The Sea Fish Industry Authority
Seafish Technology

Fish Waste Production in the United Kingdom

The Quantities Produced and Opportunities for Better Utilisation

Seafish Report Number SR537

Michaela Archer
November 2001

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Summary

The fish industry developed around fishing ports when landings were plentiful and there was little concern about environmental impacts. Nowadays, natural resources and the environment are under threat and are becoming increasingly protected by law. Government policy now focuses on the protection of resources, promoting sustainable utilisation and reducing emissions to the environment. Fishing opportunities are reduced and waste generation is increasingly penalised. Concerns about farm animal diseases are resulting in the closure of some of the existing routes of waste utilisation and adding further restriction and costs to waste disposal. It has become a significant problem for many sectors of the fish industry and is unlikely to improve.

The catching and processing of fish generates a significant amount of waste. Of a total UK fish and shellfish resource of 851,984 tonnes, it is estimated that 43% (359,964 tonnes) ends up as products for human consumption and the remainder (492,020 tonnes) is classed as waste. The majority of waste is produced in the on-shore processing sector (35% of the resource) whereas discards and processing waste at sea produce smaller quantities (17% and 5% respectively of the resource). It is not possible to estimate the quantities of waste arising in the catering and retail sectors or that which ends up in the domestic waste stream but this is thought to be small in comparison to the waste produced during catching and processing.

Discards at sea result largely from fisheries management policy and, although developments in fishing gear technology go some way towards addressing this issue, discarding has to be addressed by a change in policy. There are no restrictions on bringing ashore the waste produced from processing at sea, which could have a significant value in its own right.

During processing, much is done to maximise the yield of edible products from fish but thereafter any material is generally discarded as waste or as a low value by-product. The fishmeal route is currently the most common use of fish waste, however, this option isn't practicable for all regions of the UK or for all waste material. Other uses for waste are currently being exploited but only on a very small scale. The revenue earned from selling fish waste is extremely low. The maximum earned for fishmeal and oil production is about £70/tonne for high grade pelagic fish waste although it is usually about £30/tonne for waste received from UK pelagic processors. Demersal fish processing waste earns about £10-£30/tonne in Humberside and Grampian where there are fishmeal plants. However, this is preferable to paying £60 per tonne in landfill charges that are a harsh reality for many processors in some regions of the UK. Given current high prices for fish and increasing costs in all areas, the industry cannot afford to waste any opportunity to earn extra revenue.

Fish waste is rich in potentially valuable oils, minerals, enzymes, pigments and flavours etc. that have many alternative uses in food, pharmaceutical, agricultural, aquacultural and industrial applications. In addition to fishmeal and oil production, there is potential in silage production, fertiliser, composting, fish protein hydrolysate and fish protein concentrate. Non-nutritional uses include chitin and chitosan, carotenoid pigments, enzyme extraction, leather, glue, pharmaceuticals, cosmetics, fine chemicals, collagen, gelatin and pearl essence. There are countless other uses for this material and new uses are emerging all the time.

The concentration of the pelagic processing industry in the UK potentially facilitates fish oil recovery. The concentrations of the *Nephrops* processing industry may facilitate chitin/chitosan and carotenoid pigment production. More basic processes such as ensilage, composting and fertiliser production may be suited to smaller-scale operations in more remote regions.

The UK is trailing behind many other countries of the world in terms of exploiting this potentially valuable resource. Although the associated research is well proven and documented, little has been done to develop it further into commercial reality. To help resolve this problem, Seafish is prepared to act as facilitator between the developers of fish waste utilisation technology, the markets for the products and the fish industry itself.

This report estimates the types and quantities of fish waste generated in the different sectors, from catching to processing, and summarises the current utilisation or disposal of that waste. It then describes many of the potentially higher value utilisation opportunities for that waste and identifies some of those that may be most suitable for the UK industry. The report does not cover any wastage by the retail and catering sectors or by consumers.

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1 Introduction

The fish industry developed around fishing ports at a time when landings were plentiful and there was little concern about environmental impacts. Nowadays, natural resources and the environment are under threat and are increasingly protected by law. Government policy is now focussing on the protection of resources, promoting sustainable utilisation and reducing emissions to the environment. Fishing opportunities are reduced and waste generation and disposal are increasingly penalised. A further problem faced by the fish industry is the increasing concern about farm animal diseases, particularly those transmissible to man such as BSE. This is resulting in the closure of some of the existing routes of waste utilisation and adding further restriction and costs to waste disposal.

Whilst the UK fishery resources are reducing and the costs of our industry are increasing, imported fishery products remain available, often at low cost, and now take the major share of the retail market. Retail price competition is fierce and our industry is squeezed to very low profit margins between low retail prices and high operating costs. It is therefore essential that the industry minimises waste and maximises the value of the material available to it.

The fish industry generates a significant amount of waste. It has been previously estimated by Seafish that for each tonne of fish eaten, over a tonne of fish material is discarded either as waste or as a low value by-product. For each tonne of cod purchased by a processor nowadays for about £2,000, about 50% of that material is classed as processing waste, which typically generates less than about £40 income and at worst may incur about £60 disposal costs.

There is considerable potential for gaining more value from fish waste. It is rich in valuable minerals, enzymes, pigments and flavours that are required by many industries including food, agriculture, aquaculture and pharmaceuticals. Possible alternatives include silage production, which has potential in livestock feeding, and the production of chitin and chitosan from crustacea waste, which have many commercial uses including in water and effluent treatment and as food additives. Fish waste can also be utilised in the production of organic fertilisers and composts, which have significant benefits over chemical based products. These and other alternative uses for fish waste could potentially generate significant revenue but there are commercial and practical hurdles to be crossed before these options become a viable reality. The UK industry may be missing valuable opportunities as many of these alternatives are already commercially utilised in other countries.

This report estimates the types and quantities of fish waste generated in the different sectors of the UK industry, from catching to processing, and summarises the current utilisation or disposal of that waste. It then details many of the potentially higher value utilisation opportunities for that waste and identifies some of those that may be most suitable for the UK industry.

The report does not cover any wastage by the retail and catering sectors or by consumers. All the figures quoted are calculated using available data. Limitations in this data mean the figures can only be classed as indicative.

2 Legal Requirements for Fish Waste Disposal

The disposal of waste, particularly food waste, is strictly regulated. The main requirements of the relevant legislation are summarised below but this is not an exhaustive list. As the legal situation is constantly evolving, it is advisable to seek further guidance from the relevant authorities on the latest developments.

2.1 Processors' Waste Disposal Facilities

The Food Hygiene (Fishery Products & Live Shellfish)(Hygiene) Regulations 1998 sets out the conditions under which fish and shellfish products must be produced in order to be placed on the market. This includes requirements for hygienic waste handling and disposal. Offal/viscera should be kept separate from products intended for human consumption. On-shore processing facilities must regularly remove waste from the processing area, either by continuous means or by holding the material in leak-proof, covered containers which should be removed when full. Containers for holding waste material must be watertight and corrosion resistant and should be designed to facilitate cleaning and disinfection. If waste material is to be stored overnight, it should be housed in a dedicated waste holding area.

2.2 Food & Feed Safety

The Animal By-Products Order 1999 (as amended) applies to animals and includes fish, crustaceans and other cold-blooded creatures of any species. It specifies that any animal by-product (animal carcass, parts of animal carcasses or products of animal origin not intended for human consumption) must be disposed of through appropriate channels. These include rendering in approved premises, incineration, burning or burial (only under restricted circumstances) and treatment at a knacker's yard. For low-risk material, the by-products can also be fed to fur animals or to maggots farmed for fish bait, providing they are held in registered premises, or can be used in the production of pet food, pharmaceutical or technical products. Fish and shellfish waste is typically classed as low risk but there are exceptions. Skins and shells are excluded from the requirements of the Order provided they are not used in the manufacture of feedingstuffs. For traceability purposes, there are documentation requirements related to waste transportation and transferral.

The Order was amended in August 2001, resulting in a ban on the production and feeding of swill produced from catering waste which contains meat products or products that have been in contact with meat, or originates from premises where meat or meat products are handled, processed or produced. It includes a ban on using poultry and fish waste in swill, unless that material has first been rendered in an approved rendering plant.

At the time of writing, the EU Directive on Animal Feed on which this Order based is under review, with proposed amendments which are likely to have a greater impact on the fish industry. They include adding another level of high risk material, called 'specified risk material' (SRM), such as that affected by environmental contaminants which, if allowed to enter the food chain, could have major food safety implications. For material classed as SRM, disposal options are limited to incineration or co-incineration (burning as a fuel), rendering followed by incineration or co-incineration, or rendering followed by landfill. However, it appears that this review will clarify the permissible options for disposing of waste of animal origin, clearing up much of the confusion that currently surrounds this issue.

There is an existing UK feed ban, enforced through the Animal Protein Regulations 2001, prohibiting the use of mammalian protein (with certain specified exceptions) to ruminants and the feeding of mammalian meat and bone meal (MMBM) to all farmed livestock. Additional EU wide controls prohibit the feeding of processed animal protein to animals which are kept, fattened or bred for the production of food. Processed animal protein, as defined by the EU, includes materials other than mammalian protein and MMBM, so goes further than the UK Regulations. There are certain exceptions, however, including allowing the feeding of fishmeal to animals other than ruminants. Approximately 40% of UK derived fishmeal is currently used in ruminant diets, therefore this EU action will have serious implications for processors who send material for fishmeal production.

2.3 Disposal on Land

The Environmental Protection Act 1990 prohibits the keeping, treatment or disposal of waste on land unless a waste management licence has been granted for the purpose. It also places a duty of care onto businesses to dispose of waste correctly via an authorised waste transport operator or by taking it directly to an authorised place of disposal. There are documentation requirements associated with this.

The Waste Management Licensing Regulations 1994 permit a number of unlicensed exemptions for waste disposal. Exemptions could possibly include the spreading of shell on agricultural land or the use of shell for land reclamation or improvement. This unlicensed disposal must be registered.

The Landfill Tax Regulations became effective in 1996 and levy charges on waste deposited in landfill sites. The objectives of the tax are to encourage waste producers to minimise the volume of waste generated, reduce the amount deposited in landfills and to encourage recycling. A distinction is made between inactive/inert waste, which is currently taxed at £2 per tonne, and other waste which is taxed at the standard rate of £11 per tonne. The standard rate will be subject to a £1 per tonne per year increase for at least five years, reaching £15 per tonne in 2004. This tax is paid by landfill operators, who in turn pass the charges onto the users of the site. The tax does not include the costs of contracting a waste disposal company.

There are further restrictions on landfill. Under the Animal By-products Order 1999, the burial and burning (including landfill) of animal waste from processing and retailing facilities is prohibited if an alternative permitted disposal route exists. If it is possible to take, or arrange for someone else to take, the waste to a disposal route which does not involve burial or burning, that route must be taken, even if it is more expensive. There are exceptions to this, including if animal waste is in a place where access is difficult or if the quantity of material and distance to premises in which disposal is otherwise permitted do not justify transporting it. The burial/landfill of small quantities of waste from retail outlets may be considered acceptable if there is no alternative collection service or permitted disposal route. Waste of animal origin can only be put into a landfill site that is licensed for that purpose.

The EU Landfill Directive requires member states to reduce the quantities of biodegradable waste being disposed of to landfill to 35% of 1995 levels by 2020 at the very latest. The only way to achieve this is to encourage alternative disposal routes for all biodegradable materials. It is inevitable that landfill use will become increasingly restricted and waste disposal options that obtain value from waste, such as composting or incineration with energy recovery, will take its place. The Waste Strategies for England and Wales, and Scotland clearly define the future policy on waste.

The Fur Farming (Prohibition) Bill, introduced in 1999, will make it an offence to keep animals solely or primarily for slaughter for their fur. There is expected to be a winding-down period until the end of 2002. The ban, as outlined in the Bill, will come into force on a date to be appointed by commencement order, and will restrict this existing outlet for fish waste.

The Integrated Pollution Prevention & Control Regulations 2000 (IPPC) lay down measures designed to prevent, or where that is not practicable, to reduce emissions to air, water and land from a range of activities including food processing. The Regulations apply to installations which have a large production capacity and requires those businesses to obtain a permit to operate. This will control effluent discharges, air emissions, solid waste, noise and how the installation is operated and managed. The affected businesses will be required to demonstrate that best available techniques (BAT) have been introduced to reduce the environmental impact of its operation.

2.4 Disposal at Sea

The Food and Environment Protection Act 1985 controls the disposal of waste at sea through strict licensing. The Ministry of Agriculture, Fisheries and Food (MAFF) prohibited most forms of disposal at sea by the end of 1998. There are a few exemptions from licence control which are set out in the Deposits in the Sea (Exemptions) Order 1985. This Order permits a number of unlicensed exemptions for waste disposal from vessels or marine structures including waste arising from processing fish and shellfish at sea. A vessel is still allowed to dispose of that material even after landing its catch. However, the disposal at sea of waste from processing on-shore or waste that has been transferred to a second vessel is not permitted without a licence.

3 Estimates of the Origin, Types and Quantities of Fish and Shellfish Wastes

Different types and quantities of waste are generated at the various stages between capture and consumption. This section summarises the main types of waste produced, by quantity and origin wherever possible, between capture and processing. There is further waste in onward distribution to consumers via inland markets, retailers and caterers and the problems of waste disposal are significant to those businesses. However, the total amount of fish waste involved is thought to be relatively small and would be difficult to quantify. Much of it will be mixed with other waste. Wastage by the consumer is also not included.

The types and quantities of waste generated are based on official landing, import and export statistics collected by the Ministry of Agriculture, Fisheries and Food (MAFF), Scottish Executive Rural Affairs Department (SERAD) and Department of Agriculture for Northern Ireland (DANI) for 1999. Official landings statistics are based on the live weight of fish and shellfish and take no account of any unofficial landings. Import and export figures are based on the actual weight of the traded products, which are categorised into fresh or frozen, whole, headless, fillets, cured, prepared and preserved. Some of these categories are not further divided into the different types of fish, demersal or pelagic, and so representatives from industry were asked to estimate the ratio between demersal and pelagic species and these figures are used accordingly.

The amount of processing waste generated depends on the species and type of product. Processing yield data, published by Torry Research Station, is used to estimate the quantity of waste produced during the various stages of processing.

Due to the limitations of the available data, the resulting figures can only be considered as estimations.

3.1 The UK Fish Trade for 1999

The quantities of landings, imports and exports of marine fish and shellfish, by sector for 1999, are summarised in Table 1. These figures form the basis of all the calculations in this section.

Table 1 – The UK fish trade for 1999

	Official landings[1] (tonnes)	Imports[2] (tonnes)	Exports[2] (tonnes)	Balance of trade[2] (tonnes)
Demersal	236,398	249,404	72,640	413,162
Pelagic	107,277	147,363	114,970	139,670
Shellfish	147,891*	87,652	81,866	153,677
Total	**491,566**	**484,419**	**269,476**	**706,509**

*includes aquaculture and fishery order landings
1 – liveweight
2 – product weight

3.2 Discards

It is estimated by the Food and Agricultural Organisation (FAO) that between 17.9 and 39.5 million tonnes of whole fish are discarded worldwide each year in commercial fisheries. The International Council for the Exploitation of the Sea (ICES) estimate the amount of discards in the North Sea demersal fishery to be equivalent to 40 to 60%, by weight, of the catch. This is supported by further FAO research in the North East Atlantic region (includes Northern Europe) which estimates discarding as high as 50% of the demersal catch, by weight.

