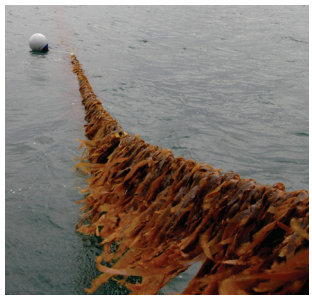
Part 1

Bord Iascaigh Mhara
Irish Sea Fisheries Board

A Market Analysis towards the Further Development of Seaweed Aquaculture in Ireland



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This document is an output of the project, PBA/SW/07/001(01), 'Development and demonstration of viable hatchery and ongrowing methodologies for seaweed species with identified commercial potential'. This project is carried out under the Sea Change Strategy with the support of the Marine Institute and the Marine Research Sub-programme of the National Development Plan, 2007-2013.

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Executive Summary

According to the Sea Change Strategy (2006), the Irish seaweed production and processing sector will be worth €30 million per annum by 2020. If this target is to be reached, then the sector must capitalise on the existing wild resource and it must necessarily expand seaweed aquaculture to augment supplies of higher value seaweeds and to provide product into the abalone and urchin farming sector, which has an estimated need of 2,000 tonnes of wet product per annum, at full production capacity. Seaweed aquaculture in Ireland is limited to only a small number of licensed sites at the current time. According to the most recent data (1997) supplied by the Department of Communications, Marine and Natural Resources (DCMNR) and the Department of Agriculture Fisheries and Food (DAFF) to BIM, there is one algal aquaculture licence in Waterford, two in Cork and one in Galway. That said, at least three further licences have now been applied for, and one has been approved in Kerry. It is hoped that work undertaken during the course of this research project, PBA/SW/07/001(01), 'Development and demonstration of viable hatchery and ongrowing methodologies for seaweed species with identified commercial value', will facilitate the licensing and further development of seaweed culture in Ireland. By perfecting culture techniques and making information available to stakeholders, it is anticipated that further engagement can be facilitated to move the seaweed aquaculture sector forward in Ireland.

Ireland's seaweed and biotechnology sector is currently worth €18 million per annum (Morrissey et al., 2011), it processes 36,000 tonnes of seaweed (wild product) and employs 185 full time equivalents (Morrissey et al., 2011). The product source is currently limited to the wild resource and product range is limited in the main to high volume, low value products such as animal feeds, plant supplements, specialist fertilisers and agricultural products. A smaller proportion goes into higher value products such as foods, cosmetics and therapies. In order to gain more from this industry, it is proposed that processors move down the value chain in order to achieve higher returns from their product. In order to do this, it is suggested that the industry needs to introduce automation and more sophisticated processing and packaging techniques. Reducing labour costs is considered a key driver of increased competitiveness in the sector. Moving away from the more traditional wild species and applying aquaculture techniques to create sustainable year round supply is also key to industry development.

Laminaria digitata and *Palmaria palmata* are two seaweed species identified as offering opportunity for cultivation in this project. *Laminaria* can be grown on long lines at sea, while at the current time, vegetative growth of *Palmaria* in tanks is the growth method that has shown success. *Laminaria digitata* can be fed as a macroalgivore diet to farmed abalone and urchins. On the other hand, *Palmaria palmata*

is considered a food delicacy and most of the national production is sold and consumed domestically (16-30 tonnes), however there is increasing demand from Spanish and French markets for the product. National production of *Laminaria* is likely to be the same or lower than *Palmaria.* *Palmaria* can also be fed to abalone. The combined requirement for these two seaweeds from the current macroalgivore sector in Ireland is 1,500-2,000 tonnes of product. While the requirement to feed macroalgivores is significant in its need for volume production of seaweed from farming, the production of significant tonnage should not allow for market distortion in terms of the value added/processed product. Dried and packaged bulk *Palmaria* makes of the order of €16-€19/kg while *Laminaria* typically makes €10-€16/kg for bulk quantities.

The value added opportunity for *Palmaria* is significant and pickers of wild product can augment their supplies by cultivating product. New technologies should be investigated to allow further automation of processes, including washing, drying, milling and packaging. A variety of Agencies now exist where linkages can be established for new product development, in particular, for example, in the increasingly fashionable area of functional foods, for example, the BIM Seafood Development Centre, Clonakilty, The Food Technology Centre, St Angelas College, Sligo and Spice O' Life Ltd in Dunmanway, Cork.

Ireland is trading on its 'clean green' image. Seaweed is used in spas and in cosmetics. New food products can be marketed using the promise of the 'Ireland Brand'. This brand stands for provenance, truth, good value and quality. Ireland has a great number of good restaurants, farmer's markets and established export markets for seafood products which can be capitalised on by innovative thinking.

1 Introduction

The Irish Seaweed industry has received much attention in recent times. The State Development Agencies, DAFF, Research Bodies and Industry Organisations have been united to a greater extent in their intentions to facilitate the development of the sector to realise its full potential.

1.1 The Wild Resource

The important issues that have come under the spotlight in recent times have included:- the potential for mechanical seaweed harvesting in Ireland, the licensing of aquaculture sites for seaweed culture and the conservation of seaweed (kelp) beds as important nursery systems for a variety of fish species. Tapping into the undisputed wealth of this natural and abundant resource has proved difficult because of the sometimes opposing interests of the organisations involved. Achieving consensus through dialogue is important. To this end, a policy group comprising representation from BIM, National Parks and Wildlife Service (NPWS), DAFF and the Marine Institute (MI) was set up with a view to determining policy in the area of seaweed. Issues tabled included the possibility of the mechanical harvesting of kelp in Ireland. The details of these discussions are beyond the scope of the current document. Suffice to say at the current time, there is considerable interest in the possibility of mechanical harvesting of seaweed. The representative agencies, in this case, NPWS and MI are operating under the precautionary principle and would like to see harvesting trials over several growing seasons to allow for regeneration studies, before any harvesting licences are issued. At the time of writing, it is understood that a Foreshore Licence for mechanical harvesting of seaweed in specified areas in the South West is about to be issued. Seaweed harvesting is carried out extensively in Norway and France. A BIM document (Walsh unpublished, 2006) on the French and Norwegian seaweed harvesting sectors is available. In France, small half - deckers operate a 'Scoubido' which is a mechanically operated turning and cutting device which is used to harvest weed in particular, from rocky shore coastlines. In Norway, the boats use a rake to drag the seashore for weed. The Norwegian seaweed harvesting industry is regulated on a grid type system whereby a square is fallowed for five years after harvest to allow for regeneration.

