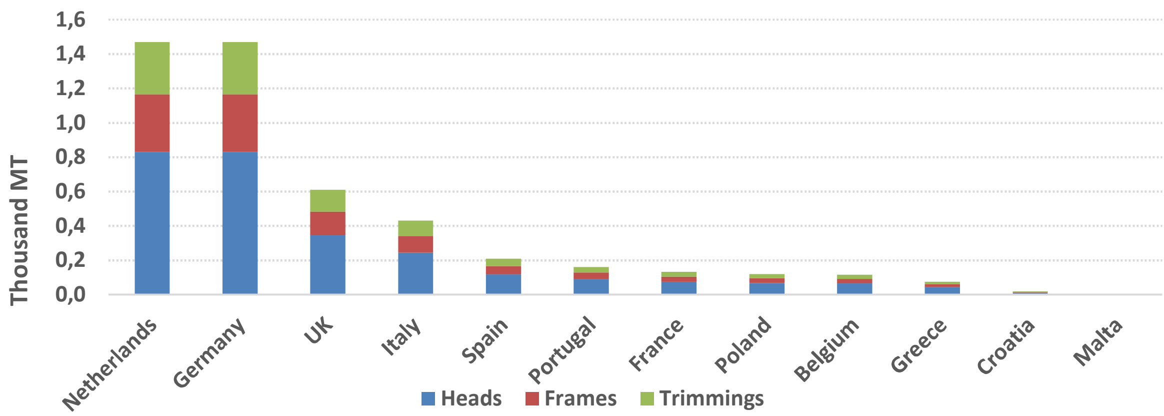

Figure 5.4 Potential flesh yield from EEA sea bream processing by-product

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Limited potential for extra flesh production from seabass is due to low secondary processing in Europe. The biggest potential, according to our model is in Northern European countries that secondary process imported HOG. However, the volumes are very small compared to salmon. Further processing in southern European exporting countries would increase the available by-products for flesh recovery, but whether this would result in more of the fish being consumed over that available from whole fish, is open to debate. A similar story is found with sea bream which has similar processing patterns to sea bass but with Germany being a more important importer than for sea bass.

5.1.4 Common carp

Common carp is not heavily processed in Europe and consequently there are few available by-products for flesh recovery. Low by-product volumes and comparatively lower perceived quality than some other species is unlikely to make recovery feasible with current processing activities. However, sale of whole carp provides the opportunity for households to maximise edible yields. Spanish carp by-products are due to their small export volumes as explained above.

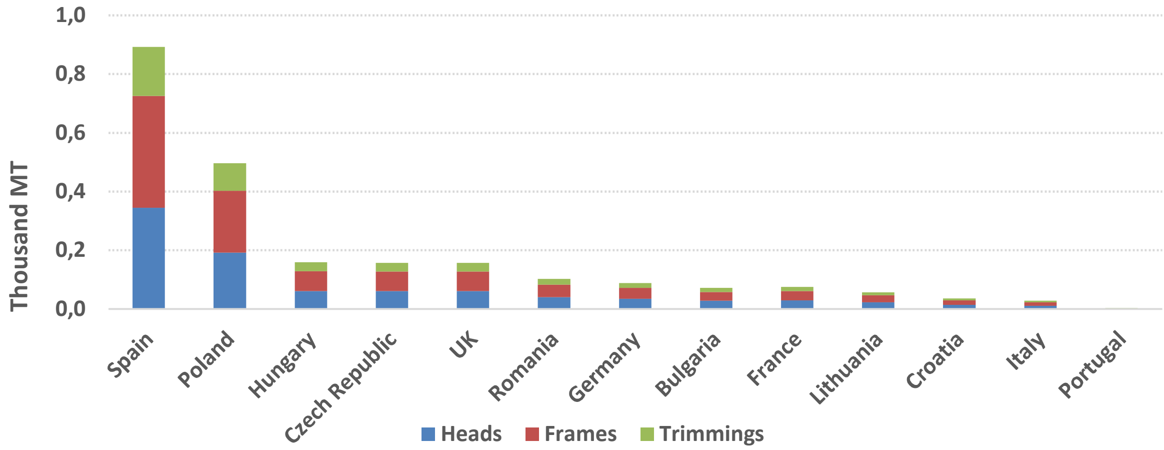

Figure 5.5 Potential flesh yield from EEA carp processing by-product

5.1.5 Turbot

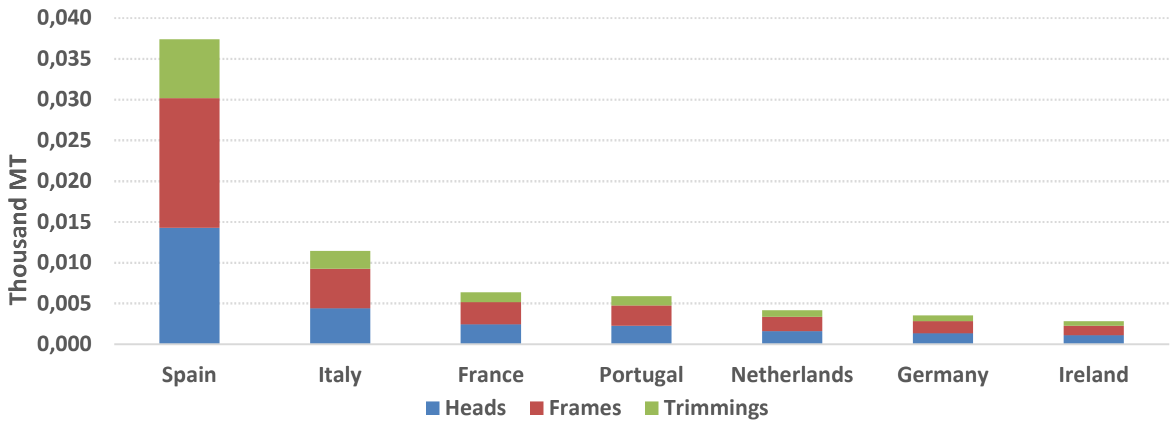

Figure 5.6 Potential flesh yield from EEA turbot processing by-product

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As a niche species, the availability of turbot by-products is very low. Most potential is from Spain, that could produce a few hundred tonnes of recovered flesh. It is likely that with such low volumes, more value could be obtained rendering into marine ingredients, perhaps mixed with other species.