Pelagic and shellfish discard figures are estimated using information provided by Seafish discard officers. These provide only an indicative level of discards due to the highly variable nature of fisheries and fishing. An estimate of the weight of discarded demersal and pelagic fish and shellfish is shown in Table 2.

Table 2 - Estimate of fish discarded at sea from UK vessels landing into the UK

	Landings (tonnes)	Discards per catch (%)			Discards (tonnes)		
		Min	Max	Ave.	Min	Max	Ave.
Demersal	236,398	40	60	50	94,559	141,839	118,199
Pelagic	107,277	5	20	12.5	5,364	21,455	13,410
Shellfish	110,929*	5	20	12.5	5,546	22,186	13,866
Total	**448,604**				**105,470**	**185,480**	**145,475**

*excludes aquaculture and fishery order landings

3.3 Processing at Sea Waste

3.3.1 Quantities of Processing at Sea Waste

Most demersal fish are processed, to some extent, at sea before landing. The resultant waste consists of guts, liver and other viscera which are removed during the gutting operation. Some demersal species may also be headed at sea and some, such as dogfish or small sized fish, receive no processing until after landing.

The ratio of gutting waste varies according to the species, fishing grounds and season. For cod, it varies between 8-22% of the whole weight of the fish but is typically 16%. As there are no published ratios for other demersal species, this figure is applied to demersal fish in general.

It is not typical for pelagic fish and shellfish to receive any processing at sea, with the exception of a proportion of the *Nephrops norvegicus* catch. Typically, the head and claws of small-sized or damaged *Nephrops* are removed and discarded at sea. These can constitute up to 67% of the liveweight of the animal.

The UK operates a few factory vessels which produce further processing waste at sea but the quantity of this waste is not considered significant to the overall picture.

Table 3 summarises the amount of processing waste generated and disposed at sea by UK vessels.

Table 3 - Estimate of Processing Waste Produced at Sea

	Processing Waste (Tonnes)
Demersal	36,966
Pelagic	--
Shellfish - Nephrops	8,796
Total	**45,762**

3.3.2 Regional Origins of Processing at Sea Waste

Currently the waste is dumped at sea, where it is produced, but if this waste is to be retained for its utilisation it would be landed with the fish. On this basis, Tables 4 and 5 respectively show the quantities of demersal and *Nephrops norvegicus* waste that would be landed by port.

Table 4 The Quantities of Demersal Waste, by Port of Landing

Port	Quantity of waste (tonnes)
Scotland Peterhead	10,668
Aberdeen	3,643
Shetland	2,768
Fraserburgh	2,219
Wick	2,158
Kinlochbervie	1,753
Mallaig	1,433
Lochinver	1,218
Ullapool	803
Ayr	272
Buckie	205
Stornoway	151
Orkney	91
Campbeltown	85
Pittenweem	82
Oban	37
Eyemouth	564
Arbroath	n/d
England & Wales Hull	1,438
Newlyn	1,087
Grimsby	817
Lowestoft	713
Milford Haven	541
Brixham	527
Whitby	523
Scarborough	466
Fleetwood	368
Plymouth	258
Bridlington	192
Looe	151
Shoreham	132
River Fal - Falmouth	110
Padstow	97
Poole	34
Portsmouth	25
Weymouth	11
Kingswear	n/d
Northern Ireland	1,330
Total	**36,966**

n/d - no data

Table 5 The Quantities of *Nephrops norvegicus* Waste, by Port of Landing

Port	Quantity of waste (tonnes)
Scotland Fraserburgh	937
Mallaig	702
Other Scotland	544
Stornoway	517
Pittenweem	473
Campbeltown	396
Troon & Saltcoats	351
Peterhead	328
Tarbert	173
Carradale	164
Lochinver	158
Barra	108
Oban	104
Snizort	88
Buckie	86
Girvan	85
Ullapool	73
Scrabster	65
Gairloch	62
Portree	34
Aberdeen	23
Eyemouth	19
Northern Ireland Kilkeel	1,085
Portavogie	857
Ardglass	731
England & Wales North Shields	275
Blyth	178
Whitehaven	133
Other England & Wales	47
Amble	2
Seahouses	1
Total	**8,796**

3.4 On-shore Processing Wastes

The very great majority of fish and shellfish processing operations are carried out in shore-based processing facilities. The amount of waste produced during processing varies according to the species, type of raw material supplied and the type of product.

Demersal fish are purchased in a number of different forms: whole, head-on gutted, headed and gutted or fillet only. During processing, the fillet, flaps and lugs are removed and sold as products for human consumption. The tongue and cheeks are also removed from some large sized species. The remainder of the fish is usually discarded as waste. Depending on the type of raw material, this can include the viscera, frame, skin, fins and head.

As pelagic fish are typically supplied to processing facilities whole, the discarded waste material includes heads, viscera, frames, lugs, flaps and, if producing skin-less fillets, skin.

Typically, the waste products from shellfish processing include shell and viscera.

This section initially outlines the basis for estimating the quantity of on-shore processing waste produced by the different sectors and then summarises the findings of this work, both by sector and region.

3.4.1 Basis of Estimation

To estimate the quantity of waste produced during on-shore processing, the ratio of edible products is applied to the overall quantity of raw material available, by species. Edible portions are defined as those that are used directly for human consumption. The effect of imports, exports and type of raw material are also accounted for. The remaining material is then assumed to be waste.

In quantifying the waste produced, figures from the Torry Research Station relating to the specific types of species and product have been used wherever possible. Where specific figures are lacking, an average for similar species or products is used.

Demersal Fish

The component parts of cod are broken down into specific ratios (Table 6). However, a typical edible product yield of 50% is generally acknowledged by industry.

Table 6 - The component parts of gutted cod

	Percentage of gutted weight
Head	25
Backbone	17
Fins & lugs	12
Skin	4
Fillet (skinned)	42
Total	**100**

Less detailed information is available on other demersal species (Table 7). Where information is not available, a general figure for all demersal species is used.

Table 7 - Edible portions of some demersal species

Species	**Edible portions (%)**
Catfish	35%
Demersal (general)	43%
Haddock (Ave.)	43%
Hake	50%
Lemon sole	42%
Ling	48%
Plaice	35%
Redfish	30%
Whiting	38%

Pelagic Fish
Approximately 53% of the whole weight of herring is classed as the edible portion and this is used to estimate the amount of waste produced in all pelagic species.

Shellfish
The edible portions of some shellfish species are outlined in Table 8. An average is derived for crustaceans and molluscs and, where a species is not listed, the respective average figure is used.

Table 8 - Edible portions of some shellfish species

Species	Edible portions (%)
Crab	32%
Lobster	44%
Nephrops (whole) (unshelled tails)	24% 58%
Shrimp, brown	35%
Prawn	40%
Crustacea (Ave.)	39%
Oyster	14%
Cockle	12%
Winkle	23%
Scallop	14%
Mussel	14%
Whelk	42%
Mollusc (Ave.)	20%

Some shellfish species (oysters, whole *Nephrops*, lobsters etc) are not processed commercially whereas for other species, such as mussels, the extent of commercial processing varies. Where not processed, shelling is carried out by the person preparing the food or by the end consumer and the waste does not end up in the commercial waste stream. From the available information, it is impossible to separate these things and so the estimate for shellfish waste includes all waste, regardless of where it is produced.

3.4.2 Quantities of On-shore Processing Waste

By applying the different ratios of edible product to the UK fish supply, an estimate of the quantity of on-shore processing waste, by sector, is derived, see Table 9.

Table 9 - Estimated quantities of on-shore processing waste

Sector	Tonnes
Demersal	154,143
Pelagic	50,269
Shellfish	
- molluscs	67,166
- crustacea	29,459
Total	**301,037**

3.4.3 Regional Origins of On-shore Processing Waste

An estimate of the quantity of waste generated in each region of the UK is derived by relating the total quantity of fish waste produced on-shore to the location of processing units and their respective proportion of fish resource processed, see Table 10. Data on regional quantities of fish processed was taken from the 1995 Survey of the UK Sea Fish Processing Industry.

Table 10 - The quantities of waste material produced by region

Region	Product processed (%)	Estimate of waste produced (tonnes)
Humberside	44%	132,456
Grampian	29%	87,302
Northern England	6%	18,062
South West England	5%	15,052
South, Midlands, Wales	5%	15,052
Highlands & Islands	4%	12,041
Other Scotland	4%	12,041
Northern Ireland	3%	9,031
Total	**100%**	**301,037**

Using the same basis of calculation, the regional origin of pelagic and *Nephrops norvegicus* waste is estimated, see Table 11.

Table 11 The Quantities of Waste Material Produced by the Pelagic and *Nephrops* Sectors, by Region

Region	Pelagic Sector		*Nephrops* Sector	
	Product processed (%)	Estimate of waste produced (tonnes)	Product processed (%)	Estimate of waste produced (tonnes)
Humberside	3%	1,508	2%	313
South West England	4%	2,011	--	--
South, Midlands, Wales	3%	1,508	--	--
Northern England	1%	502	33%	5,158
Scotland (total)	88%	44,237*	--	--
Grampian	--	--	4%	625
Highlands & Islands	--	--	23%	3,595
Other Scotland	--	--	3%	469
Northern Ireland	1%	503	35%	5,471
Total	**100%**	**50,269**	**100%**	**15,631**

* primarily Grampian & Shetland regions

3.5 Summary of the Waste Produced by the UK Sea Fish Industry

Of a total available UK fish and shellfish resource of approximately 850,000 tonnes, it is estimated that 43% ends up as products for human consumption and the remainder is classed as waste. The waste is further categorised according to its source of production in Figure 1. The majority of waste is produced in the on-shore processing sector (35% of the resource) whereas discards and processing waste at sea produce smaller quantities (17% and 5% of the resource respectively).

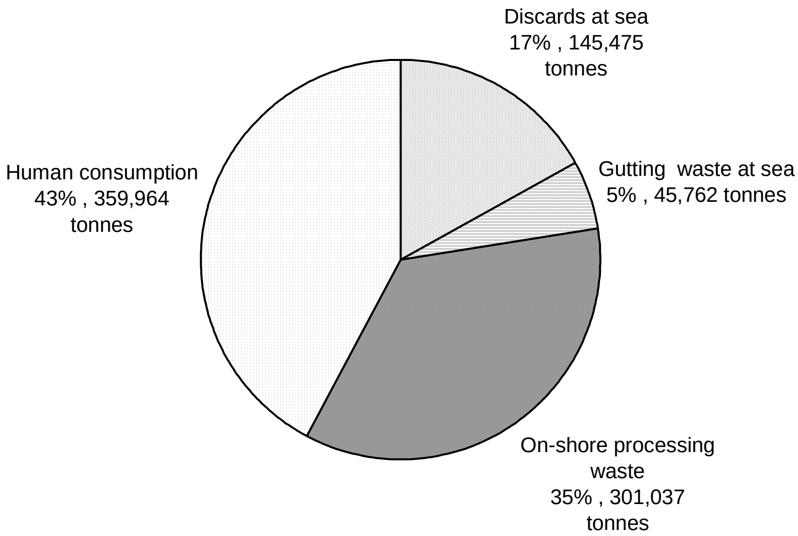

Figure 1 – The Utilisation of the Fisheries Resource

The regional distribution of waste production is shown in Figures 2, 3 and 4. Figures 5 and 6 respectively, show the regional distribution of demersal and *Nephrops* processing at sea waste, if landed.