1.2 Project, PBA/SW/07/001(01)

The direction of research funding towards sustainable seaweed development activity involving aquaculture, through projects such as this, is invaluable. The project, PBA/SW/07/001(01), 'Development and demonstration of viable hatchery and ongrowing methodologies for seaweed species with identified commercial potential', is a landmark project has been carried out under the Sea Change Strategy with the support of the Marine Institute and the Marine Research Sub-programme of the

National Development Plan, 2007-2013. The project, which aims to commercialise techniques for hatchery production and ongrowing of the two identified species, *Palmaria palmata* and *Laminaria digitata,* has run for over three and a half years, 2008-2011, and represents a unique blend of industry participants and academic institutions. The research providers, Queen's University Belfast (QUB) and National University of Ireland, Galway (NUIG) provided key knowledge to the project in the form of scientific know-how and experience in seaweed research. The industry partners comprised six small and medium sized enterprises (SME's). The industry partners are Cartron Point Shellfish Ltd., Tower Aqua Products Ltd., G and B Barge Ltd., Cleggan Seaweed Ltd., Roaring Water Bay Seaweed Co-operative Society Ltd and Irish Seaweeds Ltd (formerly, Dolphin Sea Vegetable Company). Other interested groups who have been issued with licences during the lifetime of this project have accessed the information arising from the work of the project team and have been offered seaweed collectors for ongrowing weed at sea. The industry partners can be categorised as (1) active aquaculturalists:- These are individuals with licensed sites for seaweed culture, individuals involved in aquaculture (abalone farmers) who wish to start seaweed culture to feed farmed abalone and urchins; and (2) processors:- individuals who are involved in processing wild seaweed for the food sector. Because of the mix of personnel and specialisms within the project group, there has been a unique learning opportunity created for both industry associates and academics alike.

1.3 Guiding Policy

In considering the marketing report , the Project Team looked at the available literature which described the guiding principles for the Irish seaweed sector. The Sea Change Strategy (2006) which outlined 'A Marine Knowledge, Research & Innovation Strategy for Ireland' for the period 2007 – 2013', set the target for seaweed. In relation to seaweed development, the report stated:-

By 2020, the seaweed sector will have evolved from the current hybrid of declining wild harvest and fledgling aquaculture production into a sector with:

- Sustainable, scientifically based harvesting of kelp, *Ascophyllum nodosum*, fucoids and maerl;
- Seaweed from aquaculture production forming the basis for downstream processing of value-added biopharma and nutraceutical products
- Regular use of seaweed in biotechnology

In 2020, the seaweed production and processing sector will be worth €30 million per annum and will play an increasing socio-economic role as part of the mosaic of marine resource utilisation, in the context of marine spatial planning and coastal zone management.

Douglas-Westwood (2005) is quoted in this report, giving figures for the value of global markets for marine industries (2005-2009). During that period, seaweed had a global value of €33 billion, more than the global value of marine commerce at €29 billion, marine IT @ €16 billion, minerals and aggregates @ €15 billion. Seaweed is an enormously valuable natural resource which has a global presence in the market place. The challenge for Ireland is to capitalise on this resource.

1.4 The Opportunity

The identified opportunity is to increase the value of the Irish seaweed sector from €18 million per annum to €30 million per annum by 2020. Both the wild seaweed resource and cultured seaweed are included in this expansion. The Irish seaweed industry is still made up of exploitation of the wild resource; aquaculture remains in its infancy for a variety of reasons. There are certain identified issues that will shape if, and how, the expansion will take place, which are beyond the scope of this document. Licensing of wild harvest of seaweed and licensing of aquaculture activity will have a bearing on increased availability of product.

This document takes a pragmatic look at the Irish seaweed industry and the current market, and identifies the species that are commercially exploited and the processes that are applied to them. It sets out a road map for increasing the value of the wild resource by moving product down the value chain to afford greater returns. The document also identifies new technologies and new products to add value.

For the aquaculture sector, which aims to culture and exploit different species, in this case *Palmaria* and *Laminaria*, novel uses, new products and differentiated marketing techniques are identified. The document also looks at the unique advantages that aquaculture can offer to the production cycle and, for the first time, applies them. Cultured seaweed offers traceability, continuity of supply, provenance and the possibility of organic certification. In an increasingly food and health conscious world, the benefits of seaweed in the diet are well known. It will be necessary to diversify the product range. Products are identified and their potential values documented. The potential of aquaculture supply to feed macroalgivores is identified, in particular for the large, state of the art, abalone recirculation units recently commissioned on the South West and West Coasts of Ireland.

This report should be read in conjunction with Part 2 ‘Business Plan for the Establishment of a Seaweed Hatchery and Grow-out Farm’. The document evaluates the cost of setting up a seaweed hatchery and seaweed grow-out farm producing *Laminaria* and also investigates the costs of producing *Palmaria* on land in tanks.

Key points

- Aquaculture licences need to be forthcoming for existing abalone farmers and new entrants to the seaweed aquaculture sector.
- Mechanical harvesting trials need to be undertaken with a view to commercialising the activity in a scientifically sound manner.
- Greater value must be realised from the sector through automation, streamlining and by moving down the value chain.

2 Industry overview

The world seaweed Industry is estimated to be worth US$ 5.5 – 6 billion annually, with US$ 5 billion being generated from products destined for human consumption, the remainder being generated from hydrocolloids and miscellaneous products. The global seaweed industry uses 7.5 – 8 million tonnes of wet seaweed annually (Source FAO). Over 90% of the seaweed used is cultivated; the rest is wild - harvested. While it is reported that commercial seaweed harvesting takes place in 35 countries worldwide, China and Japan are the main centres of world seaweed activity; because demand far outstrips supply, China now imports seaweed from Korea. Seaweed is an enormously versatile natural resource and has found a place in human cuisine going back centuries. Nowadays seaweeds are used not just for human food, but in a variety of advanced applications. Food supplements, fertilizers, cosmetics and medicines are now produced from seaweeds, and it is these specialisations that hold the greatest opportunity for those involved in the seaweed industry here in Ireland.