5.2 Fish protein hydrolysates and peptones

Fish protein hydrolysate (FPH), a mixture of low molecular weight protein and peptides can readily be made from fish by-products. This process is described in the flowchart (Figure 5.1) starting first with crushing of the by-products followed by a range of chemical and enzymatic treatments with heat and pressure. Liquid hydrolysates, oil and wet/dry bones (which are considered waste) are filtered and separated by centrifuge, followed by additional treatments, such as filtration, vacuum-evaporation and spray drying to give concentrated and dry FPH.

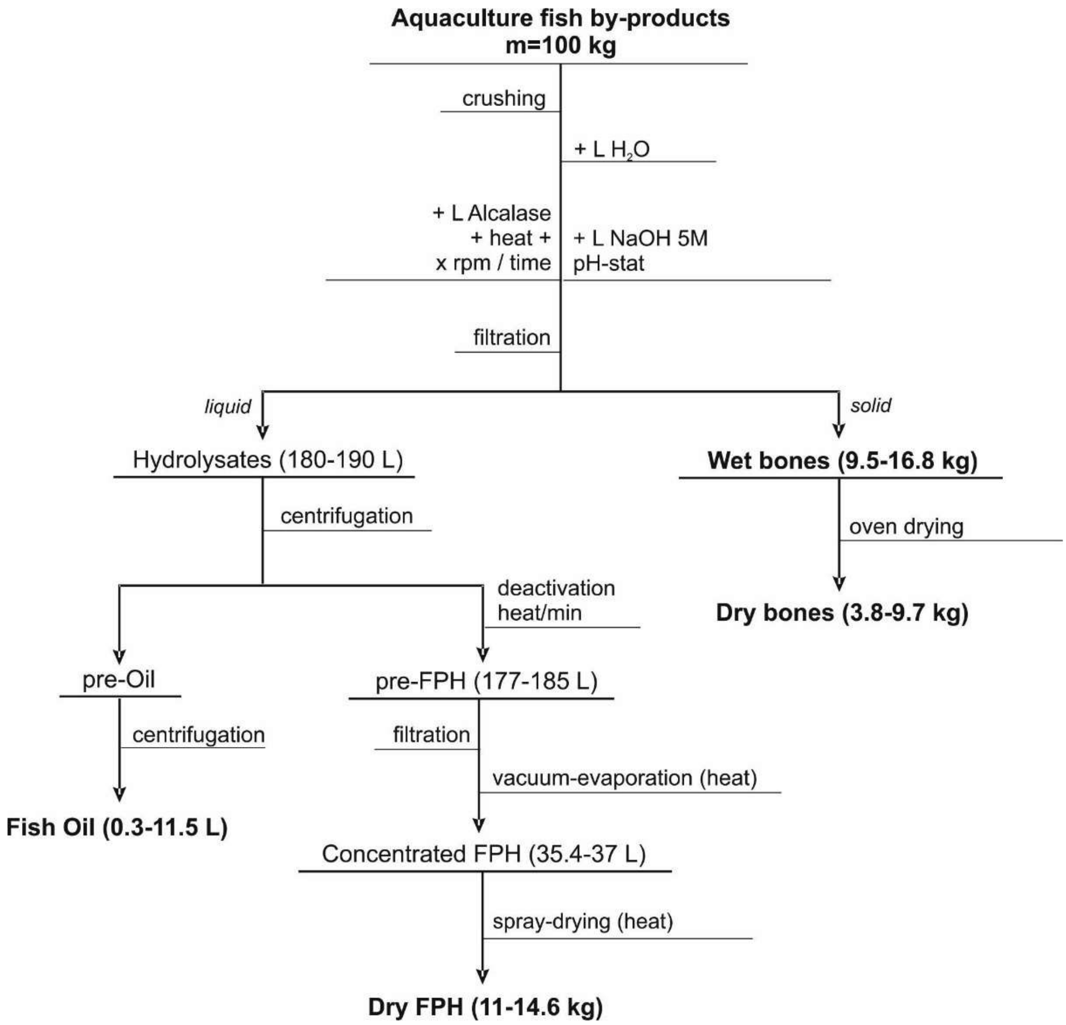

Figure 5.7 Flow chart of FPH production (provided by CSIC)

Peptones are soluble proteins formed in the early stage of protein hydrolysis. The by-products are ground and then may be subjected to two processes to produce different types of peptone; thermal or FPH peptone. For thermal peptone, water is added to the by-product mix and subjected to

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autoclaving, filtration and centrifugation, resulting in solids, bones, oil and the thermal peptone (TP). The second process includes the adding of water and Alcalase followed by filtration, resulting in bones and raw hydrolysate. The latter is then centrifuged resulting in the separation of oil and pre-peptone which is autoclaved and centrifuged to produce FPH peptone (FP), which may then be combined with the thermal peptone originating from the first process.

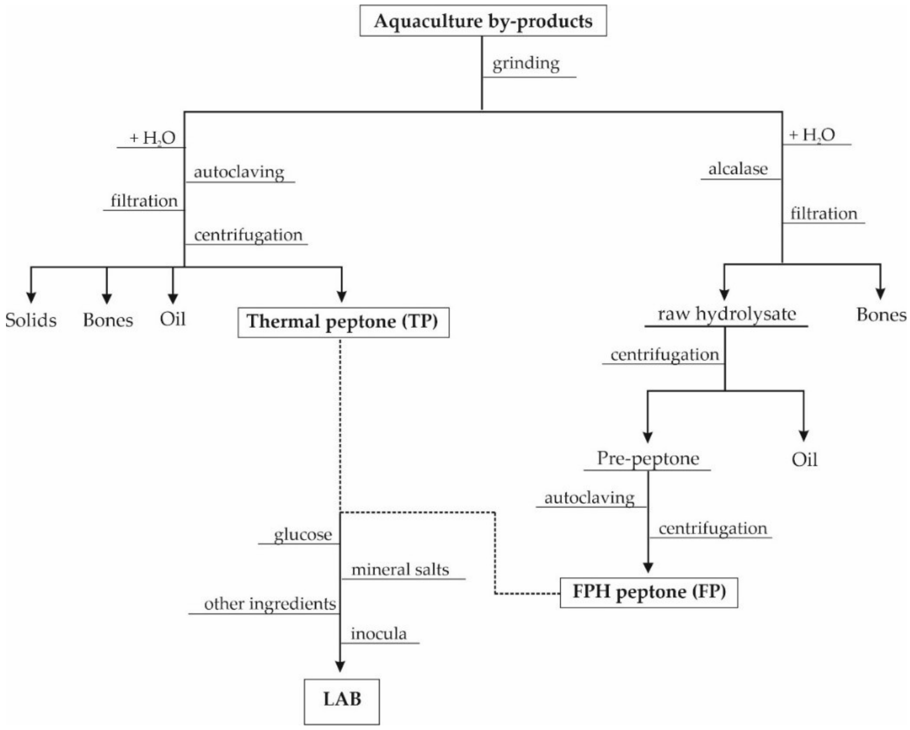

Figure 5.8 flow chart of peptone production used for producing lactic acid bacterium (LAB) (provided by CSIC)