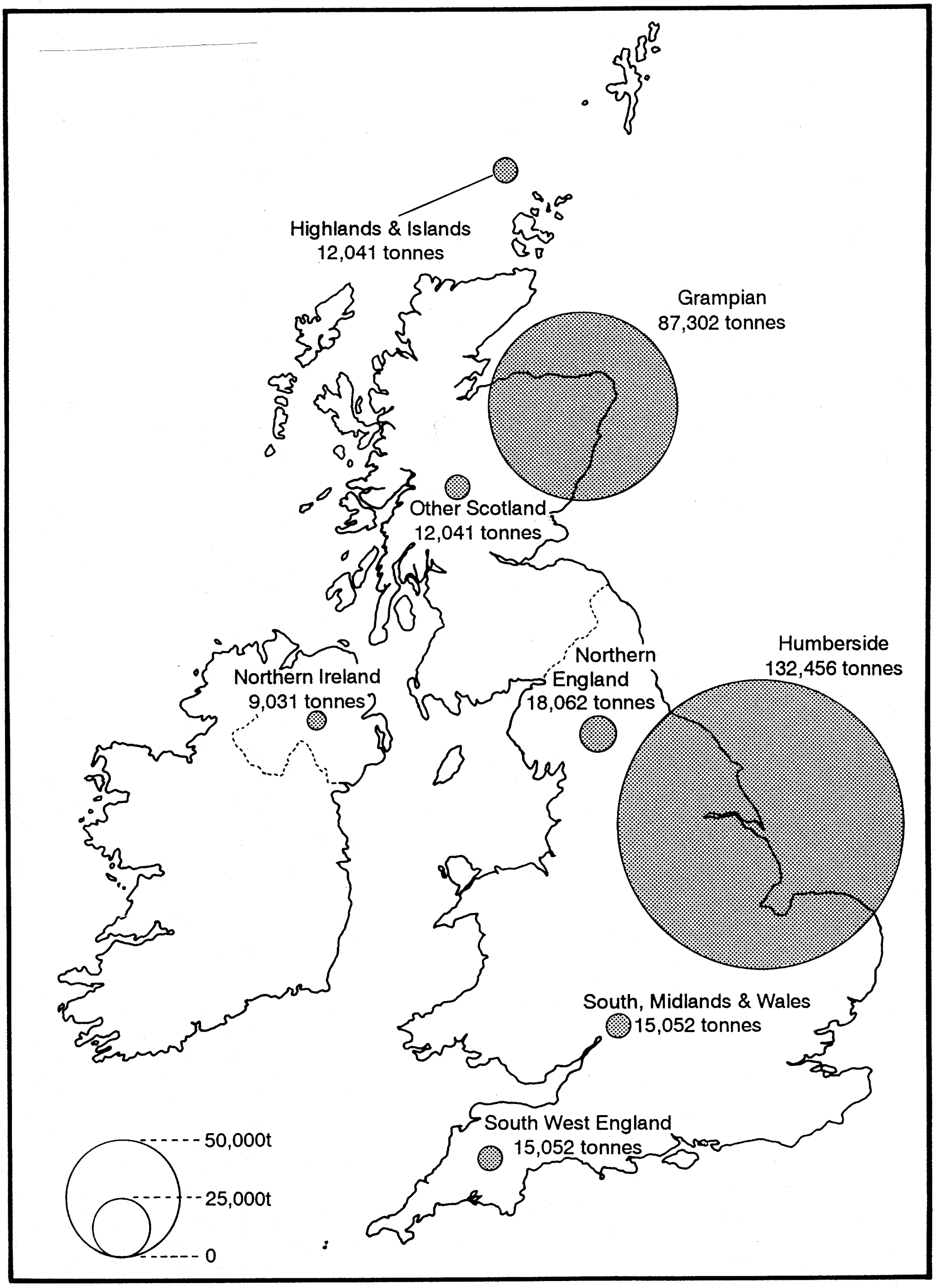

Figure 2 - Regional Distribution of all On-Shore Processing Waste Production

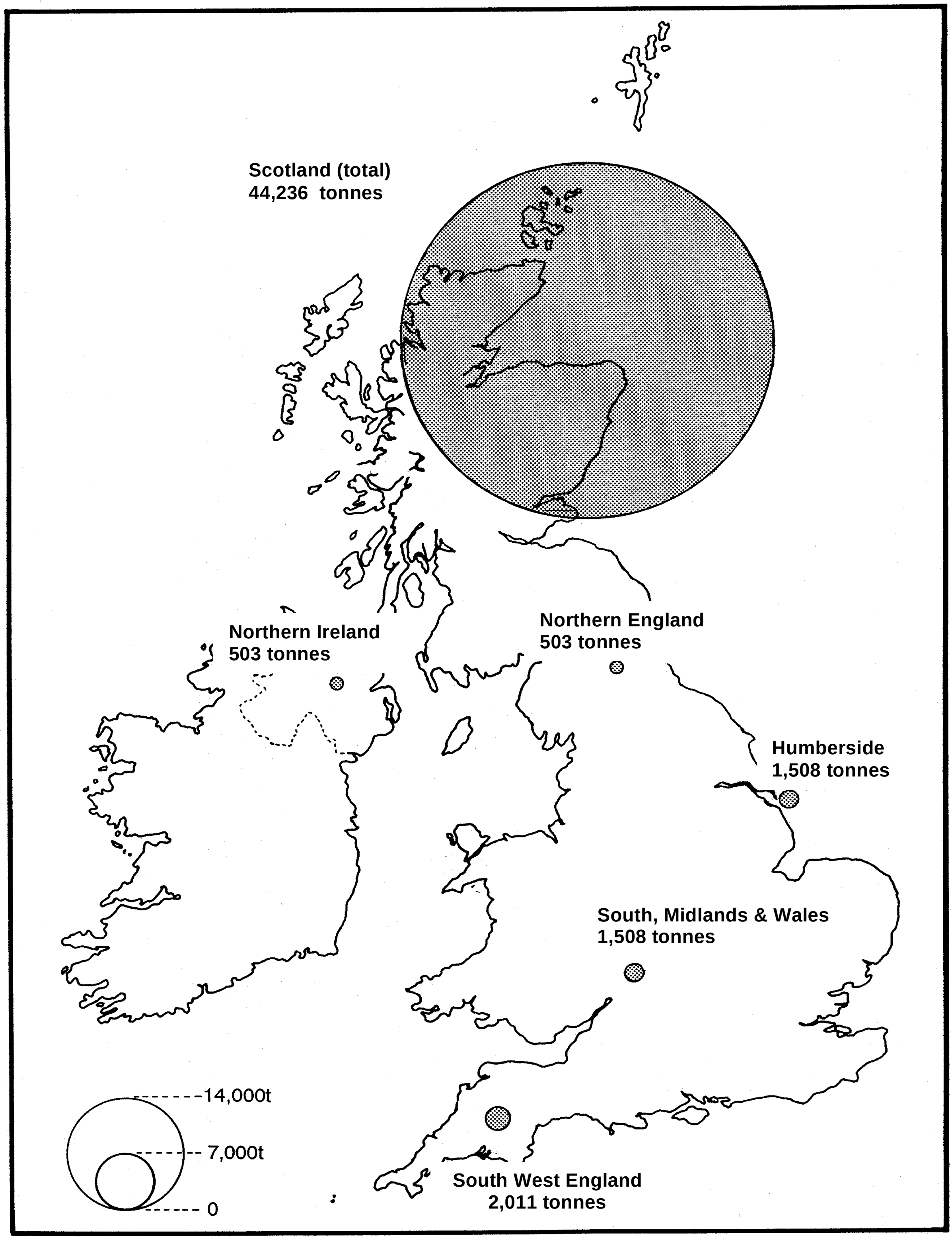

Figure 3 - Regional Distribution of On-Shore Pelagic Processing Waste Production

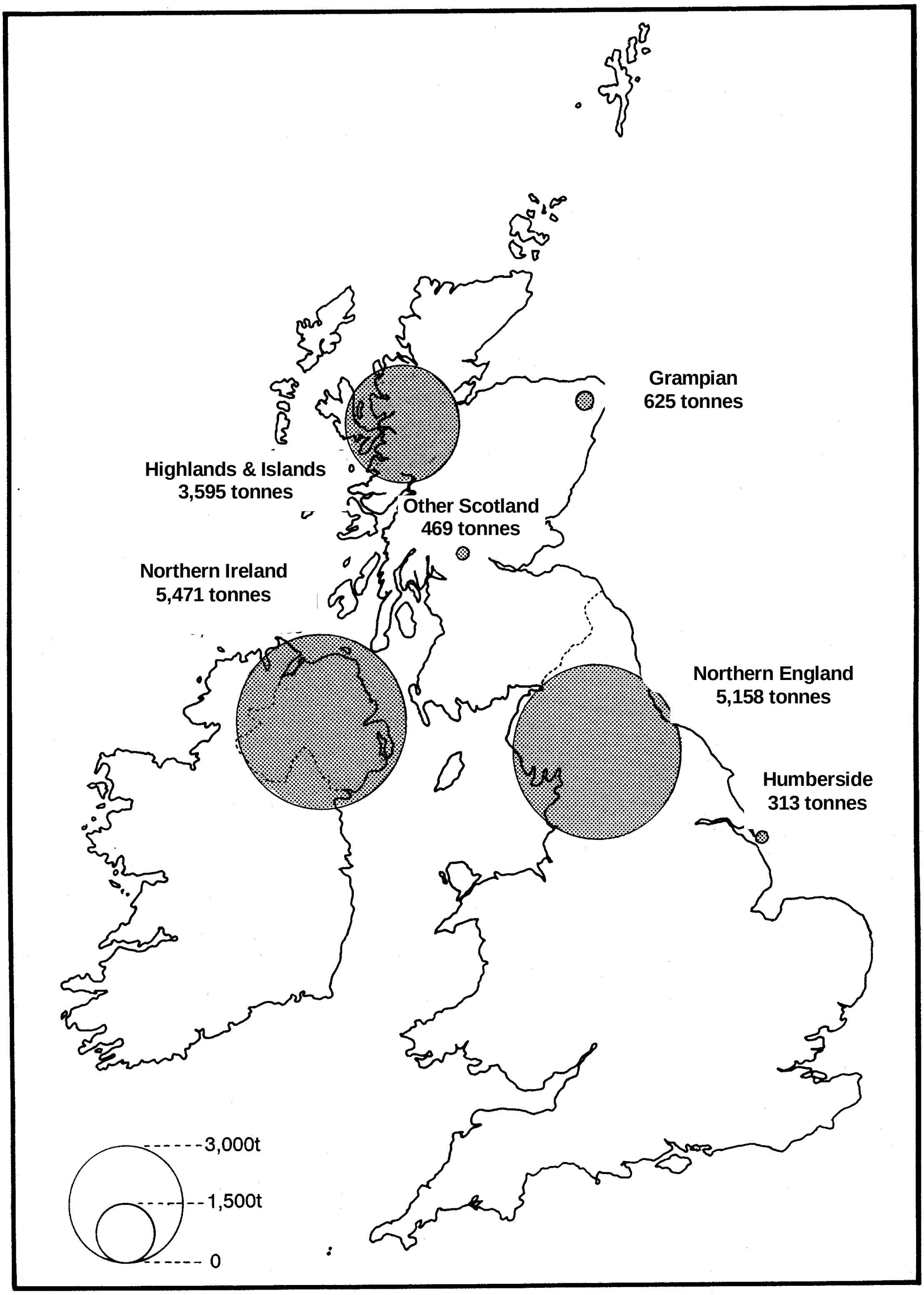

Figure 4 Regional Distribution of On-Shore *Nephrops* Processing Waste Production

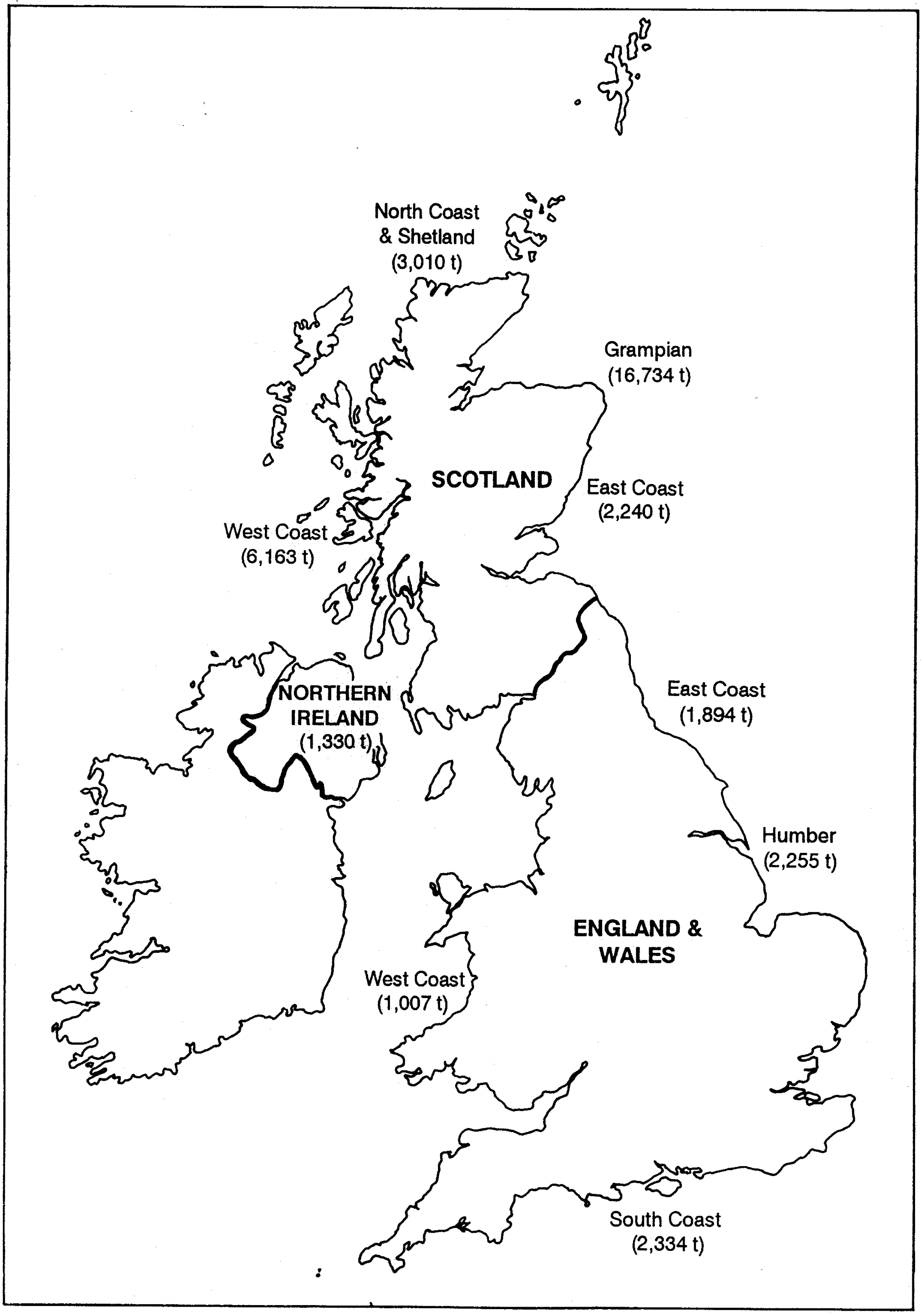

Figure 5 – Regional Distribution of Demersal Processing at Sea Waste if landed

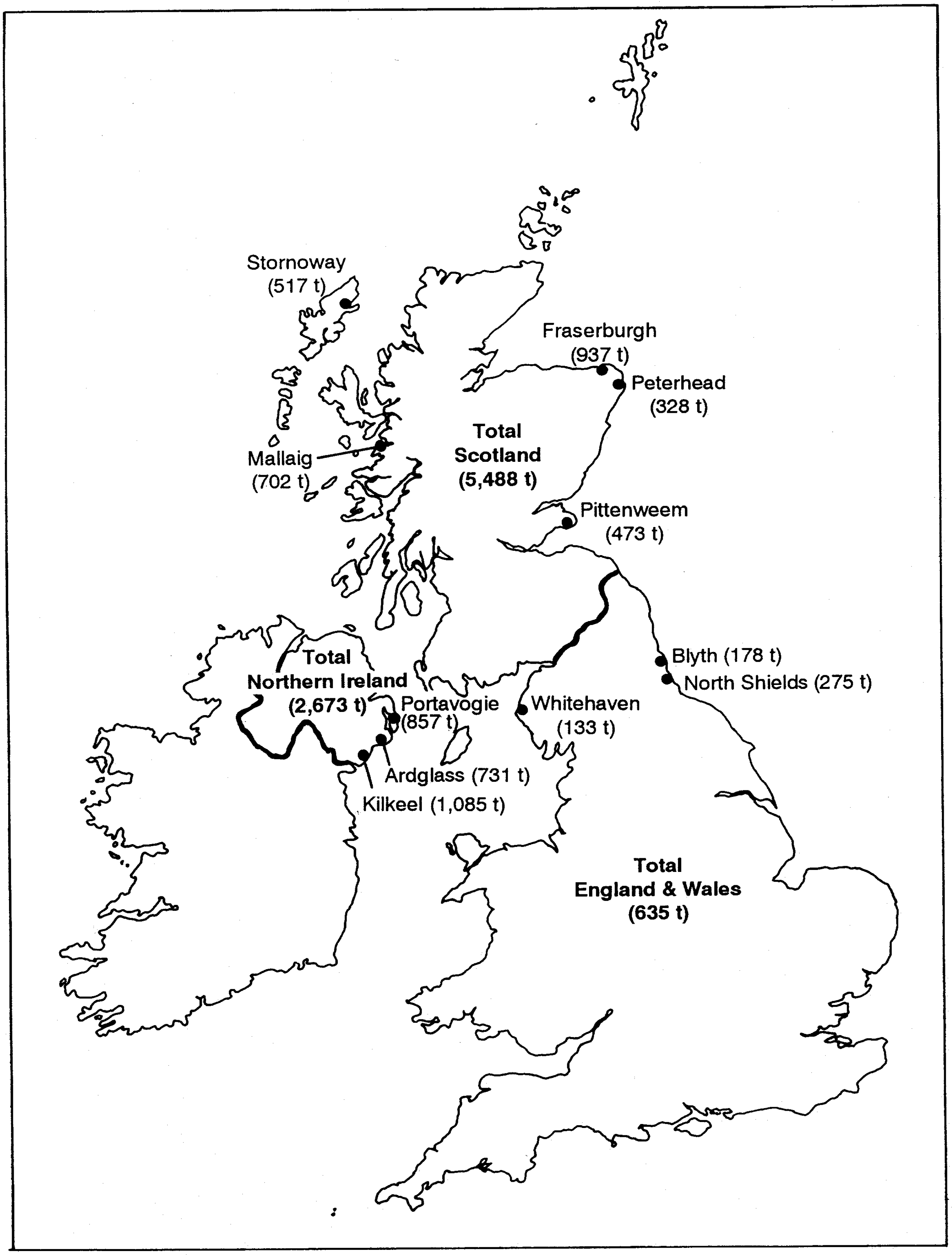

Figure 6 – Regional Distribution of *Nephrops* Processing at Sea Waste if landed (only major landing places itemised)

4 Current Fish Waste Utilisation and Disposal

The major outlet for fish waste is fishmeal and oil production. Only small quantities of fish waste are currently utilised for other purposes such as pet food, animal feed, fishing bait etc. In some areas of the UK, fish waste primarily ends up in landfill sites.