Seaweed harvesting has long been a traditional activity in Ireland. Guiry (2010) notes that the earliest record of collection of algae for food in Ireland appears in a stanza of a poem, now thought to be 12th century, describing monks harvesting the red algae, *Palmaria* (Dillisk or Dulse) from the rocks and distributing this to the poor as one of their daily duties. Historically in Ireland, seaweed was used to fertilise lazy beds for potato growing, and it was burnt in kelp kilns for the extraction of soda and potash to make glass and soap. More recently, in the 1960s, the alginate industry became established with the brown seaweed *Ascophyllum nodosum* being the favoured species for harvest. The question of seaweed cutting rights caused conflict during these times. From these early beginnings, Ireland now has a vibrant seaweed sector.

Table 1 Estimated Annual Irish National Seaweed Harvest.

Estimated Annual National Seaweed Harvest	
Species	Annual Harvest (tonnes)
Ascophyllum nodosum	25,000
Fucus serratus	200
Palmaria palmata	<100
Chondrus crispus / *Mastocarpus stellatus*	<100
Laminaria digitata	<150
H. elongata, Saccharina latissima, L. hyperborea, Ulva rigida, Pophyra spp. F. vesiculosus, A. esculenta*, etc.	<10 each

* *Ulva* harvesting may exceed 10 tonnes at times when it is removed from amenity bathing areas. Currently there is no commercial application for such material.

Table 2 Turnover, direct and indirect gross value added, and employment in the seaweed and biotechnology sector (Morrissey et al., 2011).

Turnover (€'000)	Direct GVA (€'000)	Direct employment (FTE's)	Direct and indirect GVA (€'000)
18,075	8,671	185	14,552

The Irish seaweed industry produces a wide range of products, of which agricultural and horticultural products are the most important by volume and value. The bulk of the national production goes into animal feeds, plant supplements, specialist fertilizers and general agricultural products. A small proportion of the national production goes into various cosmetics and therapies; however this sector yields disproportionately high revenue against the volume of seaweed used. Human food applications are also lucrative, although, the volume of production is low and technical problems, especially regarding the mechanisation of processing, persist.

The Irish seaweed industry employs 185 full time equivalents. The most significant employers are Arramara Teoranta, Celtic Sea Minerals, Brandon Products and Celtic Seaweed Baths.

Key Points

- Commercial seaweed harvesting takes place in 35 countries worldwide. The global seaweed industry uses 8 million tonnes of wet weed annually. Over 90% of the seaweed used is cultivated.
- Ireland has an estimated national harvest of 25,400 tonnes per annum. 100% of the seaweed used is wild.
- The Irish seaweed industry employs circa 185 full time equivalents.
- Agricultural products account for nearly 100% of the raw material used and 70% of the value generated.
- Cosmetics and therapies account for circa 1.0% of the raw material used and 30% of the value generated.

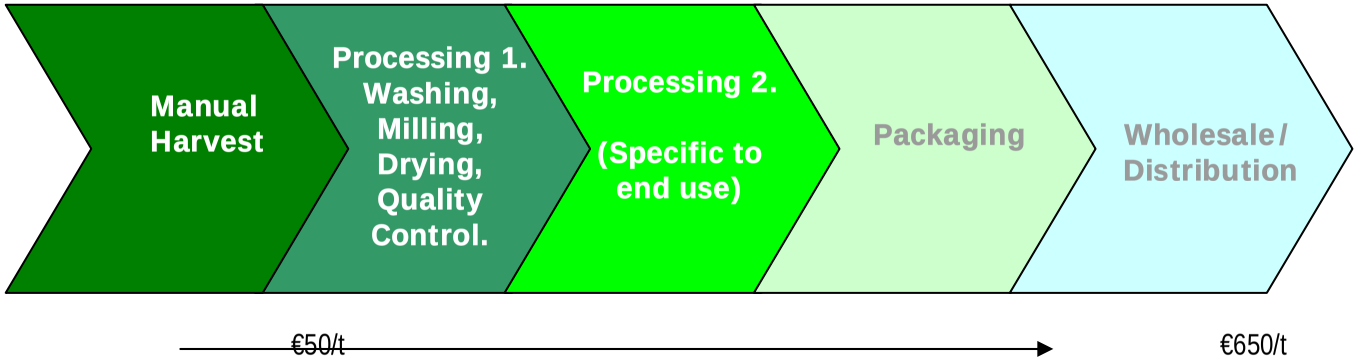


Figure 1 Generalised Diagram of value chain for bulk seaweed industry

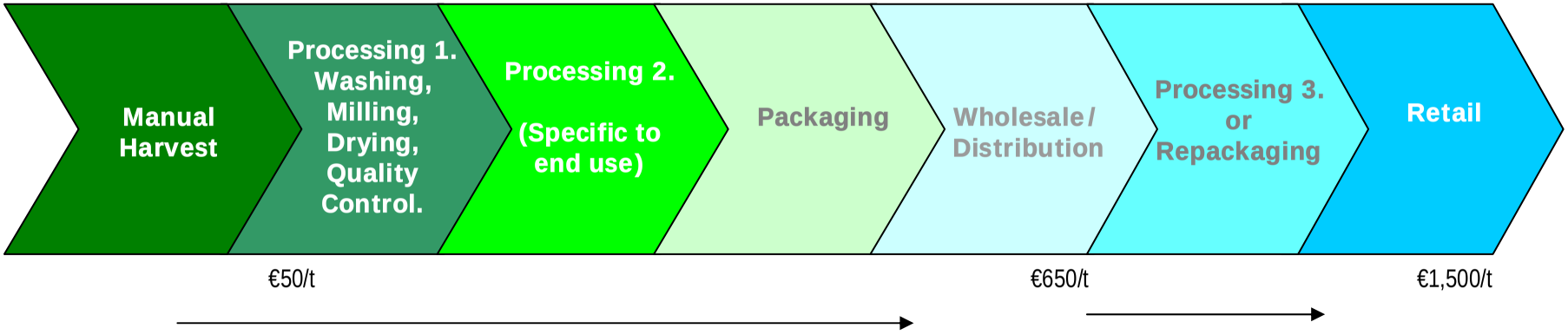


Figure 2 Generalised Diagram of the value chain in the seaweed processing industry

3 Harvesting and Processing Seaweed to Market

The food sector, consists mainly of micro enterprises employing five employees or less, with very limited automation in harvesting, drying or processing. Most enterprises operate on manual harvesting from spring to late autumn, with the majority of harvesting done at low tide, particularly during spring tide periods. The rates at which *Palmaria* or *Laminaria* can be manually harvested in good conditions typically vary from 50-100kg per person for *Palmaria* to 400kg per person for *Laminaria* per tidal cycle. The small size and dispersed nature of *Palmaria* makes it more difficult than larger seaweeds for hand harvesting.