5.2.1 FPH and peptones from Atlantic salmon by-products

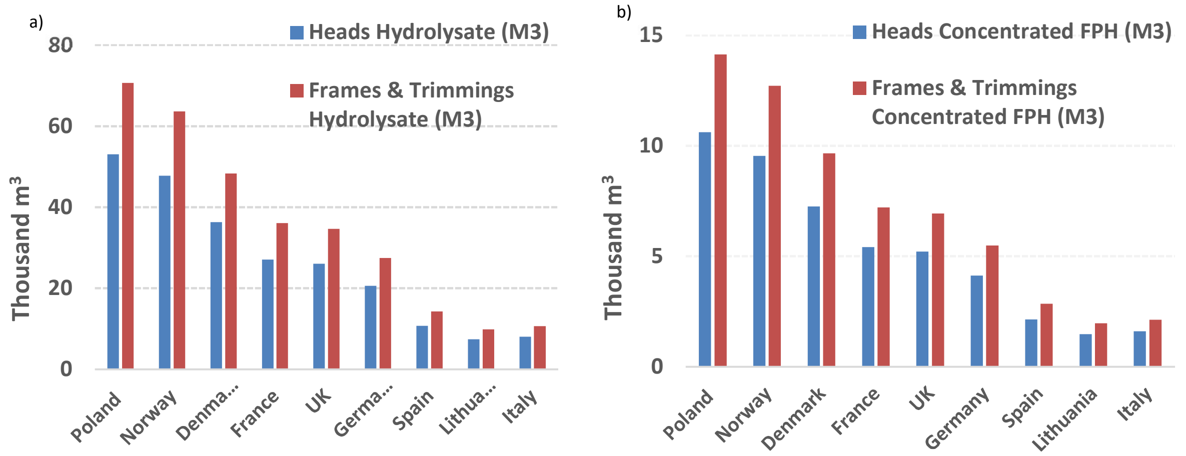

Figure 5.9 a) Liquid hydrolysate b) concentrated hydrolysate production from Atlantic salmon heads, frames and trimmings

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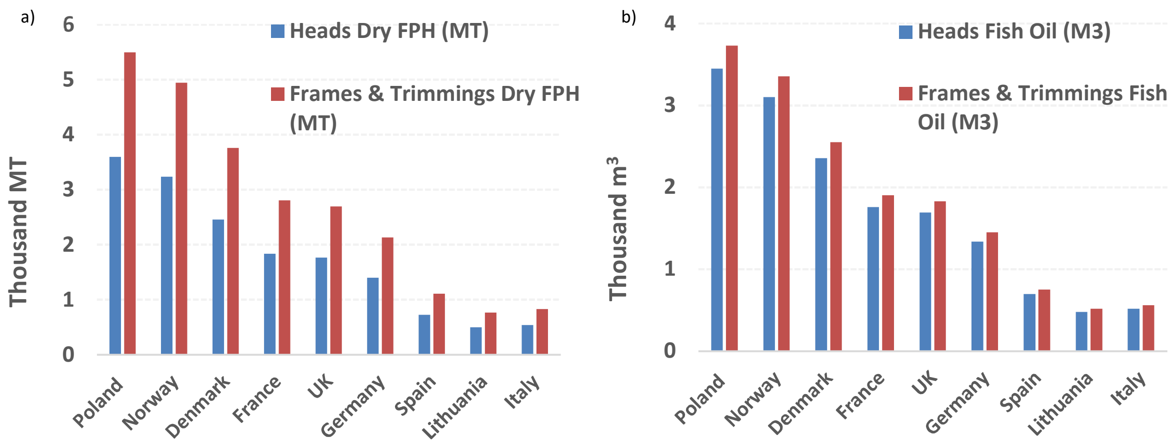

Figure 5.10: a) Dry FPH b) Fish oil from heads, frames & trimmings from Atlantic salmon heads, frames and trimmings FPH production

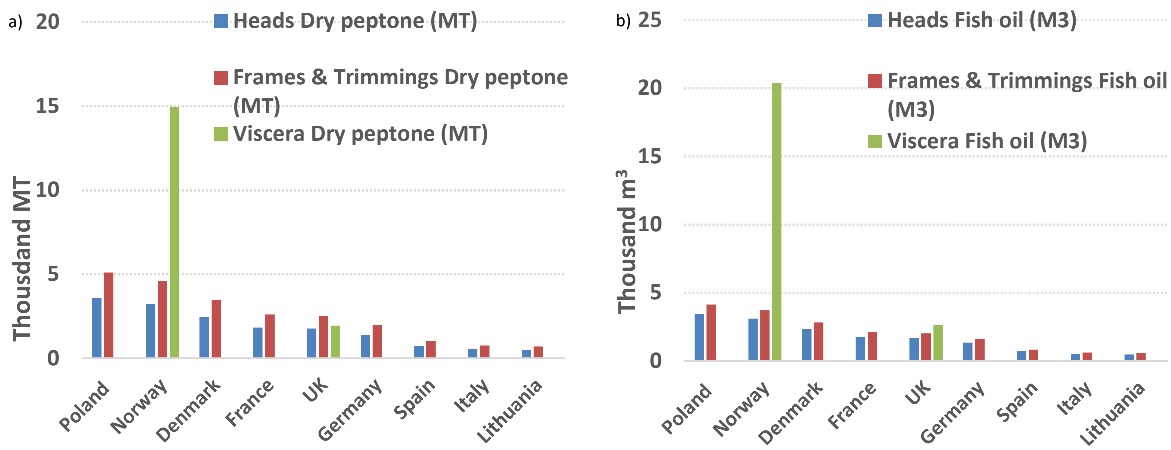

Figure 5.11: a) Peptones and b) Fish Oil from Atlantic salmon heads, frames & trimmings and viscera

Results show high volumes of FPH, peptone and oil can be produced from available by-products in Poland, Norway and Denmark. Poland shows the largest potential volume for marine ingredients from secondary processing by-products. High volumes of fish oil and dry peptones produced from viscera from primary processing in Norway and the UK could be obtained. As an indication, the oil that could be produced from peptone manufacturing, is around 10% of the around 160 thousand tonnes of high-quality fish oil used by the Norwegian salmon industry within its feed supply in 2016 (Aas et al. 2019). Although the quality of oil from by-products is likely to be lower and there may be resistance to its use in the salmon industry because of fears around intra-species feeding, it may be used in other industries and increase the overall supply of fish oil available. The yield of oil from heads, trimmings and frames is reasonably similar between peptone and hydrolysate production.