4.1 Fishmeal and Oil Production

Fishmeal and oil production requires considerable investment in plant and there are significant economies of scale. Fishmeal and oil are produced world-wide and are traded internationally as commodities.

There are currently three specialist plants in the UK which take fish for the commercial production of fishmeal and oil at Grimsby, Aberdeen and Shetland. These plants are under common ownership. Processors can only send waste material to these plants if they have passed a factory inspection and adhere to certain quality and supply conditions. Many processors who send material to the Grimsby site are bound by a contract, making the fishmeal company the sole receiver of their fish waste. A price formula is in place for supply to the Aberdeen site. Only one UK processor is known to operate its own fishmeal plant.

The processor receives a rate for the material supplied to the fishmeal plant. This rate depends on freshness quality, the oil and dry matter content and whether the material consists of whole fish or processing waste. When the material arrives at the fishmeal company it is tested for freshness quality and inspected for free water and foreign materials. Deductions are made if these exceed the agreed limits.

The rate is set by the fishmeal company and is linked to world fishmeal and oil prices, which fluctuate. Prices have been depressed but recently low production levels and strong demand, especially from Asia, have increased world fishmeal prices to about £400 per tonne. Fish oil prices have also increased in recent months to about £380 per tonne. Nowadays, the main buying interest for fish oil stems from the aquaculture industry, where it has proven benefits in the development of farmed fish. Fishmeal and oil also have significant benefits when used as an agricultural feed but the EU ban on feeding fishmeal to ruminants has affected this trade.

Fish processing waste is collected from the processor by road transport. If the processor is located within a certain distance from the fishmeal plant, the fishmeal company uses its own vehicles for transporting the material and deducts transport charges from the price paid for the waste. In other areas processors have to arrange alternative transport.

The maximum rate for pelagic fish material can be about £70/tonne if it is high grade, although processors usually receive about £30/tonne. Demersal fish processing material earns between £10-£30/tonne in Humberside and Grampian where there are local fishmeal plants. In regions located some distance from the fishmeal plant, such as the South West, South and South East of England, the transport costs negate the price paid for the waste material. In these regions, the processors have little option but to look for alternative options or pay to send their waste to landfill. In the South West, there are companies who specialise in collecting material from a number of processors, for a fee, for transport to the Grimsby fishmeal plant.

The UK is a net importer of fishmeal and oil. In 1999, nearly 290,000 tonnes of fish meals and oils were imported into the UK, indicating a significant demand that cannot be met by domestic production. A significant part of this trade is for aquacultural uses.

4.2 Smaller Scale Disposal Routes

Pet food and animal feed manufacturers also buy significant quantities of fish waste. A much smaller amount of waste is sold for maggot farming.

The sale of waste for maggot farming is highly seasonal and therefore unreliable as a mainstream disposal option. Selling material to mink farms has also been carried out on a small-scale but this will have little future due to the imminent ban on fur farming in the UK. Pet food and animal feed manufacturers are often only able to take limited supplies of material. The prices paid for these uses of fish waste vary up to about £40 per tonne depending on the outlet.

Some molluscan shell waste is used in the production of aggregates for road and path construction. A proportion of crustacea waste ends up in pet food production. In some cases this material is freely given for such uses to avoid the payment of landfill charges.

4.3 Landfill

In some areas, the only practical option for processors is to send waste to landfill sites. This is a particular problem in the South West, South coast and South East areas, which are a considerable distance away from their nearest fishmeal plant. A significant amount of shell waste is also sent to landfill as it is not wanted by the fishmeal plants. Landfill disposal charges vary between £30 to £60 per tonne, depending on the type of material. Waste of animal origin is typically more expensive to dispose of than inert waste.

There is now greater political emphasis on gaining value from waste, instead of it being discarded to landfill. Financial instruments, such as taxation, are increasingly being used to discourage the production of waste. It is expected that the costs associated with landfilling waste will continue to rise significantly.

5 Options for Better Utilisation of Waste

A review of the uses for fishery product waste, both traditional and new, was carried out using reference books, literature searches and by consulting directly with industry, with the aim of identifying uses for waste which may be more profitable than the current disposal routes.

Although the term fish waste is used to describe viscera, filleting trimmings, lugs, flaps, shell etc. it is better to think of these items as by-products or co-products as they have significant potential for use as raw material to make other products.

This section of the report is divided into five sub-sections. Section 5.1 is concerned with the potential for waste reduction at sea and/or utilising that waste. Section 5.2 is concerned with the products and processes which can be used to maximise the yield of the edible portion of fish and shellfish. Section 5.3 is concerned with the aquacultural, agricultural and bulk food fishery co-products. These uses encompass the majority of the productive use of UK fish waste which, when converted into fishmeal, is used almost exclusively in the production of fish and animal feeds. Section 5.4 is concerned with the non-food fishery co-products and includes some of the more recent developments and discoveries of high tech products and often high value uses. Section 5.5 is concerned with the more traditional fishery co-products, many of which were once commercially important but which have now been replaced by better or more cost effective modern substitutes but which may still have niche markets.

It will be essential for commercial operators to clarify the legality of the different uses of fish waste before commencing any utilisation project.

5.1 Waste at Sea

Discards form a significant part of the wastage of the fishery resource. This is primarily a result of the fisheries management regime and, as such, dealing with the problem may be beyond the scope of this report. However, Seafish continues to carry out research on the use of more selective fishing gear in order to minimise the capture of unwanted or prohibited fish. We also note that it may be more productive to bring this fish ashore for some kind of utilisation, rather than returning it dead to the sea.

In the days of the UK's distant water fisheries, the livers of the large fish were separated from the processing waste and retained for processing ashore, to recover the valuable oil. Some livers were semi-processed at sea. Nowadays the fish caught are small and the trade has discontinued. In Iceland it is compulsory for vessels to return the livers to shore for further processing into high value fish liver oil. In Norway, the total fish catch must be landed.

The processing waste produced at sea is nutritionally rich and contains a high proportion of enzymes and, in the case of viscera, bacteria. This results in a rapid spoilage rate.

If the material is to be landed fresh, effective preservation and stowage systems would have to be used and trip lengths limited. Care would also be necessary to ensure adequate hygiene standards, including separation between edible fish and waste.

However, the natural volatility of the waste can be utilised to ensile it, which would result in a more stable product with agricultural uses. Ensilage is described in more detail in Section 5.2.6. Such utilisation could be considered, particularly if there are agricultural markets for the product close to the major fish landing centres.

Nephrops norvegicus could be considered as a separate case as the industry is specialised and localised. Potentially the heads and tails could be retained or not separated at sea and be input to utilisation systems set up by the processors ashore. Potential uses for this material are described later in this chapter.

5.2 Maximising Processing Yield

5.2.1 Fish Mince

Fish mince is produced by mechanically or chemically recovering flesh from either fish filleting waste or whole fish. There are several grades of mince available. The highest grade mince is made from fresh, carefully prepared raw material, and is light in colour with few dark flakes or pieces of belly cavity. The lowest grade mince is produced by de-boning fish frames, resulting in a dark coloured mince. In frozen block form, fish mince is a valuable commodity used either for human consumption or pet food manufacture, depending on the grade of the product.

Raw Material
In the UK, demersal processing waste is the most common raw material. However, mince can also be produced from many other types of fish and shellfish, including under-utilised small and bony whitefish, pelagic fish, cephalopods, molluscs and cartilaginous species.

To ensure high quality mince, it is vital that the fish or shellfish is processed as soon as possible after capture, before spoilage occurs.

Production
Mechanical separation is the preferred technique for flesh removal. Chemical separation gives a higher yield but results in inferior quality mince.

Low-grade mince is produced by passing fish frames through a simple mechanical bone separator or de-boner. Higher quality mince is recovered from trimmings, lugs, flaps, cheeks and even whole fish. In commercially available separators, a moving belt forces the fish against a revolving, perforated drum. The flesh is forced through the perforations into the drum where a fixed screw expels the resultant coarse mince. Skin and bones are retained on the outside of the drum and removed by a scraper blade.

The yield can be adjusted by increasing the tension on the belt but this may result in undesirable materials, such as bone and pieces of skin, ending up in the mince. If whole fish are used, they should be gutted, headed and split and the section of backbone above the belly cavity removed to prevent discoloration and spoilage of the mince. They should then be thoroughly washed.

There are strict hygiene requirements for the production of mechanically recovered fish flesh that must be complied with. Mechanical recovery of fish flesh from frames must take place without undue delay after filleting, using raw materials free of guts. Where whole fish are used, they must be gutted and washed beforehand. The machinery used must be cleaned at frequent intervals and at least every two hours. After recovery, the flesh must be frozen as quickly as possible or incorporated in a product intended for freezing or stabilising treatment.

Recent technical development work has shown that low levels of whitening agents can be added to whitefish frame mince to produce a whiter product without affecting the texture or eating quality. Pelagic fish can also be utilised for mince production but it deteriorates more rapidly and further work is required to develop suitable antioxidants and binding agents to improve the texture and extend the keeping quality of this type of product. The use of any additives must comply with food legislation.

Product and Uses
Western countries generally use high quality mince to make frozen battered products such as fish fingers and fishcakes. Re-formed mince can be used for fish sausages, burgers and pastes and used as a meat extender in retextured meat products.

Canned mince is a popular product in Scandinavian countries where it is used to make fish balls. Fish mince, preferably of higher quality, is also used in pet food manufacture. In Japan and other Eastern countries, high quality fish mince is valued as the raw material for surimi, kamaboko and fermented sauce products. Fish mince is also suited to drying and low moisture food production, making it an ideal protein source in developing countries.

Conclusion
Mince production is anticipated to be a future growth area. It provides an ideal method for the further utilisation of processing waste, under-utilised species and small pelagic species. However, further technical development work is required to produce commercially acceptable mince from fish with a higher oil content.

5.2.2 Tongues, Cheeks and Fins

The tongues, cheeks and fins of large fish can be recovered either manually or mechanically. Tongues and cheeks are retailed in some parts of Europe at similar prices to fillets. Tongue and cheek meat can also be used in the production of fish mince or directly in pies, fishcakes and re-formed products.

Tongues and fins from sharks and other cartilaginous species are sought after in Eastern countries for culinary and medicinal purposes.

5.2.3 Fish Heads

Salted and fermented cod heads are considered a delicacy in Nigeria. In Iceland, popular dishes include dried fish heads softened in dairy whey.

5.2.4 Fish Stomachs

Fish stomachs are considered a culinary delicacy in Iceland, Japan and other Eastern countries. Norwegian fishermen are encouraged to retain cod stomachs, which are collected centrally and then exported to Japan. Premium quality stomachs command a high price and it is thought that tusk and ling stomachs may also be in demand.

Stomachs must be removed as soon as possible after capture and immediately frozen or kept on ice as only fresh, high quality stomachs are acceptable. In Japan the stomachs are often stewed with vegetables and spices. The stomachs may also be partially hydrolysed to create ‘changi’ a dish with a characteristic flavour and texture or they can be fully hydrolysed to make a highly prized sauce or stock. In Iceland, cod stomach filled with a piece of cod liver is a popular dish.

5.2.5 Roe

Fish roe is derived from the eggs carried by the female during the breeding season. Although caviar is the most famous roe product in Europe and Japan, roe from other fish and crustacea is eaten in many forms. Milt (fish sperm) can also be eaten, particularly herring milt.

Raw Material
Some of the most popular roe products come from cod, herring, capelin, lumpfish and salmon. In Japan there is also a market for crab and sea urchin roe. Roe can make up a large part of the body weight of the fish. For herring this can be up to 12%.

In addition to fish processing, roe can be sourced from elsewhere. Kelps or seaweed on which roe has naturally settled can be sold at a premium on the Japanese market. Harvesting herring roe on kelp has become a significant industry on the West coast of the United States. To achieve a high value product the roe must be processed as soon as possible after catching.

Production
For the European market, herring roe is commonly machine processed to give a product which consists of separate non-sticky eggs. However, for the Japanese market the whole organ or roe sack may be removed by hand. Although labour intensive, in this form it is considered a delicacy and commands a much higher price.

In the first stage of the mechanised processing of herring roe, the fish are machine filleted. The guts, including the roe sack, are then passed through a rotary drum separator to separate the small roe from the gut tissue. (It has been reported that up to a 40% increase in yield can be achieved by first treating the roe/guts with fish derived enzymes to release more roe from the roe sack prior to separation. See section 5.3.3 on enzymes).

The roe is then concentrated by passing it through a series of hydrocyclone separation stages to remove small pieces of gut tissue before being mixed with 3-5% salt solution for up to 2 hours to reduce stickiness.

Finally the roe is de-watered using a fine mesh screen or solid liquid separator before being packaged. The packaged product is left to stand to allow any remaining water to drain.

Product and Uses
Roe is often smoked or dyed red or black to satisfy customer preferences. It may then be frozen, canned or eaten fresh. In Europe roe is often boiled or pan-fried, or smoked and eaten as a pate. It may also be combined with other ingredients to make products like taramasalata. Japanese consumers prepare roe using a wide range of preparation techniques. Milt can also be pan-fried.

Some farmed fish can be difficult to raise due to a dietary imbalance in the early developmental stages of growth. Interest is growing amongst aquaculturists concerning the use of roe as a nutritional feed for fry. The roe contains all the essential vitamins and oils required for the rapid, healthy development of the young fish.

Conclusion
In the UK a large amount of demersal and pelagic roe is wasted, either at sea or during processing ashore. This product has significant potential for overseas markets.

5.2.6 Fish Soups, Stocks and Sauces

In some countries, notably in France, fish and particularly shellfish waste is used in the production of fish soups, stocks and sauces for retail sale. Fermented fish sauces have been produced since ancient times and were highly prized by the Ancient Romans. Nowadays, they are extremely popular in many Asian countries where they form a staple part of the diet. Further information on fermentation is included in Section 5.3.6 on silage and in Section 5.3.7 on fish protein hydrolysate.