There have been no reports received of the development of mechanical methods for harvesting *Palmaria* anywhere in the world. The distribution and morphology of this algae and the rugged Irish coast line suggests that such a development is highly unlikely and that hand harvesting is the only viable option to access wild stocks.

Laminaria may be harvested mechanically and some trials have been carried out in Ireland, however, the NPWS have repeatedly stated that they would require medium or long term studies to show that mechanical harvesting of seaweed was not damaging either the resource, the benthos or associated flora and fauna. Furthermore, the NPWS has stated that they would like scientific proof that the removal of seaweed would not be a contributor to coastal erosion and would not decrease productivity in coastal ecosystems.

3.1 Processing *Palmaria palmata* and *Laminaria digitata*

The bulk of *Palmaria* and *Laminaria* that is processed in Ireland undergoes very rudimentary processing. In most cases, the material is sorted by hand for quality control immediately after harvesting. It is then placed on trays or frames to be dried overnight in heated rooms or in areas equipped with fans and dehumidifiers.

The bulk of the seaweed industry utilizes drying as a method of preservation for a number of reasons;

- It is the best method of preserving the organoleptic qualities of the product.
- It reduces the weight of the product, which is beneficial for shipping.
- It does not require extensive training for operators.
- It does not require the purchase of expensive processing equipment.

Drying has several disadvantages:

- It requires significant labour inputs, e.g. stacking, spreading, turning etc.
- It requires approximately two “man-days” to process 500kg of fresh seaweed.
- It requires significant energy inputs (electricity/gas/forced air etc.).
- The process is managed unscientifically (dryness checked “by touch” etc.).

Figure 3 A homemade Herb Dryer. Source www.mycountrygarden.net

Similar rudimentary systems are widely used to dry seaweed in Ireland and abroad. Many such systems utilize perforated shelving, dehumidifiers, extractor fans and heaters.

Discussions with seaweed harvesters have revealed that it takes three hours to harvest 100kg of *Palmaria* in medium abundance areas, with favourable tidal conditions. It takes 6-8 hours to dry the same material using fans and dehumidifiers utilising reduced rate electricity supplies (Energy cost = €7.00/100kg). The final usable dry yield is approximately 20kg.

The main problem that persists is the requirement of processors to handle the material extensively during the drying stage; this delays the process and adds significantly to the labour cost.

Once drying operations have been completed, the material is stabilized to a point that it can be stored for a period prior to other operations such as chopping, grinding, mixing and packing. In many ways drying (as a means of preservation) is the most crucial step in processing most seaweed, any failing in this operation will lead to losses due to spoilage and contamination etc.

In order to increase the attractiveness of the seaweed sector to new entrepreneurs, it is an absolute requirement that automated processes be transferred or developed to reduce the labour and energy costs of processing seaweeds like *Palmaria* and *Laminaria*.

The transfer of time and labour saving devices into the seaweed industry would be a significant boost to processors because it would reduce the cost of processing. Significant effort and investment may be required to identify and transfer technologies and to obtain the support of expert service providers that can assist the Irish seaweed sector to transfer existing technology or to develop novel indigenous technology that can be used to process seaweed.

Efforts should be made by relevant agencies to identify and transfer handling, processing and other labour saving techniques and equipment from other countries. France, Canada and Israel all have comparable labour and energy costs and all have advanced macro-algal and micro-algal industries. Ireland's industry may be larger than many countries in terms of production volumes, however, with the exception of a few operators, it is a relatively technologically backward seaweed industry. Automation, particularly in the areas of drying processing and packaging, must be improved in Ireland in order to reduce labour costs and production times; many seaweed processors have expressed dissatisfaction with existing processing techniques due to their inefficiency and high labour costs. Technology such as rotary drum dryers, fluid bed dryers and freeze dryers must be integrated into the Irish seaweed processing industry.

It is self evident that the purchase cost, running cost and scale of a great deal of modern processing equipment are outside of the reach of all but a few seaweed processors, therefore it may be necessary to coordinate and facilitate the industry to access contract manufacturers or to provide a suitable pilot plant that can be employed by several enterprises.