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5.2.2 FPH, oil and peptones from rainbow trout by-products

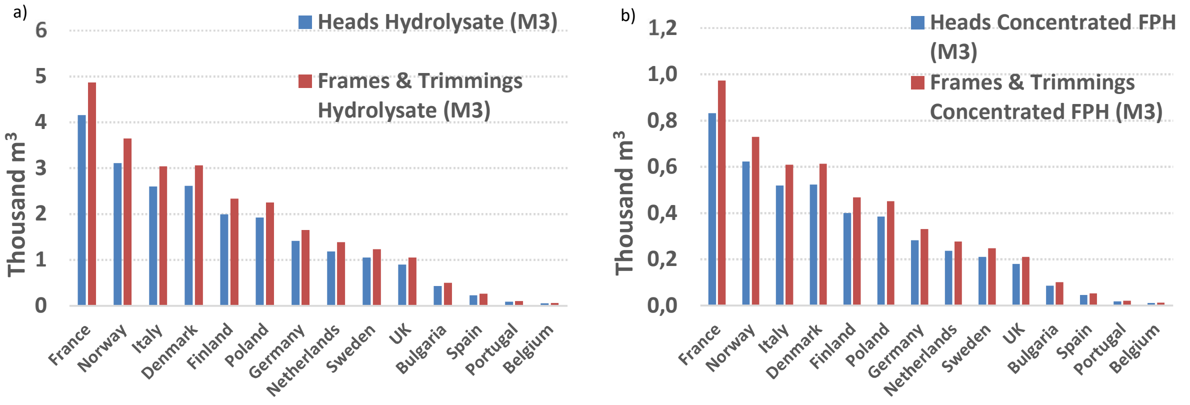

Figure 5.12: a) Liquid hydrolysate b) concentrated hydrolysate production from Atlantic salmon heads, frames and trimmings

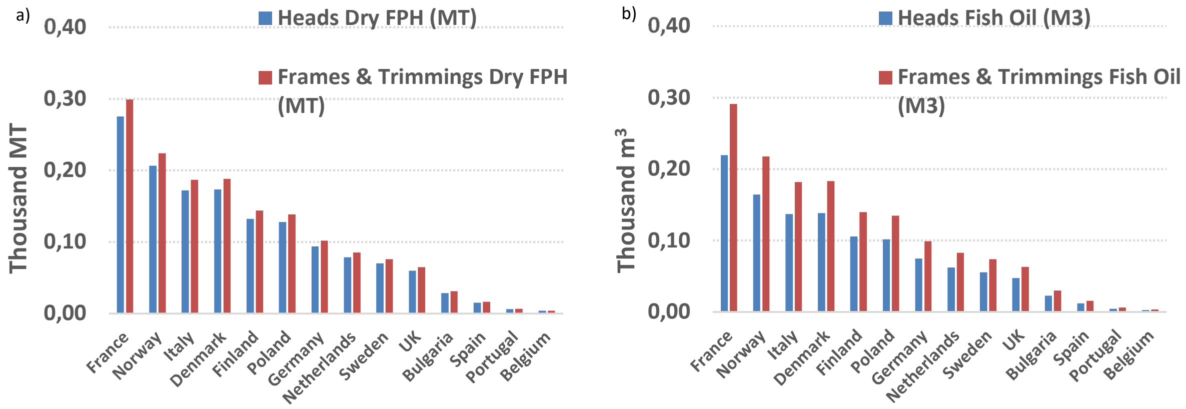

Figure 5.13 a) Dry FPH b) Fish oil from heads, frames & trimmings from Rainbow trout heads, frames and trimmings FPH production

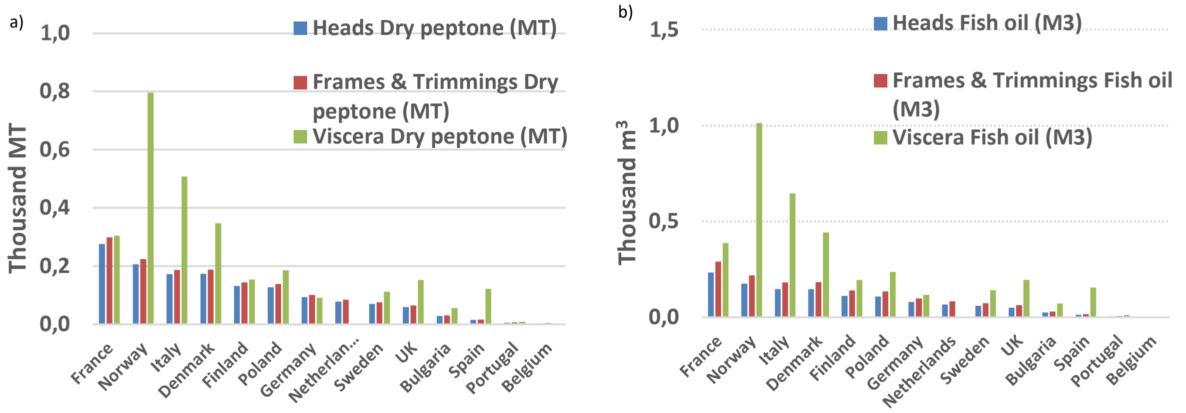

Figure 5.14: a) Peptones and b) Fish Oil from rainbow trout heads, frames & trimmings and viscera

France, Norway and Italy, who produce and process large quantities of rainbow trout have the largest potential for producing FPH from trout heads, frames and trimmings but is small compared to Atlantic

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salmon. Modest quantities of oil may be produced from the viscera of producing countries where primary processing occurs.