5.3 Aquacultural, Agricultural and Bulk Food Uses

Despite the exceptional nutritional value of fishery products, they are caught up in EU concerns about BSE and contaminants in animal feed. Fish are not considered to be carriers of prion diseases but the broadly based EU actions taken to protect the animal feed chain have resulted in a ban on the use of all meat and bone meal in the feed of ruminants. Also, the valuable oils in fish do accumulate environmental contaminants such as dioxins, resulting in EU proposals to set limits for dioxins (and ultimately PCB's) in animal feed. This may further limit the use of some of these fishery products.

5.3.1 Fishmeal

Fishmeal is a highly nutritious powder, produced by drying and grinding whole fish or processing waste. Standard fishmeal is blended with other ingredients and used as animal feed but meal produced from fish of high freshness quality commands a premium price and is sought after as an aquacultural and agricultural weaning feed. Developments in fishmeal production technology have resulted in equipment becoming more compact, with a shorter process time.

Raw Material
The type, nature and freshness quality of the raw material are extremely important in fishmeal production as they relate to the protein and ash content, and total volatile nitrogen (TVN) level of the finished product. These factors, and others such as histamine levels, digestibility and salt and moisture content, dictate the grade of the fishmeal produced and hence its value.

Fishmeal can be made from almost any species of whole fish or their processing waste. The UK fishmeal plants use mainly processing waste whilst South American and other EU countries primarily use whole, industrially fished species. Fish sourced from our Northern European waters are thought to have higher dioxin levels than those from the Southern hemisphere.

Production
A diagrammatic presentation of a large-scale fishmeal plant is shown in Figure 7.

The first stages of fishmeal production are cooking and pressing which yield two products: the liquid ‘presswater’ and the pressed solid ‘presscake’. The presswater is desludged to remove any solid particles which are then added to the presscake. The desludged presswater is then passed through a centrifuge to separate the oil from the water. The crude fish oil is further processed or sold, whilst the liquid (stickwater) is fed back into the process after evaporation. The presscake, along with the material from the presswater, is dried to produce fishmeal.

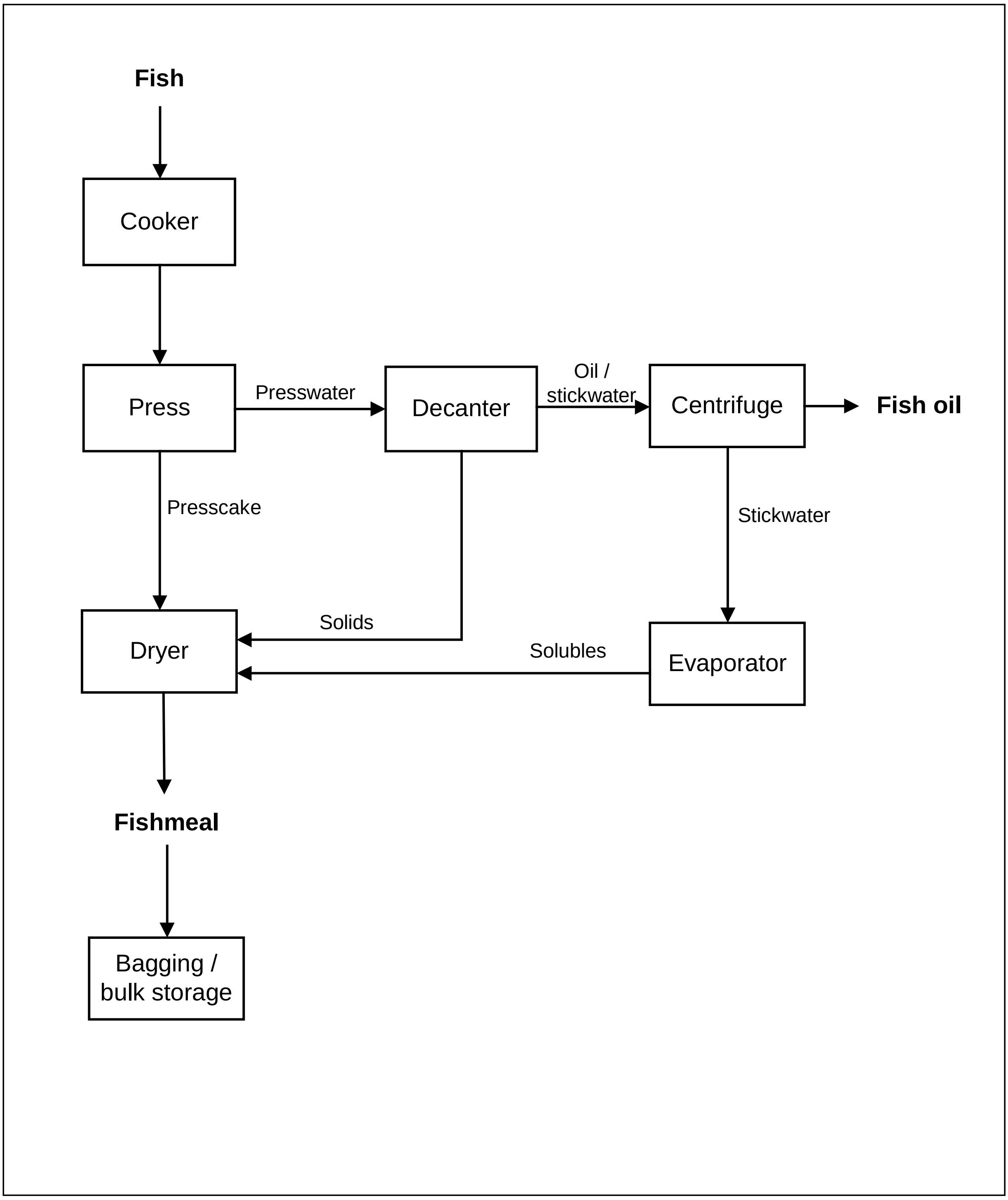

Figure 7 – The basic stages of fish meal production at a large-scale fishmeal plant

Drying the presscake prevents bacterial spoilage. It is then ground to break down small pieces of bone before packaging.

There are variations in the way fishmeal can be produced but the fundamental principles remain the same. For example, developments in two phase drying technology allow shorter drying times at lower temperatures.

Compact fishmeal plants can be used for converting small quantities of fish waste at a processing facility. These vary in capacity from upwards of 1 tonne of raw material per day but are costly to purchase and operate.

Fishmeal has a residual oil content and it is not yet technically feasible to remove environmental contaminants such as dioxins from the meal itself.

Products and Uses
Fishmeal is produced in a number of grades dependant on its composition. High grade fishmeal is in demand from agriculture and aquaculture where it can be blended with fish oil to make a feed which provides the best possible source of digestible protein and essential vitamins and oils, for the rapid growth of farmed fish, piglets and poultry. As yet unidentified components of the feed are thought to be responsible for the accelerated growth and improved resistance to disease shown by fish and animals reared on a fishmeal diet. The increased digestibility of high grade feed not only improves growth, but it is estimated that a 1% increase in digestibility from 90% to 91% results in the amount of waste discharged by farmed fish being reduced by 5%.

Of UK produced fishmeal, 75% is used in aquaculture (ref United Fish Products). The UK fishmeal industry has a traceability system in place to prevent farmed salmon and trout being fed with meal derived from the same species.

Conclusion
The advantages of high grade fishmeal as an aquaculture feed saw an increase in demand during the 1990's particularly from the Far East which utilises a significant proportion of world fish meal products. It is thought that with the new generation of meal equipment it may be economical for large pelagic processors to install compact ‘in-house’ fishmeal plant, especially if fish oil is extracted during the process. Such equipment has been installed on recently constructed Norwegian vessels but the economics of installing such equipment must be carefully considered.

The environmental contamination of the sources of European produced fishmeal and EU bans on the use of meat and bone meal in feed for ruminants, may impact on its future.

5.3.2 Fish Oils

Fish oil can be categorised as two types, body oil contained within the muscle of the fish and liver oil obtained from the liver and viscera. Oil extracted from whole fish or processing waste is a mixture of the two. Each oil type has different properties, which can dictate its use.

The most significant use of fish oil is in aquaculture which uses between 70-80% of all fish oil produced (ref United Fish Products). It is also used in lower value, bulk industrial-type applications such as margarine production and, in the case of liver oil, in high value pharmaceutical products. Recent health and development studies have demonstrated the considerable benefits of Omega 3 long chain fatty acids in both humans and weaning animals. Omega 3 fatty acids are found in relatively large amounts in all types of fish oil.

Raw Material
Pelagic fish such as mackerel, herring and pilchard along with certain sharks, are a rich source of muscle oil. Anchovy and horse mackerel are particularly high in Omega-3. Other fish such as cod, haddock, hake, skate, ray and sharks contain a high quantity of oil in their liver. The nutritional quality of liver oil varies between species and the amount of oil contained in a fish depends on the season, spawning and feeding habits.

Fish freshness is particularly important for oil production as spoilage breaks down valuable components of the oil. The time taken between catching and processing the fish should be minimised and the storage temperature should be carefully controlled. These factors are especially important for liver oil production as liver has a very high content of active enzymes.

Where livers are removed on board the fishing vessel, they should either be processed immediately, if an onboard oil plant is available, or suitably preserved.

Production
Crude fish oil is produced as part of the fishmeal process but this needs further processing before use, see Figure 8. These processes are generally not undertaken at the fishmeal plant.

If the crude oil is to be used for animal or fish feed, it is generally washed and centrifuged before use.

If the crude oil is to be used directly in the human food chain it needs to be refined in order to produce a stable and purified oil. This is an extremely intensive process. At the first stage, alkaline refining is carried out to neutralise free fatty acids in the crude oil which would quickly break down in storage causing oxidative rancidity. The resultant mixture is allowed to settle after which the clear oil can be removed.

The clear oil is then usually washed to remove any residual materials.

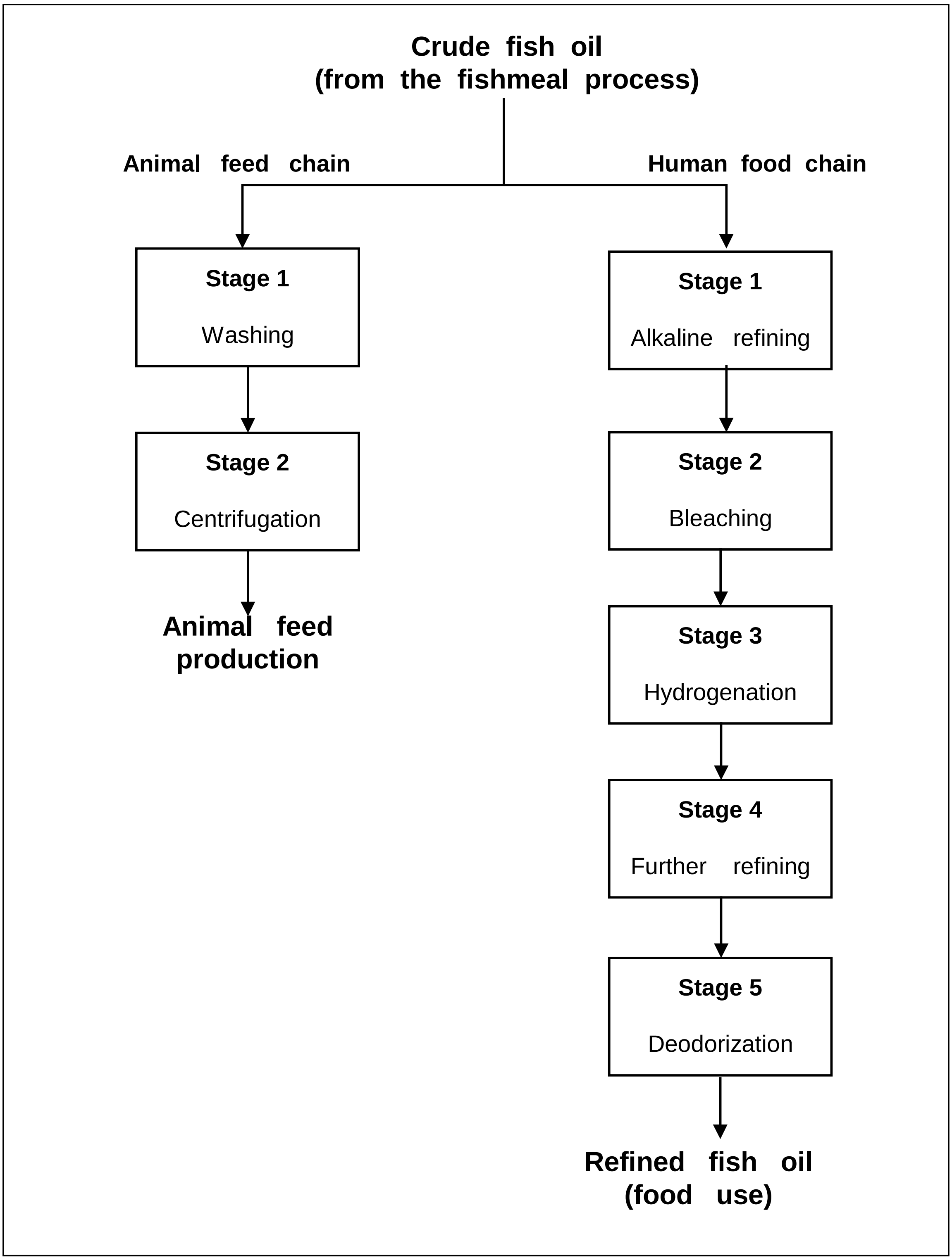

Figure 8 – The basic stages of processing crude fish oil

Bleaching is achieved by mixing the oil with natural or activated clays and agitating for a period of time to remove some of the natural pigments and undesirable fatty acids. Bleaching can be carried out as a batch or continuous process.

Hydrogenation produces edible fats from the liquid oil and consists of the direct addition of hydrogen to the oil in the presence of a catalyst. It is only achieved if gaseous hydrogen, liquid oil and solid catalyst (usually nickel) are brought together at a suitable temperature and pressure. It is common to further refine the hydrogenated oil before deodorization to improve the flavour stability.

Deodorization is the removal of small quantities of the more volatile compounds which helps to stabilise the odour and taste of the oil. It is usually carried out by vacuum steam distillation.

Liver oil can be extracted by centrifuging, direct steaming, vacuum cooking or solvent extraction. Vitamins A and D can be extracted from the crude liver oil by saponification (basic hydrolysis reaction) and polar extraction.

Further processes can remove environmental contaminants, such as dioxins, to counter any potential health concerns.

Products and Uses
Nowadays the major use for fish oil is the incorporation into animal feed, especially in aquaculture. Approximately 95% of UK produced fish oil is used for aquacultural purposes (ref United Fish Products). Recent studies have also shown the benefits of feeding fish oil to poultry, pigs and cows. A fish oil enriched diet is particularly beneficial for weaning and young animals. Not only do the animals show increased growth and resistance to disease, but recent studies have shown that animals fed on a diet rich in Omega 3 fatty acids store these components in their flesh or eggs, resulting in the health benefits being passed on through the food chain. In humans, Omega 3 fatty acids reduce the risk of coronary heart disease and appear to reduce susceptibility to inflammatory, allergic and immune disease, amongst other benefits.