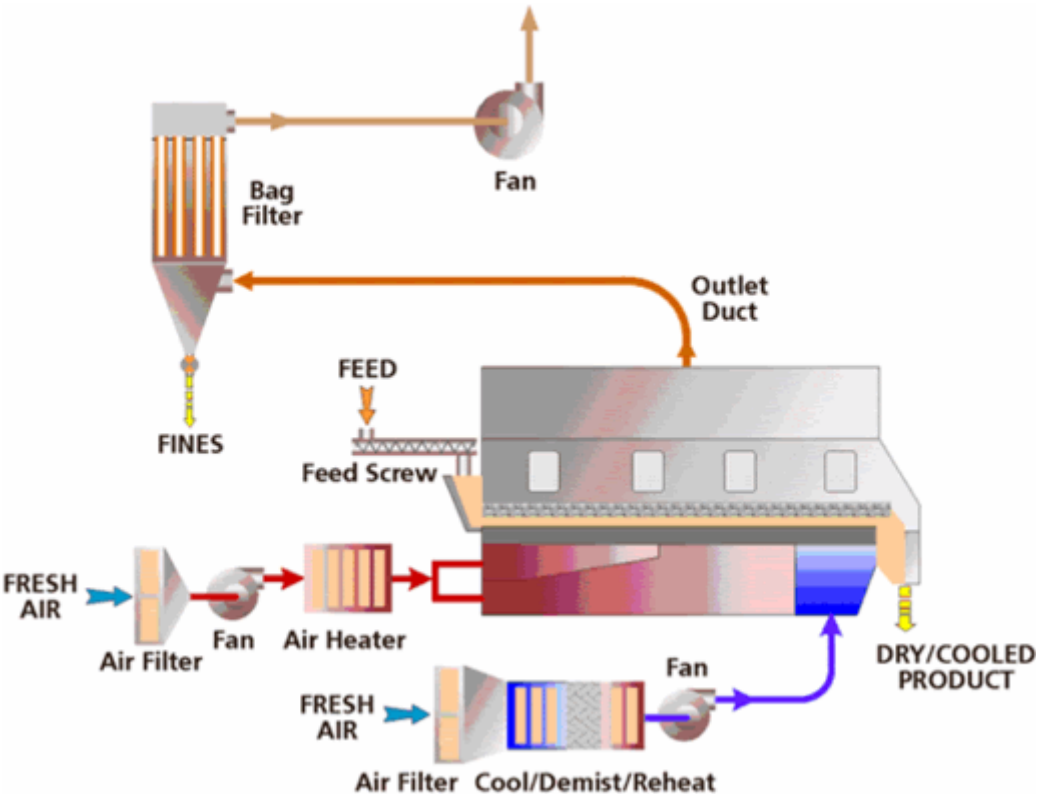


Figure 4. Diagram of fluid bed dryer system. Source www.geap.com

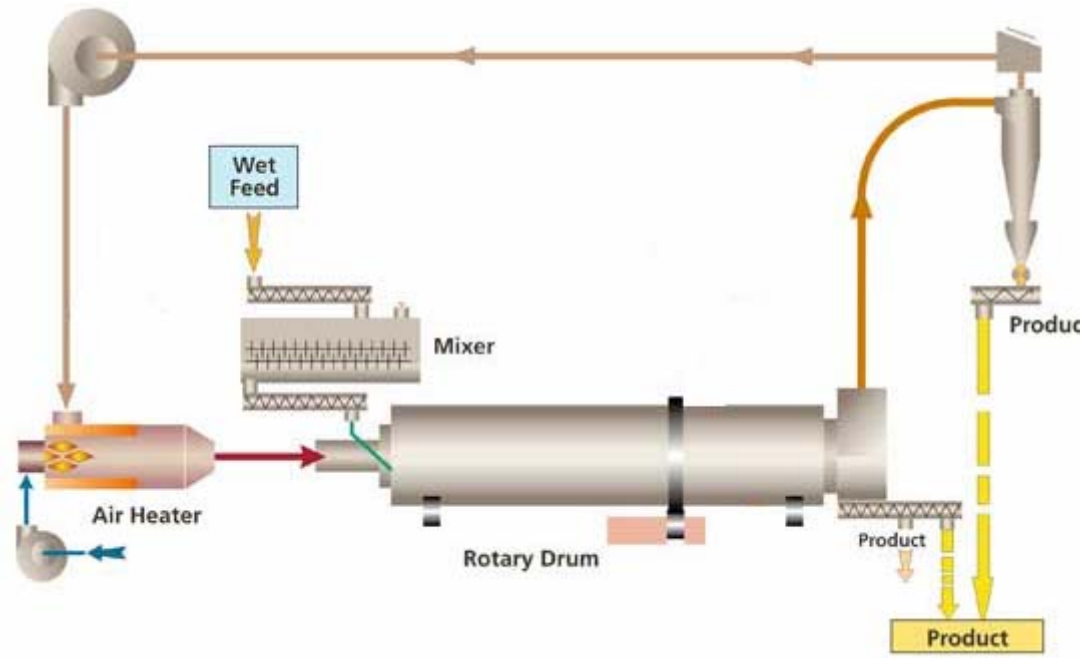


Figure 5. Simplified Diagram of Rotary Drum Drying System. Source www.geap.com

3.2 Adding value through Processing

Developing processing appears to be the most appropriate method for the Irish seaweed industry to add value to their products. Currently seaweed processing is relatively underdeveloped and a significant portion of all the seaweed produced in Ireland is sold for further processing both domestically and abroad.

It is important for the long term sustainability of the sector that more value is added to seaweed here in Ireland and that the bulk of the revenue generated from sales remains here.

In order to add value and maximise revenue from seaweed, significant technical development is required in the areas of drying, milling, production of liquid extracts, production of fine powders, manufacture of cosmetic ingredients and the manufacture of edible and non-edible consumer products such as snacks, sauces, flavourings and skincare products.