5.2.3 *Oil and peptones from European seabass and sea bream by-products*

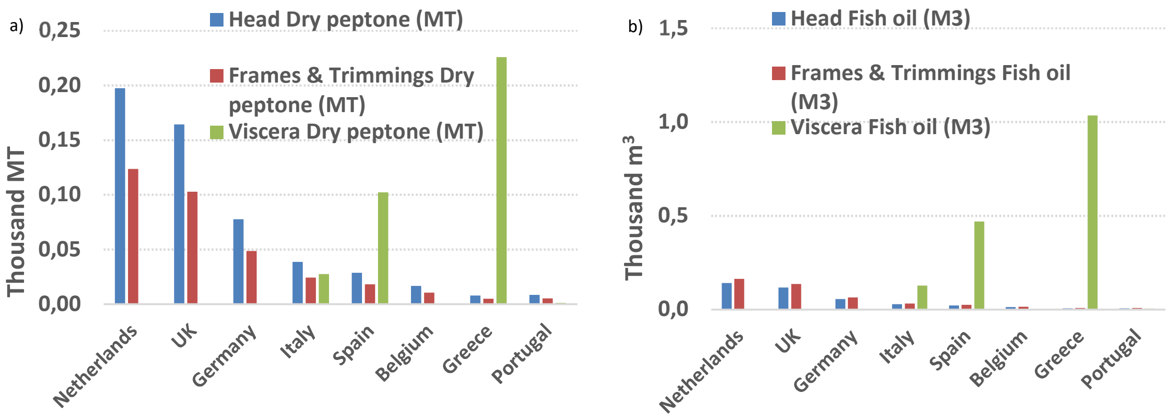

Figure 5.15: a) Peptones and b) Fish Oil from sea bass heads, frames & trimmings and viscera

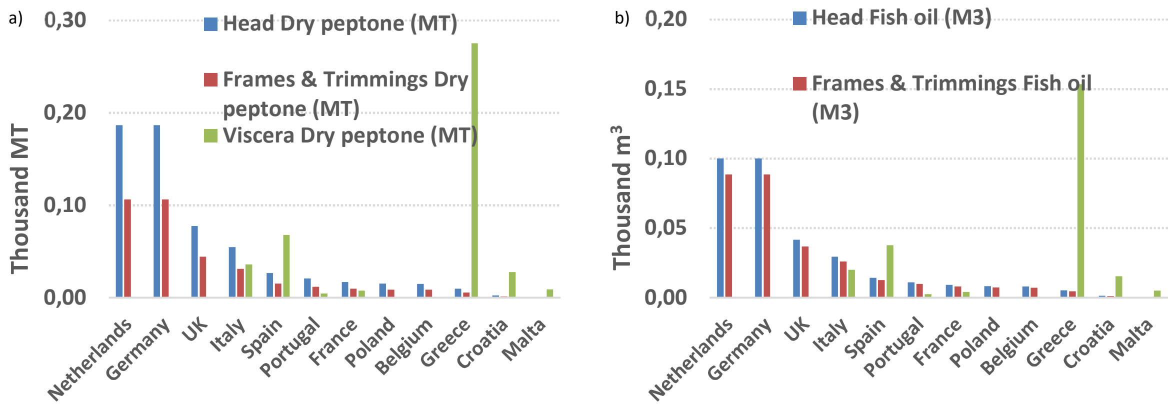

Figure 5.16: a) Peptones and b) Fish Oil from sea bream heads, frames & trimmings and viscera

Modest volumes of fish oil and dry peptones could potentially be produced from seabass and sea bream viscera in the major producing countries, such as Greece and Spain. Importing countries also show potential to produce dry peptones from heads, frames and trimmings but the volumes are quite low.

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5.2.4 *FPH, oil and peptones from* turbot by-products

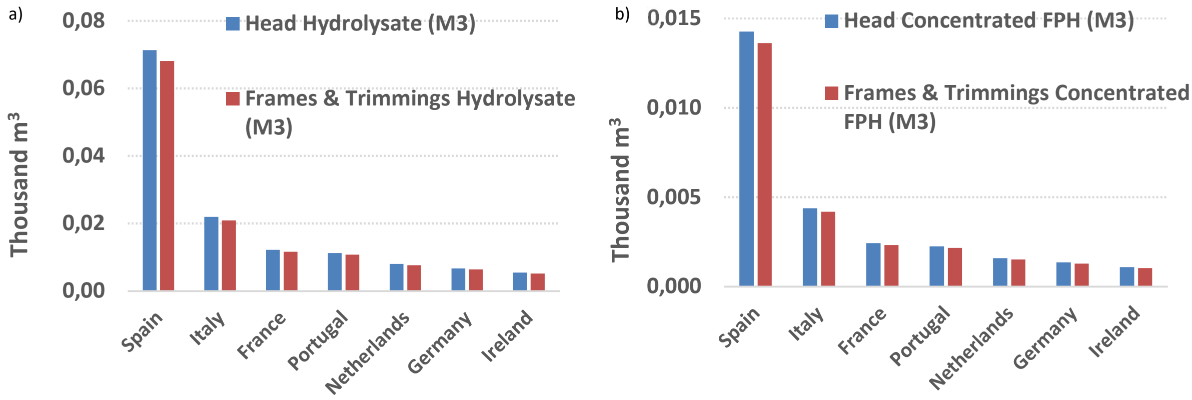

Figure 5.17 a) Liquid hydrolysate b) concentrated hydrolysate production from turbot heads, frames and trimmings

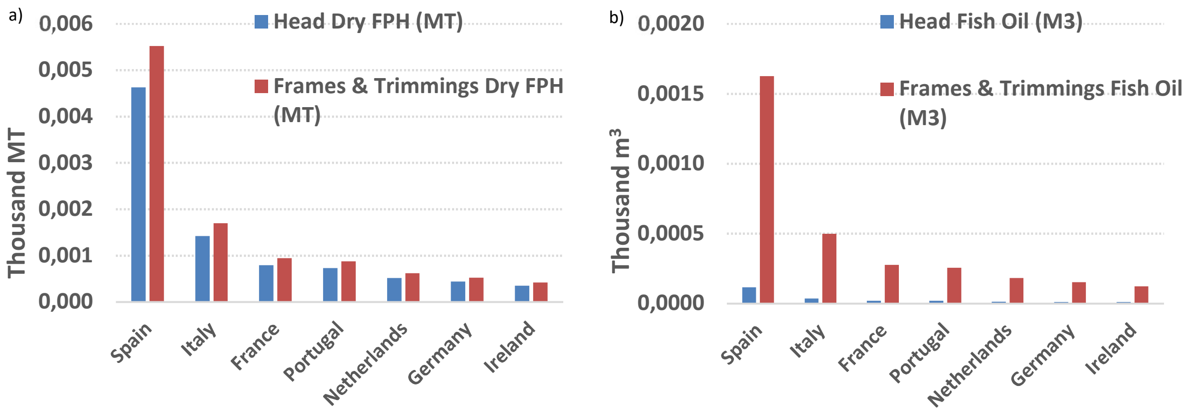

Figure 5.18: a) Dry FPH b) Fish oil from heads, frames & trimmings from turbot heads, frames and trimmings FPH production