There have been, and still are, many uses of fish oil within the food industry but this is now a much smaller market than animal feed. Uses include the manufacture of margarine, peanut butter, low fat milk and incorporation into retextured meat products. Other uses have been in metal processing and to make ink, soap, rubber, lubricants, paints and varnishes, leather treatment, insecticide compounding, fire retardants, fungicidal derivatives, rust inhibitors, candles, water repellents and plasticisers.

Liver oil not only contains significant amounts of Omega 3 fatty acids but has also been traditionally valued for its high level of Vitamins A and D, and lecithin which is extracted for pharmaceutical purposes.

Conclusion
The health benefits linked to the consumption of fish oils and the active research currently being carried out in this area are encouraging. The new generation of compact fishmeal processing equipment may allow large-scale processors to recover the oil from the pelagic processing waste or livers/viscera on site. It may make economic sense to prevent fish livers and viscera from being discarded at sea as this valuable raw material could be utilised for oil production. The concentrations of the pelagic industry may facilitate oil recovery.

5.3.3 Pet Food/Other Animal Feed

Pet food manufacturers demand the highest quality fish frames and offal, usually in a frozen block form. At the pet food factory it is defrosted, cooked and blended with other ingredients before being either canned or extruded to produce dried pet food. Generally, pet food manufacturers pay slightly more for fish waste than the fishmeal company, but some pay only the costs of transporting the material. Additional freezing costs are incurred if they require the material to be in frozen form.

Maggot farms require relatively small volumes of fish waste, and accept low quality material. Demand from maggot farms is unreliable but the prices offered for the waste are higher than the rates offered by the fishmeal company. Processors currently receive about £20 to £30 per tonne of material.

It may be also lucrative to pass fish waste through a deboning machine and distribute frozen mince to local retail outlets for the domestic pet food market.

Conclusions
Although supplying material to pet food/other animal food outlets currently provides slightly more income, processors should be aware that they may face penalties if they are breaking the requirements of any exclusive contract between themselves and the fishmeal company.

5.3.4 Fertiliser

For thousands of years, fish based fertiliser has been used to supply crops with a balanced source of nitrogen, phosphorous and potassium. Traditionally this was simply by spreading the waste on the land.

Liquid fish fertiliser is produced by mixing whole fish or processing waste with sulphuric acid, which releases sulphates and phosphates and reduces fishy odours. Alternatively the addition of urea solubilises the fish proteins, which become available to plants after being broken down by bacteria in the soil.

There are a number of advantages of using fish based fertiliser which has been solubilised with urea: the resulting fertiliser does not readily leach out of the soil and it releases nutrients into the soil slowly unlike modern chemical fertilisers.
Another source is the anaerobic digestion of fish waste which leads to the production of methane and sludge. The methane is generally recycled into the

digestion process to generate electricity/heat whereas the sludge can be used as an organic fertiliser.

5.3.5 Composting

Composting uses micro-organisms to convert the fish waste and plant material into a useful soil enhancer.

Raw Material
Highly nitrogenous fish material is most suitable for composting. The most common materials used include aquaculture mortalities, viscera, frames, whole oily fish and shellfish waste. These materials are relatively rich in protein and putrefy rapidly.

Production
Composting relies on mixing proteinaceous and carbonaceous matter in the correct ratio. The biologically optimum ratio for carbon to nitrogen is 30:1. Typically, nitrogenous fish waste is mixed with a rich source of carbon such as wood waste (sawdust, peat, wood chippings etc).

Composting usually takes about four to six weeks. Over this time, the waste is converted by micro-organisms into rich humus. Regular aeration is necessary to prevent overheating and the development of anaerobic ‘pockets’, both of which can destroy the useful bacteria. The heat generated by the microbial action pasteurises the product, eliminating odours and destroying weed seeds and disease organisms. The final compost products are generally rich in organic matter (40-70%) and contain between 1-4% nitrogen.

Products and Uses
Compost is used as a soil enhancer to improve the nutrient content of the soil in order to favour growing conditions. This has mass potential for both domestic and commercial markets, particularly as it is an organic product. A standard sack of compost (100 litres) retails at approximately £4.

Composting has been heavily researched and publicised in the United States as an economically viable fish waste disposal option. Fish based compost is currently being commercially produced, particularly in areas with large quantities of fish and forestry waste. The heat produced during the process is used to heat commercial greenhouses.

Conclusion
Although composting is well established in the UK, so far it has only been produced at pilot scale with fish waste. Given that composting is a process that can utilise all parts

of fish and shellfish and there is a significant market for the end product, it has significant potential. However, the process does require a significant area of land, preferably remote because of the odours produced, with a ready bulk supply of carboniferous material and fish waste.

5.3.6 Silage

Fish silage is a liquid product that can be made from a wide variety of fish species and which has a high nutritional value similar to that of the fish itself. It is a widely established product in Denmark and Scandinavia, which produce large volumes of silage for use as a pig feed. Silage is made either by the natural enzymic and microbial liquefaction/ digestion of fish or by the addition of acid.

Raw Material
Silage is usually produced from industrial pelagic fish such as capelin, herring, sprat, horse mackerel and sand eel, which are relatively low in value and caught in large quantities. Fish processing waste can be used as a raw material. Cartilaginous species such as skates or rays tend to take more time to liquefy and consequently are best mixed with other species. The protein digestibility, vitamin content and hence the quality of the silage is directly related to the quality of raw material, which should be processed as soon as possible after catching.

Production
The four basic stages of silage production using acid are shown in Figure 9.

In the first stages of the process, the fish is minced to rupture the cells. This increases the surface area and releases enzymes, reducing the liquefaction time. The minced fish is then transferred to a mixing tank where it is acidified by adding 3.5% formic acid to reduce the pH to 4 or below, which prevents bacterial spoilage. Hydrochloric or sulphuric acid can be used as cheaper alternatives to formic acid but they result in a lower pH than required and so the silage must be further treated before use. After the initial mixing, the silage process starts naturally. Occasional stirring helps to ensure uniformity.

Silage can also be produced by fermentation through adding a carbohydrate source such as molasses along with lactobacilli starter culture (lactic acid producing bacteria) to fish and fish waste. Lactobacilli convert sugar into lactic acid, which preserves the fish and creates favourable conditions for the production of silage. In addition to acid, some types of lactobacilli produce other substances, such as antibiotics or bacteriocins, which help to limit the growth of spoilage bacteria. The fermentation process has an optimum temperature (typically 25° to 30°C). There may be a requirement for heating at some times of the year.

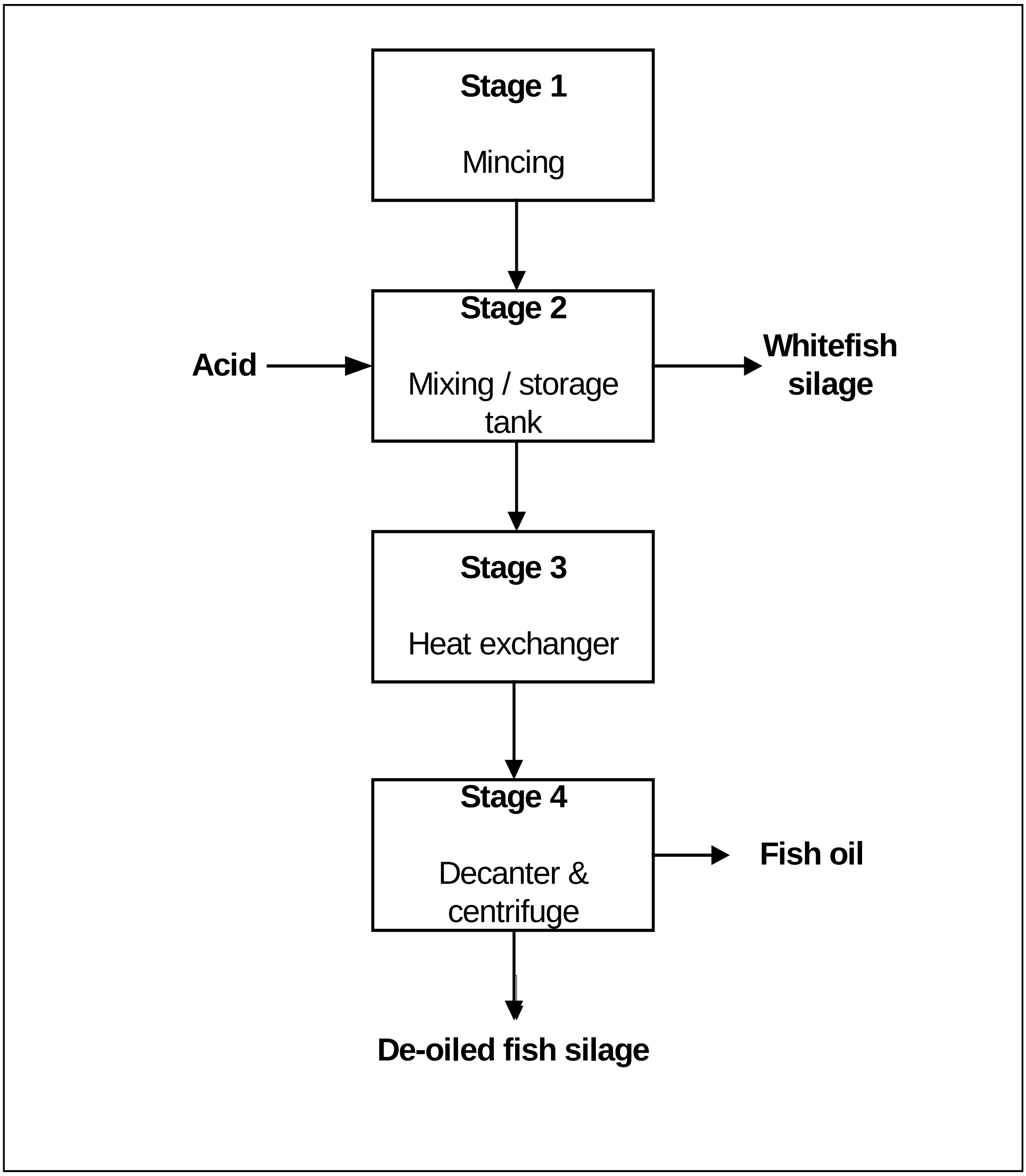

Figure 9 – The basic stages of silage production, using acid

Generally pelagic fish liquefy much faster than demersal fish and fresh fish liquefy quicker than stale fish. In all cases, the warmer the temperature the faster the process.

If pelagic fish are used, it may be necessary to reduce the oil content of the silage to below 2%, by heating followed by centrifuging. This prevents an undesirable fishy taint developing in the flesh of the animals fed upon it. Once the silage is prepared it can be transported as a liquid in bulk or containers.

Products and Uses
Fish silage can be used the same way as fishmeal in animal feed, however, liquid feeding and handling systems are required. Until recently fish silage was used primarily in a liquid form as a pig feed and to a lesser extent as poultry feed. The Danish pig industry is a major outlet for this material. However, in Norway fish silage has found a market in the manufacture of moist feed pellets for fish aquaculture and it can also be added to cereal to produce a drier feed for pigs.

Conclusion
In comparison to fishmeal, silage production is relatively simple and inexpensive with much lower capital equipment, production and labour costs. However, being in a relatively low concentration liquid form, the main disadvantages are transport costs. The silage process is more likely to succeed in areas where fish waste is regularly available and where pig farms are located nearby.

Production of a semi moist feed or paste product would reduce transport costs and open up new markets for silage products. Similarly the application of new concentration techniques such as membrane filtration technology may further reduce drying costs. If the silage process uses pelagic fish as a raw material, the fish oil recovered from the process can be sold as a product in its own right to offset drying costs.

Use as pig, poultry and fish feed escapes the ruminant feed ban but the material will remain subject to the proposed dioxin restrictions.

5.3.7 Fish Protein Hydrolysate

Fish protein hydrolysate (FPH) is a powdered product, typically cream in colour. It is produced by the use of enzymes to break down fish proteins into amino acids (proteolysis). The resultant product is highly functional, contributing whipping, gelling and texturing properties when used as an ingredient in food products.

Unlike silage production, specific enzymes and/or microbial starter cultures are added to the fish to accelerate proteolysis. Digestion parameters such as time, temperature and pH are tightly controlled to produce FPH with the desired properties.

Raw Material
Whole demersal fish or frames are the favoured raw material for FPH production, although the technology is available to utilise pelagic fish.

As pelagic species have a high oil content, this must be removed in order to prevent strong flavours forming in the product. To produce the most versatile product, the fish should be processed as soon as possible after catching.

Production
A typical process for the production of FPH, shown in Figure 10, involves first mincing the fish and adding it to a digestion vessel with water. A quantity of enzymes are added, with the amount depending on proteolytic activity and the percentage of protein in the reaction mixture.

The reaction time, operating temperature and pH are varied to suit the end product. At the end of the reaction, the protein suspension is drained off and filtered to remove bones and undigested skin. Pasteurisation follows to prevent further enzymic activity. To prevent deterioration of the product it is dried, normally by conventional methods. There are further variations in the production process, which are not described here.

Products and Uses
FPH is commercially produced in France where it is used as a milk substitute for young goats, lambs and pigs. In the USA, herring waste is fermented using molasses as the carbohydrate source and extruded to produce a pig weaning feed. There are many other fermented products including sauces made from a wide variety of species such as sardine, herring and squid. These are particularly popular in Asia.

It is likely that FPH will develop more commercial applications in the future. Work has shown that FPH can be used to produce a fish peptone broth, which makes an excellent microbiological growth media, especially suitable for culturing marine organisms. Hydrolysed fish products may become significant in pet food production.

In Europe, FPH is not currently produced commercially for use in products destined for human consumption. Until recently, its use has been limited due to fishy odours and bitter flavours. These can be reduced by selecting the correct enzymes and by controlling the degree of proteolysis. The unique flavour however is considered on advantage when FPH is used in flavourings, sauces or gravy.

One potential use for FPH is its development as a functional additive (binding agent) to produce a succulent fibrous texture and flavour to fish mince.

Conclusion

Despite its potential, FPH struggles to compete with soya bean as a protein source. It may have excellent functional properties but is more expensive than ingredients produced from vegetable sources. There are also negative perceptions of the associated odour and colour of FPH, which may be overcome with targeted marketing. With the continued research and development into FPH production it is likely that it will develop more commercial applications in the future.