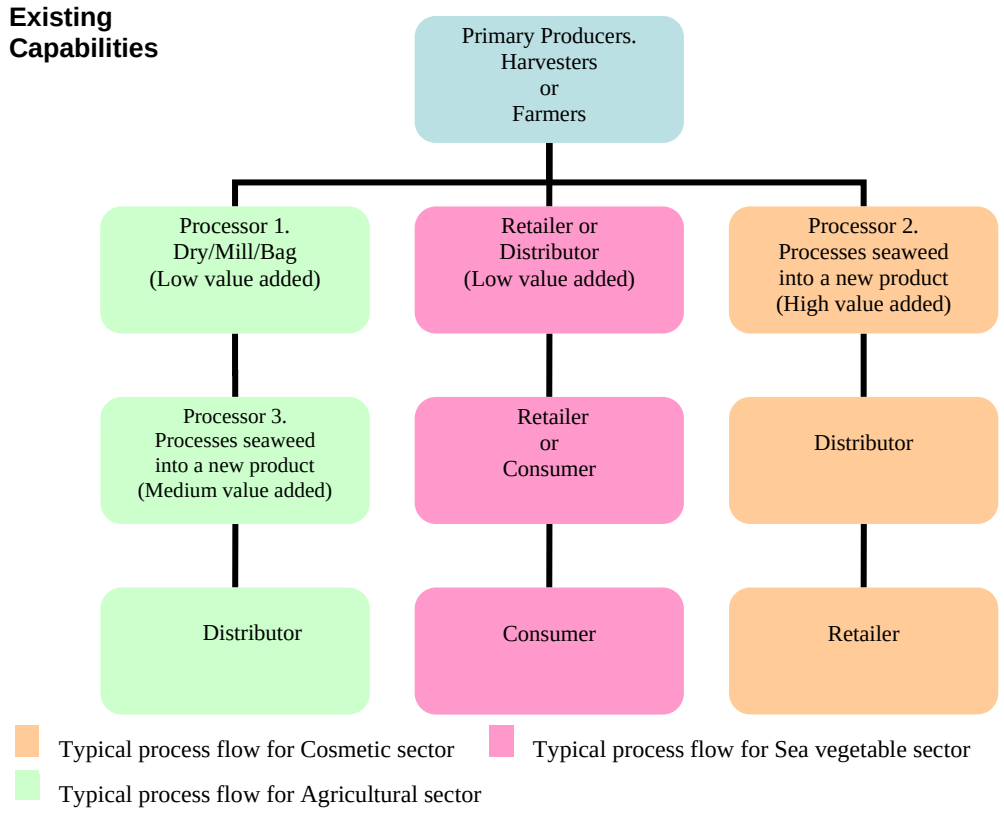
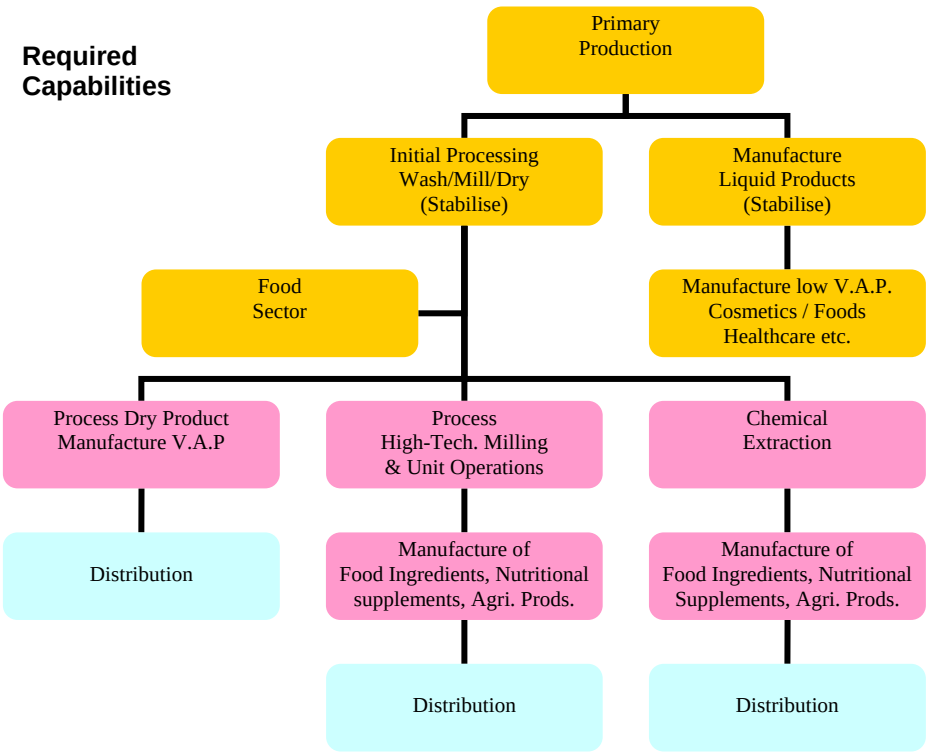


Figure 6 Process flow diagram.



Capabilities to be retained/extended by Industry

Capabilities that should be developed internally.

Activities to be *"outsourced"* to Partners or Customers

V.A.P. = Value Added Product

3.3 Milling / Grinding

Possible examples of future production would be the manufacture of freeze dried seaweed granules for cosmetics, fine powders (100 mesh/<0.149mm/149 microns) for food applications etc.
In order to develop such capability in Ireland, seaweed processors must be encouraged and financially supported to invest in state of the art processing equipment.

Sieve Designation		Nominal Sieve Opening		
Standard	Mesh	Inches	mm	Microns
1.00 mm	No. 18	0.0394	1	1000
0.841 mm	No. 20	0.0331	0.841	841
0.707 mm	No. 25	0.0278	0.707	707
0.595 mm	No. 30	0.0234	0.595	595
0.500 mm	No. 35	0.0197	0.5	500
0.420 mm	No. 40	0.0165	0.42	420
0.354 mm	No. 45	0.0139	0.354	354
0.297 mm	No. 50	0.0117	0.297	297
0.250 mm	No. 60	0.0098	0.25	250
0.210 mm	No. 70	0.0083	0.21	210
0.177 mm	No. 80	0.007	0.177	177
0.149 mm	No. 100	0.0059	0.149	149
0.125 mm	No. 120	0.0049	0.125	125
0.105 mm	No. 140	0.0041	0.105	105

Table 3. various particle sizes. Most Irish seaweed producers are only capable of producing larger sized particles, approx. 1000 micron Ø. source www.sigmaaldrich.com

Irish seaweed processors must achieve greater skill in milling technology in order to pursue opportunities in areas such as the manufacture of food supplements, cosmetics and functional ingredients.

3.4 Extraction

In terms of manufacturing high quality extracts for food, pharmaceutical, cosmetic and biotechnology applications, there must be technical development. Universities and other institutes such as BIM and Teagasc could take a lead in developing pilot plants or facilitating the use of under utilized existing plants in order to develop the means and technical know-how within the sector. The key areas for investigation should be as follows.

1. Separation (basket centrifuge, centrifuge, centrifugal decanter etc.)
2. Filtration (microfiltration, nanofiltration)
3. Evaporation (vacuum, scraped surface)
4. Spray drying
5. Drying

Dedicated extraction equipment of various sizes is available from numerous producers. Pilot scale equipment has already been introduced by BIM to a number of operators in Ireland and some small scale manufacturing is underway.

Figure 7. An example of medium scale extraction equipment, a ”Timatic Maxi” Extractor
Left: Control Panel. Right: Extraction chamber for solvent/material interface.

Key points

- More value must be added to seaweed here in Ireland.
- Technical development must be spearheaded by Universities and Agencies, in association with industry, in terms of the manufacture of high quality extracts for food, pharmaceutical, cosmetic and biotechnology applications.
- Technology, such as rotary drum dryers, fluid bed dryers and freeze dryers must be integrated into the Irish seaweed processing industry to reduce labour costs and production times.
- Existing resources such as the National Food Centre in Ashtown and BIM's Seafood Development Centre in Clonakilty must be used to deliver efficient state of the art processing capability to the seaweed industry.

4 Markets

4.1 Food Products

The dominant market for edible seaweed is the domestic food market; much of the edible seaweed produced in Ireland is sold directly to health-food stores, specialist retailers and supermarkets. A relatively small proportion of national production is being exported to Spain and the United Kingdom, mostly as bulk consignments, with a small proportion being third-party pre-packed products for specific distributors. Very few value-added, branded products are being sold abroad. This sector is liable to periodic fluctuations in the supply of raw materials, mainly as a result of periods of consistently poor weather conditions or low recruitment and growth of seaweed.