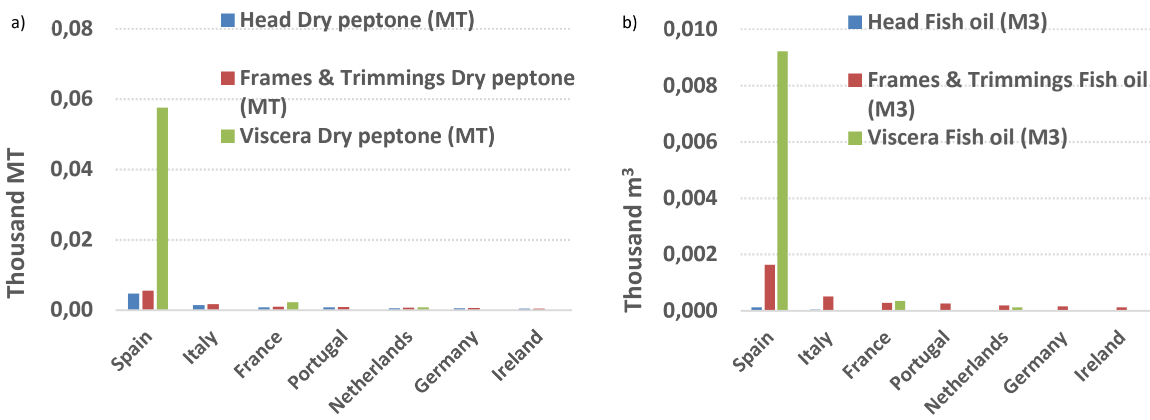

Figure 5.19: a) Peptones and b) Fish Oil from turbot heads, frames & trimmings and viscera

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Highest potential for FPH is in Spain, which produces and process, as well as imports, turbot. Volumes are low compared to other species because of the low volumes of by-product available.

Low volumes of fish oil and dry peptones could be produced from turbot viscera in Spain as the largest producer and processor of turbot. Importing countries may also produce peptones from secondary processing by-products. The volumes of peptones obtainable from heads and trimmings and frames are relatively similar. However, fish oil yields (Annex 2) differ significantly between different by-products.

5.3 Gelatine and Collagen Production from Skins

Collagen is the major component of connective tissues and as an important component in skin and bone structure is the most abundant protein in vertebrates. There are at least 26 forms (Li et al 2005) of collagen with varying properties which affect its application. Preparation from skin is with a water wash and chemical treatments, followed up by filtration to form an acid soluble collagen solution. This is followed up by further chemical treatment and change of temperature and freeze-drying resulting acid soluble collagen.

Gelatine is a mixture of proteins prepared from the breaking of cross-linkages and denaturation of collagen but otherwise is similar in amino/imino-acid composition to the parent collagen and therefore exhibits a range of properties. It is less valuable than collagen but potentially has a broader range of applications. It is extracted by treatment with acids followed by a water wash. At the end, water is extracted by temperature and centrifugation followed up by filtration, resulting in a gelatine solution, which is then dried into gelatine crystals.