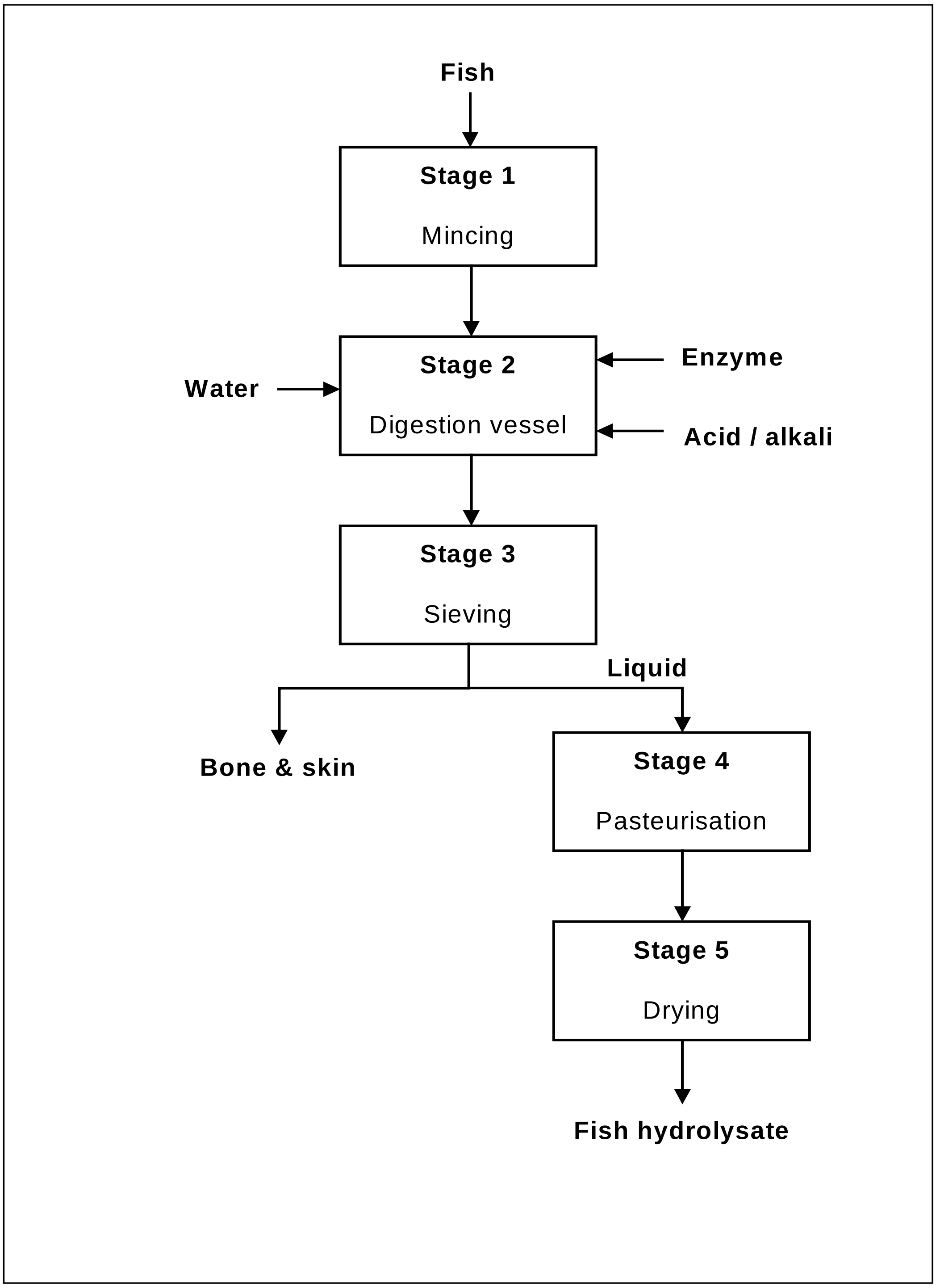

Figure 10 – A process for the production of fish protein hydrolysate

5.3.8 Fish Protein Concentrate

Fish protein concentrate (FPC) is a highly nutritious powdered product with a protein concentration higher than that of the original fish, intended for human consumption. Although nutritious, FPC generally has poor functional properties. Depending on its quality and degree of refinement, it can be either used as a food ingredient to boost protein content or, as in some less developed countries, eaten directly as a food product in its own right.

FPC can be categorised into three grades. Type A is a tasteless, odourless white powder whilst Type B retains a fishy flavour and odour. Type C is essentially hygienically produced fishmeal.

Raw Material
FPC can be made from almost any size or species of fresh fish. The fish should be processed as soon as possible after capture to produce a high quality Type A product. Work has shown that the raw material can be stored for up to eight days on ice before the nutritional value of the resultant FPC is affected. Only material suitable for human consumption should be used.

Production
The production of types A and B is fairly complex. Raw fish is minced and multi-stage solvent extraction using ethanol or propanol is carried out, along with centrifugation, to remove water, fat and fishy flavour/odour components.

At each stage of the process the solid cake becomes more concentrated. For type A production, the fat content is reduced to less than 0.75% compared to 3% for type B. The FPC is then dried and milled into a powder. Type C production is relatively simple as it can be made using a hygienic fishmeal process.

Products and Uses
FPC Type A has been added to a wide variety of products including staples such as bread, pasta, soups, rice dishes and stews as well as many other foods including milkshakes, biscuits, infants foods etc. However, the high degree of solvent extraction destroys any functional properties of the protein such as binding, gelling and whipping. Type A has never found commercial use in the USA due to regulatory problems with the FDA. Other countries produced it until about 1980 and it has been used as a protein supplement in less developed countries.

Type B FPC has been trialled as a nutritional supplement in developing countries such as India, Sri Lanka and Indonesia where products with a strong fish flavour and odour are enjoyed. The acceptance of FPC in this form was generally good. There was, however, negative reaction in countries where only very fresh fish are eaten.

Conclusions
Type A FPC is far more costly to produce than Type B due to the complex level of processing required to achieve extreme blandness. It is likely that developments in soya bean protein production, which gives a very similar product at lower cost effectively ended FPC-A production. FPC-B is currently promoted and still being produced as a food product in its own right.

Recent work has shown that enzyme modification of FPC gives a bland flavour with good functional properties. In this form FPC may find applications as a food ingredient.

5.3.9 Seaweed

Seaweeds are marine plants which are rich in nutrients, trace minerals and carbohydrates. They contain compounds which possess excellent functional properties which make good gelling and thickening agents. Common seaweeds, which form the basis of international trade, include the brown seaweeds (*Macrocytic*, *Hizikia*, and *Laminana*, commonly known as 'kelp' and *Undaria* spp.), red seaweeds (*Porphyria* spp.) and the green seaweeds (*Caulerpa*, *Ulva* and *Enteromorpha* spp).

Raw Material
Seaweeds can be either harvested from wild beds or farmed. Harvesting is either carried out by hand picking or by using equipment which trims off a proportion of the plant allowing it to rapidly grow back to be re-harvested many times.

Product and Uses
In Japan brown seaweeds are eaten as a vegetable, used to make stock or sold in dried form as a seasoning or ready to eat snack. Red algae provide an important source of carageenan and agar which are valuable compounds with excellent functional properties which are used in the human food industry as gelling and thickening agents. Brown algae yield algin, laminarin and mannitol (carbohydrates) which are used for animal food and fertiliser. Porphyria (purple larva) has a high protein content (25% to 35%) and is sought after for wrapping sushi. Some seaweeds can command a high price, so much so that some developing countries import expensive western fertilisers to fertilise large ocean growing areas. Recently, seaweeds have been used in healthcare products such as moisturisers and cleansers, and in healthfoods.

Conclusion
The uses for seaweed are of potentially high value. Although seaweeds are not a direct by-product of the fish industry, they may provide an opportunity to diversify into different products, particularly for in-shore vessels.

5.4 Non Nutritional Uses

5.4.1 Chitin and Chitosan

Chitin is a naturally occurring non-toxic, biodegradable polymer which is found in abundance in nature. Chitin and chitosan are industrially manufactured from shellfish waste, the main producers being Japan and the USA. After extraction, chitin is converted into a more readily usable form called chitosan which has many commercial uses within the water treatment, cosmetic, food and pharmaceutical industries.

Raw Material
Chitin is commercially extracted from crab, shrimp, lobster, prawn and other shellfish processing waste which contain 14% - 35% chitin on a dry weight basis. The shells of bivalve shellfish such as clams and oysters contain relatively low levels of chitin (3-6%) and the small amount of chitin is complexed with a high proportion of minerals which often makes extraction uneconomical. Cephalopods such as squid and cuttlefish contain up to 40% chitin in their backbone. The extraction of such a pure source of chitin has the advantage of not requiring a demineralisation step to remove calcium salts, but unfortunately the backbone of squid only represents about 1% of the total body weight.

Whatever the chitin source, the raw material should be processed as soon as possible after catching to limit microbiological and enzymatic spoilage which reduce the chitin yield.

Production
The important properties of chitosan vary with the type and quality of raw material. However, desirable properties can be selected by controlling the amount of protein and mineral impurities present in the final product. This is achieved by carefully controlling the processing conditions. Chitin can be produced in either a water soluble or non water soluble form. The production of chitin and chitosan using traditional chemical methods is shown in Figure 11.

The first stage of chitin extraction is to finely grind the shell waste. Valuable carotenoid pigments such as B carotene, canthaxanthin and astaxanthin are extracted into a non-polar solvent, such as edible oil, at 60^{o}C. Deproteinisation and demineralisation are carried out by washing with dilute acid and alkali to produce chitin.

Deacetylation of the chitin by a concentrated alkali at high temperature produces chitosan.

There are also new biological methods for extracting chitin, which produce a more consistent product than traditional chemical methods. Biological methods involve using milder treatments to remove some of the components associated with the shell, such as proteins.

Investigations have involved removing the flesh from crustacean waste by enzymic digestion, by growing proteolytic bacteria on the shells or by using proteolytic enzymes (protein splitting).

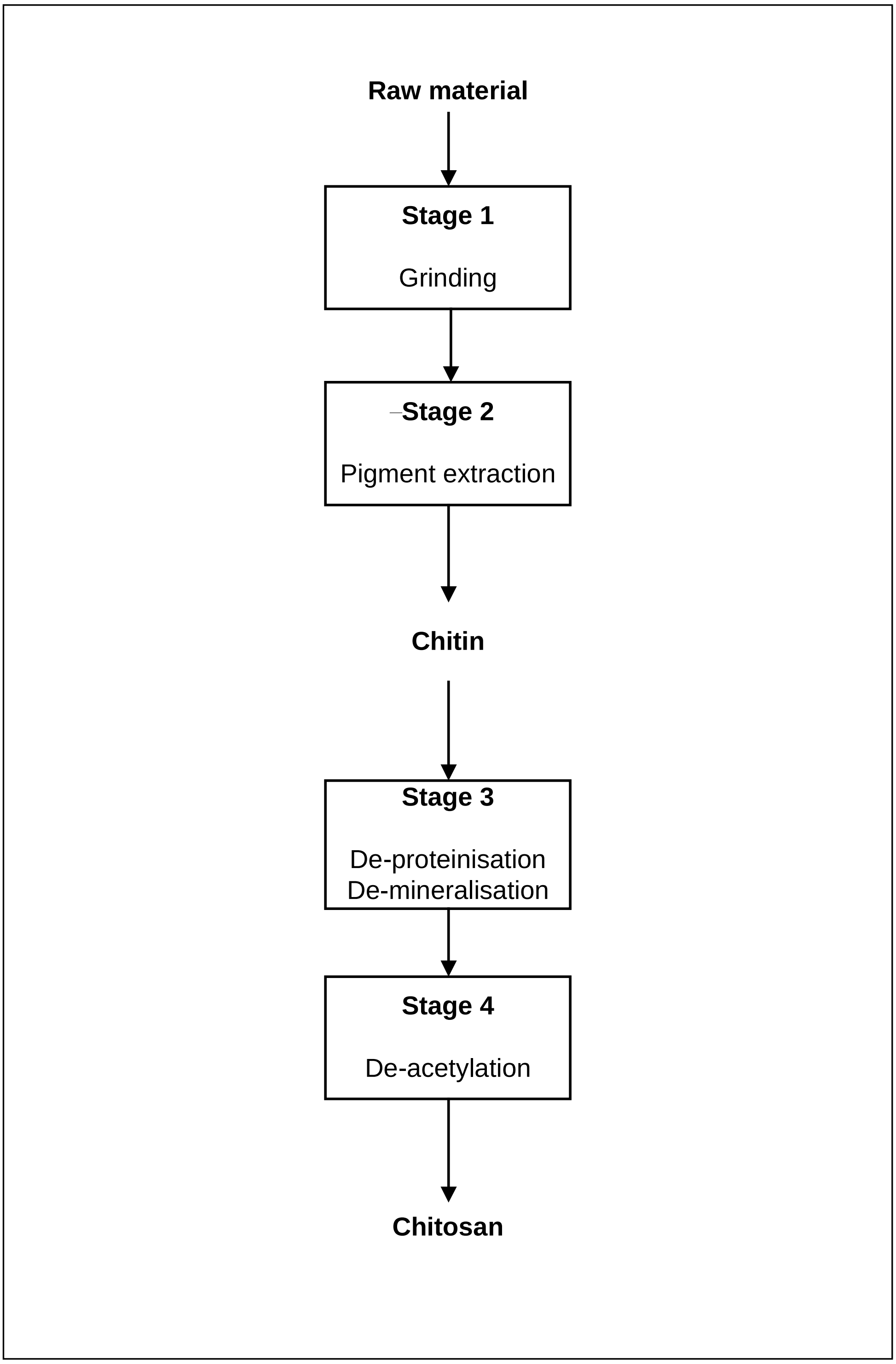

Figure 11 – Chemical chitin and chitosan production

Of a series of enzymes tested, chymotrypsin was found to be the most effective, achieving a similar degree of deproteinisation to that of the chemical method. Lactic acid fermentation can also be used as a biological method to extract chitin. This is essentially a controlled fermentation process whereby *lactobacilli* and a carbohydrate source are added to the waste. The lactic acid produced dissolves the calcium carbonate mineral content of the shells, resulting in a liquefied material from which valuable protein, chitin and pigment components can be obtained. The activity of the *lactobacilli* also inhibits spoilage organisms.

Chitosan can also be biologically recovered from chitin using enzymic methods or fermentation. Again this produces chitosan with consistent properties.

Products and Uses
The majority of industrially produced chitosan is used in the drinking water and waste water treatment industries to remove heavy metals, pesticides and dyes from contaminated drinking water. In effluent treatment, chitosan is used as a coagulating agent to remove proteins and aid clarification. It has the advantage over traditional chemical flocculating agents in that it is non-toxic and so the recovered organic waste can be used in animal feeds.

In paper production, chitosan can be added to wet pulp to give high strength to the finished paper. In the cosmetic industry it is used in the development of hair and skin-care products. A potential opportunity with significant scope is its use as an active ingredient in ion-exchange filters.

The medical uses of chitosan include its incorporation into bandages to reduce inflammation and promote wound healing. Purified chitosan is used in hypocholesterolemic treatment to reduce cholesterol levels in the blood. It is also used in controlled or targeted drug release systems. Other medical uses include as a blood coagulant during vascular surgery and in dental care to prevent bacterial plaque formation.

In the food industry, chitosan is used to clarify fruit juices. The functional properties of chitin and chitosan make them attractive food additives as they can be used as gelling, thickening, adhesion or extending agents. Chitosan can also be used for texture control of foods, as an emulsifier and as a food preservative.