Price fluctuation is therefore quite common in this sector and is usually related to supply problems. It is believed that, at most, 3 to 6 tonnes of domestically produced seaweed food products are consumed in Ireland annually.

4.2 Agriculture Products

The agriculture sector is the largest sector in the Irish seaweed industry by volume and sale, estimated to have turnover of in excess of €5 million per annum and to use approximately 20,000 tonnes of seaweed per annum. This sector employs approximately 100 people on a full time basis.

Agricultural products made from seaweed were exported to over 30 countries in 2009, the bulk of sales going to South America, Europe, the Middle East and Asia. Most agricultural seaweed exports are used in the horticulture industry, mainly in fruit, vegetable and flower production; a proportion is also exported for grass products, mainly for use on sports surfaces such as golf courses.

The agriculture sector is well placed to continue to grow due to increasing demand pushing up food production and prices worldwide and the consistent growth of the organic agriculture sector.

4.3 Cosmetic Products

The cosmetics sector is worth approximately €2.5 million per annum, and employs approximately 60 people in sales, marketing, promotions, manufacturing, development and provision of services. The

sector mainly utilises *Fucus serratus* and smaller amounts of *Ascophyllum nodosum*, *Palmaria palmata*, *Chondrus crispus*, Lithothamnion corallioides and Laminariales.

The sector is divided amongst therapy centres providing seaweed baths and treatments and manufacturers that produce branded consumer products. This sector has experienced moderate growth and the leading companies have continued to strive to develop new products and services. The bulk of this sector's revenue has been generated through retail products, however, larger volume products intended for spas and treatment centres appear to be growing in importance.

This sector has saturated the domestic market and competition amongst the various companies appears to be forcing some to move into new markets. The sector is believed to hold significant growth potential, particularly for export markets; however, scientific data to support market claims and improved product development training and support are required.

4.4 Pricing

In November 2009, good quality, dried, *Palmaria* was typically wholesaling for between €16/kg & €19/kg for bulk quantities (Source: Bláth na Mara). In the same period *Palmaria* was retailing at various prices ranging from €2.29/40g to €2.99/28g (€57-€106/kg source: Evergreen Health-food, Galway) with retail prices typically including at least a 100% mark up on the initial purchase cost.

In November 2009, good quality, dried, *Laminaria* was typically wholesaling at €10/kg to €16/kg for bulk quantities and retailing at about €2.99/50g to €4.80/40g (€59.80-120/kg Source: Evergreen Health-food, Galway & www.seaweedproducts.ie); as in the case with *Palmaria,* retailers are believed to be marking up products by at least 100%.

Palmaria achieves a premium when compared with all other seaweeds including *Laminaria.* The production of branded, pre-packed units requires higher labour and packaging inputs and costs compared to bulk selling. However, the return is significantly higher and demand amongst retailers and consumers appears to be consistent throughout the year.

Most of the national production of *Palmaria* is sold and consumed domestically, however, there is increasing demand from European markets particularly, from Spain and France. The bulk of the demand originates from wholesalers who cannot meet their demand for *Palmaria* domestically.

Palmaria palmata is also available through a number of domestic and international websites, including www.seaveg.com, a US based site, which is run by Maine Coast Sea Vegetables. This website offers 2 oz (57g) packs of *Palmaria palmata* for $5.50 (€3.85) and bulk quantities at $23.50 per lb (€36.24 per kg)

Laminaria appears to be in much less demand and the European market for kelp products appears to be adequately supplied, most likely from a combination of French and Norwegian suppliers of *A. esculenta*, *Laminaria digitata* and *Laminaria hyperborea* and imported Asian seaweed such as *Saccharina japonica.*

The bulk market for seaweed appears to be liable to be less stable, both in terms of price and demand, and prices offered by European customers are not freely available from Irish producers, however, discussions have revealed that for bulk packed consignments of 100kg and over, prices are generally in the region of €13/kg to €17/kg with *Palmaria* achieving a price premium of about 50% over *Laminaria*. Accurate figures for the national production of dried *Palmaria* are difficult to come by and previous survey attempts have generally not been well received by the industry. It is estimated that the national production of *Palmaria* is between 16 and 30 tonnes per annum. National production of *Laminaria* is likely to be similar or lower. Agricultural products typically generate revenue of €1.50 / 2.00 per litre (5-7% seaweed solids) but this low value is offset by the high volume of sales that are being achieved and the relatively low marketing costs when compared to food and cosmetics products. (Agricultural products are generally sold through agricultural distributors - the nature of the product and the requirements of the users mean that packaging, marketing, design and promotional costs are much lower than for other sectors).

Some companies have reported strong export demand (UK) for seaweed, particularly for *Fucus serratus* and *Chondrus crispus*.

Key points

- Most of the edible seaweed produced in Ireland is consumed in Ireland (3-6 tonnes). A small proportion of national production is exported to Spain and the UK. There is increasing demand from Spain and France for *Palmaria.* Price indications vary between €16 and €19/kg for bulk quantities ex. Ireland.
- Agricultural products made from seaweed (worth €5m) are exported to over 30 countries.
- Agricultural products are worth €1.50/2.00 per litre.
- The cosmetics sector is worth €2.5m. It is thought that there is significant growth potential for export markets.

5 Developing the Domestic Market for Seaweed Products

It appears that a key requirement of developing the market for seaweed products is to provide support to the producers in a number of key areas.

5.1 Increased Production Capacity

Increased production of seaweed can be achieved by facilitating the industry to culture species such as *Laminaria digitata* and *Palmaria palmata*. At present, BIM, MI, Udaras na Gaeltachta (UnaG), QUB and NUIG provide a wide range of financial, technical and scientific support to interested parties throughout the island of Ireland.

The current difficulties in obtaining or renewing aquaculture licences being experienced by the finfish and shellfish industry suggests that seaweed aquaculture may be liable to objections and delays during the licence applications process. Reports of this kind are useful in informing and facilitating the licensing process.

Production increases may also be achieved by supporting licensed parties to increase wild harvest of key sea vegetables. Should the industry be able to increase the wild harvest in a sustainable way, by 5 to 10 tonnes (125,000 – 250,000 units), then increased consumer demand would probably be met in the short term to medium term.