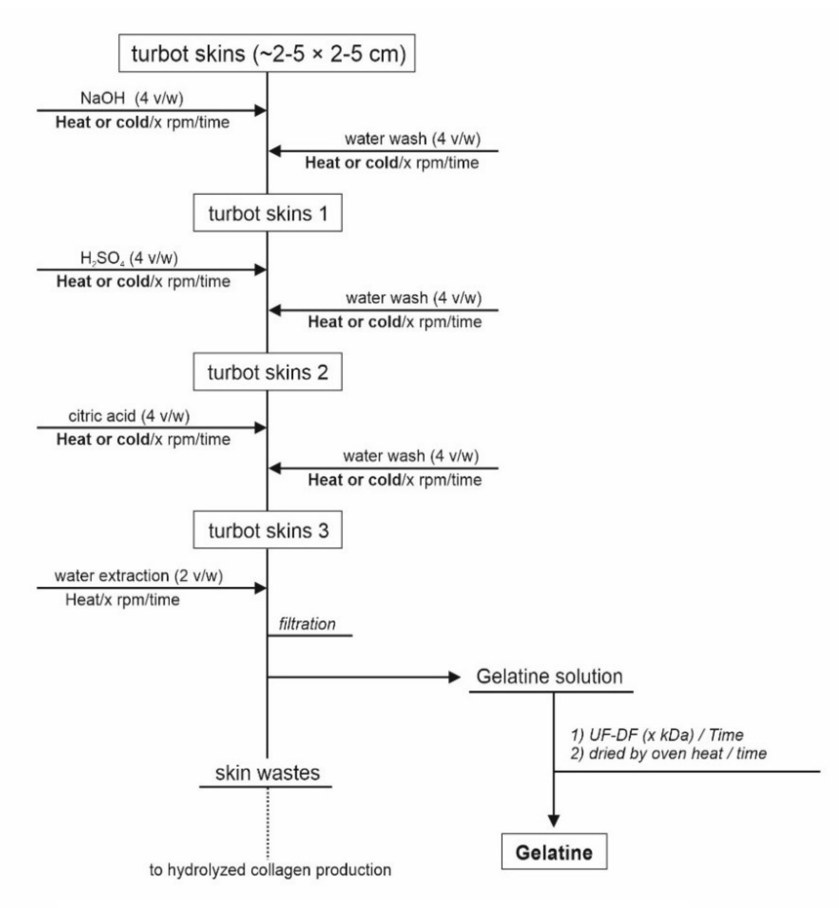

Figure 5.20. Gelatine production process from turbot

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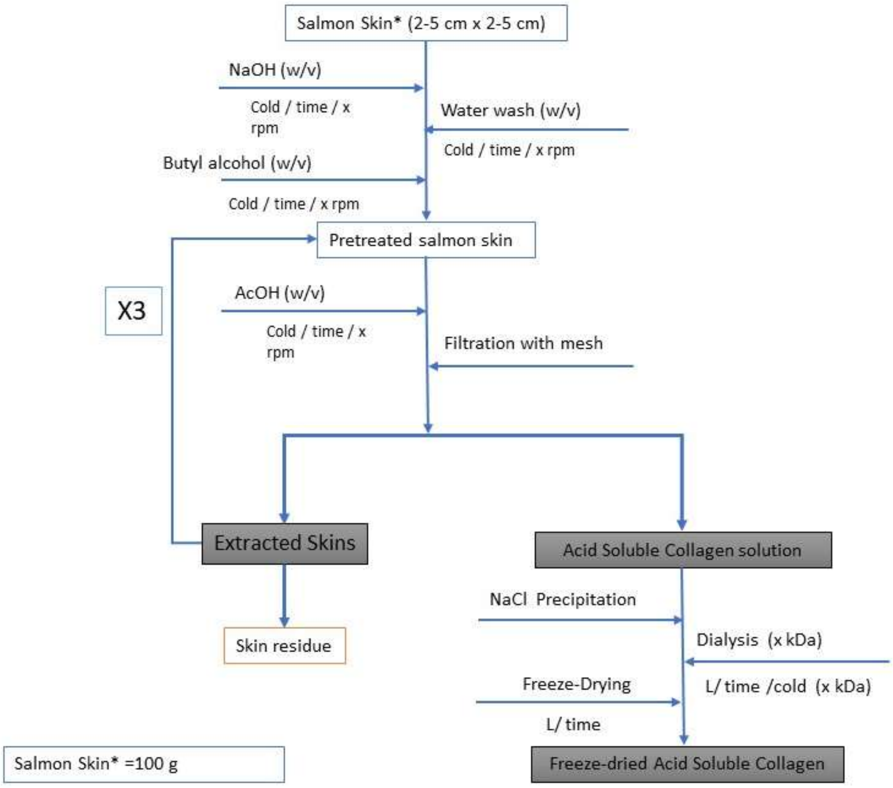

Figure 5.21. Collagen production process from salmon skins

5.3.1 Collagen and gelatine extraction from Atlantic salmon skins

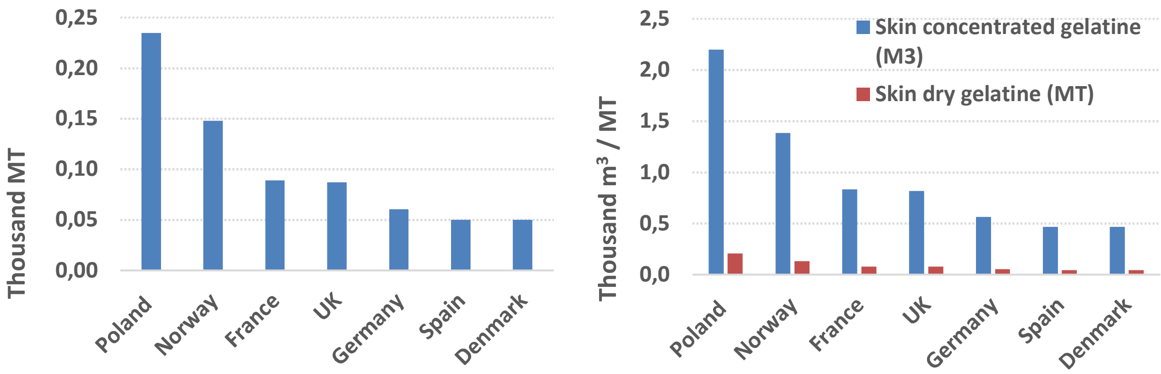

Figure 5.22: a) Collagen b) Gelatines from Atlantic salmon skins

A large proportion of global gelatine production and demand is within the EU, reported to be around 150 thousand tonnes, out of a global supply of around 400 thousand tonnes (International Leather Maker accessed 21/10/2020). Growing demand is from the cosmetics and pharmaceutical industry, and if the properties of fish gelatines prove to be favourable, they could make an important contribution to global supplies. As much of the supply of global gelatine is from porcine or bovine resources, the potential for targeting religious groups is of interest. However, if it is to compete with traditional sources, fish gelatines must display similar properties, such as gel strength and thermal

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stability. Indications are that cold water fish gelatines have lower thermal stability than terrestrial sources. Another important physical characteristic is the bloom strength, which is a measure of the strength of the gelatine. Indications from Task 2.2 results show that turbot gelatines are within similar ranges to porcine gelatine, but salmon is lower. However, lower bloom strength gelatines may have different applications to porcine, such as in chilled desserts (Newton et al 2014).

Marine collagen is also of growing interest although from the figures, European aquaculture looks less likely to make an impact on the world market than gelatine. Fish collagens are of interest because of their solubility properties, which are attractive for cosmetics industries. The properties of fish gelatines and collagens will be incorporated and further described in D2.3

Note that although collagen and gelatine extraction were investigated by CSIC as part of Task 2.2, there are currently no turbot skins available from processing activities. Therefore, there is no projected volumes of turbot collagen and gelatine available.

6 Conclusion

The aquaculture industry fulfils an important role to meet growing demands for seafood. However, according to Jackson and Newton (2016) there are approximately 0.6 million tonnes of unutilised seafood by-products across Europe. Redirecting by-products for direct human consumption or as feed ingredient would increase the efficiency of the industry by cutting waste and providing more raw materials across the food industry, that could help bridge the protein gap according to circular economy principles.

Our results indicate that there are substantial volumes of edible yield from by-products, particularly salmon which could be directed to human consumption. For other species, the full edible yields may be obtained from consumption of whole fish or from separation from processing by-products. However, abstracting those edible portions may be difficult, mechanically from by-products or in-home consumption scenarios, and as yet, has not been fully assessed. There are large salmon by-product volumes, especially in Norway, because of large production volumes in combination with efficient processing, resulting in e.g. large volumes of fish oil from viscera. Secondary processing of salmon is more geographically decentralised, especially to Eastern Europe (e.g. Poland). Consequently, most potential for by-product derived feed ingredients, such as hydrolysate, peptones and fish oil are not always near the production centres and dispersed volumes of by-products may make value addition less attractive. Volumes of rainbow trout, European seabass and gilthead seabream are less than for salmon because production and level of processing is lower, but there are some similarities in that producing countries are not necessarily the centres for secondary processing. However, processors (e.g. Greece) could produce large volumes of products from viscera, particularly fish oil.