Chitin incorporated into animal feeds at 0.5% level has been reported to decrease the animals food consumption whilst increasing the body weight. It has been suggested that the antibody behaviour of chitosan may reduce the need for regular antibiotic doses in feed. Chitosan may also have significant potential in agricultural uses as it can act as a fungicide, virucide, growth enhancer, nutrient carrier and as a protective agent for plants and trees.

Conclusions
Although chitosan has been commercially produced for 20 years the total amount of chitosan produced each year is relatively low, at several thousand tonnes.

Over the past few years there has been a dramatic rise in the number of new and potential uses for chitin and chitosan within the food, pharmaceutical and agricultural industries.

Commercial prices vary according to the grade of the product. Purified powder can cost up to £50 per gram.

It is expected that the growth in demand and production of chitin and chitosan will continue. However, achieving a regular and consistent supply of high quality raw material appears to be a current major concern of many large potential users and producers of chitin. Biologically extracted chitin is typically more expensive than chemically extracted chitin but costs may be offset by utilisation of by-products such as the proteins and natural pigments. The concentration of the *Nephrops* processing industry in the UK could potentially provide the basis for commercial production.

5.4.2 Carotenoid Pigments

Carotenoid pigments are a group of pigments which give fish and shellfish their red and pink colouring. These pigments cannot be synthesised by the fish and shellfish themselves so must be taken up in the diet. They play an important part in the development and life cycle of the animal which makes them an essential and valuable component of aquaculture feeds. Carotenoid pigments are commercially extracted from shellfish waste during chitin and chitosan production.

Raw Material
Carotenoid pigments are extracted from crab and shrimp processing waste. The pigments are present in very small amounts (120-150 µg/g) in the shell of the animal. Shells should be processed soon after capture to prevent enzymic and microbiological degradation.

Production
The main carotenoid pigments extracted from shellfish waste are astaxanthin and canthaxanthin which are marketed commercially as Carophyll® pink (8%) and Carophyll® red (10%).

These pigments are usually extracted during commercial chitin production using a non-polar solvent, such as edible oil, at 60°C with an oil to discard ratio of 2:1. Another extraction method uses proteolytic enzymes to extract the pigments in their natural state (bound to protein). In this stabilised form pigments are taken up more readily by farmed fish and have the further advantage of boosting the protein content of the feed.

Products and Uses
The main use of these pigments is in commercial aquaculture feeds to provide colour and to ensure maximum growth and development of fish and shellfish. In some fish species, heavily pigmented males have a breeding advantage over less pigmented males. Research has shown that red trout eggs hatch more effectively than pale eggs, as the pigments are thought to act as sperm activators. Consumer research into farmed salmon has shown that customers tend to purchase fish only with the characteristic pink/red colouring.

Other promising uses of astaxanthin and canthaxanthin include nutraceutical and pharmaceutical applications. Astaxanthin has strong antioxidative properties and is proven more effective than beta-carotene and vitamin E, which are commonly used in anti-ageing products. Astaxanthin is soon to be launched in America as a nutraceutical product following trials which highlighted its effectiveness in treating Alzheimer’s and Parkinson’s Diseases, cholesterol disease, strokes and cancer.

Current prices for astaxanthin are in the region of £92 per gram.

Conclusion
The future of the fish feed market is promising, as aquaculture is expected to grow from $34 billion per year (equivalent to 24% of total global fisheries production) to $49 billion by 2010. The demand for these high value pigments for incorporation into aquaculture feeds can only increase.

Again there would appear to be potential here, in conjunction with chitin/chitosan recovery, for utilisation of *Nephrops norvegicus* waste.

5.4.3 Enzymes

An enzyme is a biological catalyst which can be used to speed up a favourable chemical reaction. A range of protease (protein splitting) enzymes including pepsin, trypsin, chymotrypsin, collagenases and calpains can be extracted from the gut and viscera of demersal and pelagic fish, cephalopods and shellfish.

Raw Material
Enzymes are commercially extracted from cod viscera in Norway and Iceland. It is likely that the viscera of most other species of larger fish could also be used as a source of raw material. To achieve maximum enzyme extraction from the raw material, it is vital that the viscera are processed as soon as possible after removal, as spoilage will reduce the quality and yield of enzymes.

Production
Enzymes are currently extracted from the fish viscera using classical methods. A typical enzyme extraction process involves mincing the fish, followed by repeated centrifugation and precipitation to remove solid material and concentrate the enzyme. This would be followed by purification and drying to stabilise the enzyme.

Other methods in commercial use include the recovery of pepsin from silage made from whole cod viscera. The enzyme is concentrated by ultrafiltration before drying.

Products and Uses
The unique characteristics of fish enzymes enable them to work at low temperatures and a range of neutral to alkaline pH values when other non-aquatic enzymes are reduced in efficiency. Fish derived enzymes are currently used commercially in fish processing applications to remove skin, scales and membranes that are otherwise difficult to remove e.g. tuna or skate skin. They can also be used in roe processing to hydrolyse the roe sack, allowing the release of up to 50% more roe than the traditional rotary drum separator process alone.

The special characteristics of fish derived enzymes are invaluable for many food processing operations. Cod pepsin is used to prevent off flavours developing during the ageing of cheddar cheese. Trypsin has been used for the recovery of carotenoid pigments from crustacean waste for use in aquaculture feeds however there are still some technical problems which have to be overcome. Fish enzymes are also used in baking, meat tenderisation, milk, leather production, caviar, fish sauce and fish flavouring production.

Other uses of fish enzymes include the production of FPC as an additive in aquaculture feed to aid fish digestion.

In France, enzymes are used commercially to recover flavourings from fish and shellfish. Essentially the material is liquefied to enable the removal of bone and shell and the remaining material used to make concentrated flavourings.

Conclusion
Enzymes are a valuable commodity. Atlantic cod trypsin costs approximately £60 per 5mg vial. Fish derived enzymes are not as popular as enzymes from other sources as they are not as well understood, the raw material may only be seasonally available and they are considered unattractive due to preconceived ideas about odours. It is expected that the demand for these unique enzymes will dramatically increase in the future as further work into biotechnology continues.

5.4.4 Leather

Fish skins can be processed in the same way as terrestrial animal skins to make leather. Fish leather is supple, soft, breathable, strong and often attractively patterned.

Larger fish are more suited to leather production due to the size of the skins. Common sources of leather include shark, salmon, ling, cod and hagfish skins, which are used to make clothing, shoes, handbags, wallets, belts and other small items.
Currently there are a significant number of companies in Alaska, Canada, North America and Korea advertising fish leather products on the Internet.

5.4.5 Mollusc Shells

Mollusc shells can be utilised in a variety of ways. Milled shells can be used in animal feeds as a calcium source, which is especially important for laying hens. The Dutch mollusc industry utilises large quantities of shell for this purpose. The shell is returned to the sea for natural cleansing after processing has removed the meats, and is re-harvested later for milling. Clean shells are not subject to animal waste disposal restrictions, however, there are restrictions on disposing of material to sea.

Shells can be broken up for use as a hard core for road foundations or driveways or as an attractive substitute for gravel. Washed, crushed and sorted shells are currently retailing at about £20 for 25kg. Whole, washed cockle shells are currently retailing through a major DIY chain at about £7 for 25kg. Certain shells are sought after by collectors or used as a raw material in jewellery manufacture.

5.4.6 Pharmaceuticals, Cosmetics and Fine Chemicals

A range of medical and high value chemicals have been produced from fish and shellfish. Antifreeze proteins have been extracted from the blood of cold water fish. These glycoproteins are known to protect mammalian cells at cryogenic temperatures, and have found uses in the cold storage of donor tissue and organs.

Deoxyribonucleic acid (DNA) is commercially extracted and purified from cod, herring and salmon milt in Tromsø, Norway for pharmaceutical use. The DNA can be further processed into the drug AZT, which has been used in the treatment of HIV.

Research has been carried out into glycogen poly-sugars which are contained in the stock left over from boiling scallop processing waste. The sugar has been shown to have anti cancer properties when injected into animals at a dose of 200 mg.

Squalene is a naturally occurring hydrocarbon found in some plant and fish oils. It is commercially extracted from shark livers. Squalene was used to treat diabetes and tuberculosis in Japanese hospitals but in subsequent years was used in cancer treatments. It also has anti-fungal and antioxidative properties, providing scope for other pharmaceutical and cosmetic uses. Purified squalene currently retails at about £200 per litre.

5.5 Traditional Uses

Many of the traditional co-products derived from fish have been replaced by more modern materials. Some of them are still used but usually in small-scale or specialist applications.

5.5.1 Collagen

Collagen is the most common protein in the animal kingdom. It is the principal protein found in skin and bones. Collagen can be isolated from the skin, bone and fins of fish waste. It is extracted by dissolving the waste material in heated dilute acid or salt solution. Collagen, extracted from the swim bladders of sturgeon, is used as the source of isinglass, which is a clarification agent for beer.

The swim bladders of other deep, cold water fish can also be used. Other uses include gelatin production, nutritional supplements, sausage casings and in cosmetic products claiming anti-ageing properties. Fish derived collagen has experienced a recent revival in demand due to the BSE situation.

5.5.2 Fish Glue

Fish glue can be made from either fish skin or fish frames. The choice of raw material controls the characteristics of the final glue product. Fish skins are the most popular raw material. The first stage of the process is to wash the skins in water before treating them with an alkali. This is followed by neutralisation and another washing stage. The treated skins are then steamed for eight hours to extract the glue.

Fish glue is still used by some traditional cabinetmakers because its relatively long drying time allows glued joints to be moved and adjusted. Apart from this, fish glue has effectively been replaced by modern adhesives which offer desirable characteristics that are lacking in liquid fish glue.

5.5.3 Gelatin

Fish gelatin is a clear sweet solution with the capability to form gels. It is produced by hydrolysis of collagen in a process similar to that of fish glue production but at a much lower temperature and over a shorter time to ensure the removal of impurities. Fish gelatin has been used in food products, photographic processing, coating applications and in the chemical etching of metals. Unfortunately gelatin from aquatic sources is not as good as animal gelatin and now has few uses. However, it has recently seen an increase in demand due to the BSE situation.

5.5.4 Pearl Essence

Pearl essence is an iridescent chemical called guanin which gives fresh fish its iridescent shine. The scales of pelagic fish are a potentially rich source of guanin. Extraction can be carried out by several methods including protease digestion followed by organic solvent extraction, or gentle agitation in a small amount of water followed by centrifugal separation. After extraction the guanin crystals are stabilised in either an organic or aqueous suspension.

Guanin is mixed with lacquers and plastics to give a pearl effect used in jewellery, other fancy goods and nail varnish. Guanin has now been largely replaced by titanium compounds, which give the same effect but are cheaper to produce.

6 Discussion

From capture to processing, the UK fish industry produces a very large quantity of fish waste. Of an estimated total resource of 850,000 tonnes, approximately 43% ends up as products for human consumption whilst the remaining 57% is classed as fish and shellfish waste. Of the total quantity of waste produced, the majority (301,037 tonnes) is produced in the processing sector, although the quantities of waste from fish discards and processing at sea are also significant. Much of this waste production is concentrated in regional processing centres.

With shortages in UK supply, the quayside costs of fish have been steadily increasing over recent years. A tonne of cod currently costs in the region of £2,000. Of this, approximately 50% is discarded by processors as a low value by-product or as waste. For shellfish this waste can constitute as much as 87% of the liveweight of the animal. Currently, little is done to realise this 'lost' investment or the potential value of the waste material,

Fishmeal and oil production remains the major use of fish waste in the UK. Fishmeal and nowadays fish oil are largely used in animal and particularly aquaculture feed. Despite the very considerable benefits of these materials, EU restrictions on the use of meat and bone meal and further problems of dioxin contamination may affect these markets. The maximum earned for fishmeal and oil production is about £70/tonne for high grade pelagic fish waste although UK pelagic processors usually receive about £30/tonne. Demersal fish processing waste earns about £10-£30/tonne in Humberside and Grampian where there are fishmeal plants. With only three large fishmeal plants in the UK, much of the fish waste produced in the more remote regions ends up being disposed of at landfill sites, at costs of about £60 per tonne. These landfill costs are likely to increase yet further in the future as a result of environmental policy.

The fish processing industry is being squeezed between high raw material costs and product price competition in the retail sector, with imported products being readily available, whilst operating costs also increase. The industry cannot afford not to make better use of its waste.

The wastage of discards at sea results largely from fisheries management policy and has to addressed by changes in that policy. Processing waste produced at sea could potentially be brought ashore at the major landing centres and be utilised together with the processing waste produced ashore.

The processing industry is aware of the need to maximise the yield of food products from its raw material. A number of options for this have been identified and are described, including fish mince production and utilising parts of the fish such as roes, tongues, stomachs and fins, all of which find good markets in some parts of the world. Fish soup, paste and sauce production are further options.

Even after maximising the direct food product yield, a large quantity of waste will remain. This waste material is rich in potentially valuable oils, minerals, enzymes, pigments and flavours, etc. that have many alternative uses in food, pharmaceutical, agricultural, aquacultural and industrial applications. There has already been considerable research into potential production and uses of these materials and a number of such options have been identified and are described.

These include a range of agricultural, aquacultural and human nutritional uses, apart from fishmeal and oil production, such as silage, fertiliser, composting, fish protein hydrolysate and fish protein concentrate. Non-nutritional uses include chitin and chitosan production and carotenoid pigments from shellfish, enzyme extraction, fish leather and fish glue, pharmaceutical, cosmetic, and fine chemical uses, and collagen, gelatin and pearl essence production. Many of these uses are commercial reality in other parts of the world and, no doubt there are many other potential uses.

In the UK context there is concentration of waste production at the major landing/processing centres, which is advantageous in respect of establishing co-product manufacturing industry, but the needs of the outlying regions also need to be taken into account. The concentrations of the pelagic industry potentially facilitate oil recovery. The concentrations of the *Nephrops* industry potentially facilitate chitin/chitosan and carotenoid pigment extraction. More basic processes such as ensilage, composting and fertiliser production may be more suited to smaller scale operations in remoter regions and, indeed, because of the odour implications some of these processes may require remote locations. The need for a local market for some of these products, such as silage, is another factor to be considered.

Currently, much of the fish waste generated in the UK is of poor quality; it is not hygienically handled and storage temperatures are often uncontrolled leading to rapid spoilage. In order to yield the best quality for many of these co-products, which in turn would generate the most income, fish waste would have to be handled and stored under hygienic conditions and suitably preserved. Investment in freezing equipment may be necessary for some products.

There is a gulf between the science, together with the technical possibilities of fish waste utilisation, and commercial reality in the UK. Although the options described are technically feasible, many are unproven in the UK and they are not necessarily commercially feasible. Commercial feasibility will depend on finding the necessary investment capital, which in turn will require assurance of supplies of raw material and of markets for the products, and of a favourable balance between revenue and costs. To help bridge this gulf, Seafish is prepared to act as 'facilitator' between the developers of fish waste utilisation technology, the markets for the products and the fish industry itself. Pilot projects in this area may qualify for financial assistance. For further information on developing collaborative projects please contact:

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