Production volumes play an important role in the availability of by-products. However, by-product availability could be increased by intensifying the processing stage. Our results indicate that Atlantic salmon and rainbow trout are the most advanced species in terms of processing intensity. By-product availability for European seabass, gilthead sea bream, common carp and turbot are low because of

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local preference for consuming these species unprocessed. In some circumstances, such as for carps, there is some change to more processed products, but preference remains for purchasing fish live in most circumstances. More processing could improve efficiency by providing more materials for marine ingredients thus increasing total food yield indirectly and economic output without increasing the production capacity. However, the pros and cons of whole fish consumption, directing processing by-products to direct human consumption or to feed ingredients has not been fully investigated in terms of yields and efficiencies. Some of these efficiencies will be determined by feed trials containing by-product derived feed ingredients in WP1, together with data analysed within WP4. However, utilising the whole animal as strategically as possible to enhance sustainability is imperative for the future sustainability of the seafood industry.

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Annex 1: Commodity trade per species

Atlantic salmon

Countries selected based on the main EU/EEA producers (EC, 2012b) and most important import and export countries within EU/EEA; UK, Ireland, Norway, Denmark, Poland, Lithuania, Spain, Germany, Italy, Portugal and France.

Table A1.1: Selected Atlantic salmon commodities (FAO, 2020).

Commodity
Atlantic and Danube salmons, fresh or chilled
Atlantic salmon and Danube salmon, frozen
Salmon fillets, dried, salted or in brine
Salmon fillets, fresh or chilled
Salmon fillets, frozen
Salmon minced, prepared or preserved
Salmon nei, not minced, prepared or preserved
Salmonoids meat, fresh or chilled, nei
Salmonoids nei, minced, prepared or preserved
Salmonoids, fresh or chilled, nei
Salmonoids, frozen
Salmonoids, not minced, prepared or preserved
Salmons, fresh or chilled, nei
Salmons, live
Salmons, salted or in brine
Salmons, smoked

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Rainbow trout

Countries selected based on the main EU/EEA producers (EC, 2012a) and most important import and export countries within EU/EEA; Norway, Italy, France, Denmark, Spain, Germany, UK, Poland, Portugal, Belgium and The Netherlands.

Table A1.2: Selected rainbow trout commodities (FAO, 2020).

Commodity
Trout fillets, fresh and chilled
Trout fillets, frozen
Trouts and chars live
Trouts and chars, fresh or chilled
Trouts and chars, frozen
Trouts and chars, smoked

European Seabass

Countries selected based on the main EU/EEA producers (EC, no date) and most important import and export countries within EU/EEA; Greece, Spain, Italy, France, Croatia, Portugal, Germany, UK, Belgium and the Netherlands.

Table A1.3: Selected European seabass commodities (FAO, 2020) and their conversion factors to LW (FAO, n.d.).

Commodity
Seabass, fresh or chilled
Seabass, frozen

Gilt-head seabream

Countries selected based on the main EU/EEA producers (EC, 2012b) and most important import and export countries within EU/EEA; Greece, Spain, Italy, Croatia, Malta, France, Portugal, Germany, UK, Poland, Belgium and The Netherlands.

Table A1.4: Selected gilt-head seabream commodities (FAO, 2020) and their conversion factors to LW (FAO, n.d.).

Commodity
Gilt-head seabream, fresh or chilled
Gilt-head seabream, frozen

Common carp

Countries selected based on the main EU/EEA producers (EC, 2012c) and most important import and export countries within EU/EEA; Poland, Germany, Czech Republic, Hungary, UK, Spain, Italy and Portugal.

Table A1.5: Selected common carp commodities (FAO, 2020) and their conversion factors to LW (FAO, n.d.).

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Commodity
Carps live
Carps, eels and snakeheads, fillets, fresh or chilled
Carps, eels and snakeheads, fillets, frozen
Carps, fresh or chilled
Carps, frozen

Turbot

Countries selected based on the main EU/EEA producers (EC, 2012d) and most important import and export countries within EU/EEA; Spain, Portugal, France, The Netherlands, Italy, Germany and Ireland.

Table A1.6: Selected turbot commodities (FAO, 2020) and their conversion factor to LW (FAO, n.d.).

Commodity (Commodity)
Turbot, fresh or chilled
Turbots, frozen

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Annex 2: Yields FPH, peptones and gelatines

Table A2.1: FPH yields from by-products.

Species/by-product (100 kg)	Yield/100kg				
Output	**Hydrolysate (L)**	**Wet bones (kg)**	**Fish oil (L)**	**Concentrate FPH (L)**	**FPH (kg)**
Atlantic salmon heads	177	10.7	11.5	35.4	12
Atlantic salmon trimmings (20%) and frames (80%)	180	10.2	9.5	36	14
Rainbow trout heads	178	10	9.4	35.6	11.8
Rainbow trout trimmings (10%) and frames (90%)	179	9.5	10.7	35.8	11
Turbot heads	185	16.8	0.3	37	12
Turbot trimmings (15%) and frames (85%)	180	16.4	4.3	36	14.6

Table A2.2: Peptone yields from by-products.

Species/by-product (100 kg)	Yield/100 kg		
	Wet bones (kg)	**Fish oil (L)**	**Dry peptone (kg)**
Atlantic salmon heads	10.5	11.5	12
Atlantic salmon trimmings (20%) and frames (80%)	10.2	10.5	13
Atlantic salmon viscera	0	15	11
Rainbow trout heads	10	10	11.8
Rainbow trout trimmings (10%) and frames (90%)	9.5	10.7	11
Rainbow trout viscera	0	14	11
Turbot heads	16.8	0.3	12
Turbot trimmings (15%) and frames (85%)	16.4	4.3	14.6
Turbot viscera	0	2	12.5
Gilt-head seabream heads	19.9	5.9	11

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Gilt-head seabream trimmings (13%) and frames (87%)	14	10.6	12.7
Gilt-head seabream viscera	7.3*	3.9	7
European seabass heads	19.2	8.1	11.4
European seabass trimmings (16%) and frames (84%)	10.6	13.8	10.5
European seabass viscera	0	27.5	6

**Assumed due to contamination*

Table A2.3: Gelatines yields from by-products.

Species/by-product (100 kg)	**Treatment**	**Yield/100 kg**	
		Concentrated gelatine (L)	**Gelatine (kg)**
Turbot skin	By chemical (at room temperature) and thermal processing	50	5.2
Turbot skin	By chemical (at 4^0C) and thermal processing	50	8.2
Salmon Skin	by chemical (at room temperature) and thermal processing	50	4.7

Table A2.4: Collagen yields from by-products.

Species/by-product (100 kg)	**Yield/100 kg**	
Output	**Dialyzed (L)**	**Collagen (kg)**
Turbot skin	2260	17.7
Atlantic salmon skin	400	5.34

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