5.2 Improving Processing Capability

Processing and handling systems must be improved in order to support active seaweed producers to achieve increased mechanisation, improved food safety and handling techniques and reduced inputs of labour. At present, the most common method of processing and preserving edible seaweeds is to dry the material, by a wide variety of methods used, which requires significant inputs of energy and labour. BIM, through the Seafood Development Centre (SDC) in Clonakilty, intends to work with the industry and with qualified engineers and food processing technicians, to improve existing processing techniques and to identify transferable processing technologies from other sectors, particularly for drying and packaging of edible seaweeds.

5.3 Supporting New Product Development

The BIM Seafood Development Centre shall also support the industry to develop novel products from seaweeds that may be able to achieve more market cross over. At present, the bulk of Irish seaweed is processed and packaged in a rudimentary fashion, which does not afford the product particular appeal to new consumers. It also makes new purchasing unlikely as the product may be seen as requiring extensive knowledge for preparation and use. It is proposed that a series of product development workshops will be held to allow industry to familiarise itself with the implementation of in-house product development trials. It is further proposed that the seaweed industry will be facilitated to carry out private product development trials in the SDC, with support from suitably qualified persons such as chefs, food technologists and processing technicians. It is further recommended that financial support be provided in so far as possible, for the development of novel, ready to use seaweed products such as soups, sauces, relishes etc.

There should also be attempts to increase seaweed sales into food service outlets, as a means of broadening the appeal of seaweed and allowing consumers an opportunity to try seaweed products without having to engage in any preparation of the product. Previous BIM market research on fish sales has shown that consumers are less likely to purchase products if they are concerned that they lack the necessary skills to correctly prepare them, suggesting an element of “fear of the unknown” amongst consumers.

5.4 Provision of consumer information and in-store promotional material

The provision of consumer and retail oriented promotional material may be beneficial to the seaweed sector if delivered some time after the industry has stepped up production and innovation.

In order to support increased consumer interest and purchasing and retailer confidence, it is recommended that items such as nutritional information, preparation guides and general information be made available to the industry and distributed widely amongst producers and from there to their network of retailers.

It is recommended that the promotional material be developed in conjunction with agencies such as Bord Bia. It is recommended that support for increased promotional capability should not be made available

until the industry has had the appropriate lead time to increase production and to develop innovative products.

Promotional material can be focused on such issues as nutritional content and gourmet aspects. Certain market segments, such as vegetarians and health-focused consumers should be specifically targeted.

5.5 Improving the profile of seaweed amongst retailers

The seaweed sector should be supported to improve the profile of its products amongst retailers. Retailers remain the key element in supporting increased sales; consumers, especially in the health food and gourmet food sectors, interact closely with retail staff, therefore the retailer is a valuable source of product information.

Several companies have reported that a single, committed retailer in the health-food sector can generate significant sales by providing advice and testimonials to consumers. It is proposed that the seaweed sector be supported to engage in a sustained promotional campaign at key Irish trade events such as “Rude Health” and a number of food and gastronomy events.

5.6 Expertise within the Seaweed Industry

The Irish seaweed industry comprises entrepreneurs that have become involved in the industry, having previously worked in other industries, such as the food industry or the manufacturing industry. The bulk of the larger companies and the more technically oriented companies are mostly well equipped with qualified and experienced personnel. Occasional, supplementary training in specific areas should suffice.

Micro-enterprises are characterised by entrepreneurs who have gradually become involved in the seaweed industry, mainly on an opportunistic basis. This sector is relatively poorly equipped in terms of training, formal qualifications or transferable skills from other sectors.

The owners and employees of many of the small enterprises have “learnt by doing” and standards and skills are haphazard and informal. There is an obvious need to improve skills through the provision of training in the areas of processing, food safety and general business skills.

A key element in developing the edible seaweed sector, and indeed the wider seaweed industry, is the provision of various training courses to current companies and new entrants.

In order to support the development of this sector, it should be considered if it is worthwhile to incorporate participation in training courses as a condition of receiving financial or technical support from state agencies. Training courses and support funding for 3rd party training courses have been widely offered to the seaweed sector, however there has been little enthusiasm for additional training from established enterprises. The informal and haphazard standards that are widely found in the industry may be acting as an obstacle to growth and it may discourage potential customers from purchasing Irish seaweed because of concerns over processing standards.

It is proposed that a series of workshops and training courses be delivered in order to facilitate companies to acquire new skills and capabilities and funding provided to the seaweed industry to enable it to participate in relevant third party courses.

BIM has developed and equipped a multi-functional seafood innovation centre at Clonakilty, Co. Cork, and the seaweed industry is encouraged to make use of these facilities.

The centre contains processing equipment, packaging equipment, development and preparation units, demonstration kitchens, and lecture rooms. There are also technicians and experienced industry mentors on site to support companies or individuals that are approved to use the various resources in the centre.

Innovation in the areas of new product development, food processing and packaging technology shall be specifically prioritised in order to maximise the benefit to the seaweed sector.

The provision of such training is likely to have a significant impact on enabling seaweed processors to communicate effectively and market their products successfully. At present, there is very little communications capability within the sector. Therefore many opportunities may be lost through difficulties in sourcing seaweed directly from producers, and this may have a limiting effect on sales and revenue.

It is recommended that the following services be provided, either through the direct provision of training workshops and courses or through the provision of financial support to companies to participate in courses offered by other institutions.

1. Food Hygiene and Food Processing courses
2. Product / Packaging innovation workshops / mentoring
3. Marketing courses.
4. Communication and I.T. courses
5. Business Management courses

In order to secure the future of the Irish seaweed industry, it will be necessary that new opportunities in functional foods, health and well being products and high value added cosmetic products are pursued by Irish companies.

The existing model used by seaweed processors will not be suitable for such markets. Therefore there must be a move away from rudimentary processing and anecdotal claims for the benefits of seaweed.

5.7 Product Innovation & Product Formats

Processing standards must be improved significantly and the industry must be supported to invest in better and more efficient processing facilities. Currently, most Irish seaweed products are washed, graded, dried and packaged, with little done to increase consumer appeal or interest. Dried seaweed may appear inaccessible and unfamiliar to a wide range of consumers. Product formats must be improved to make seaweed easier to understand and use by a wider range of consumers. For example carrageen (*C. crispus*) is widely available in Ireland, but product formats (packaged dried plants) are not user friendly and the preparation of carrageen is complicated for uninitiated consumers.

New, appealing, user-friendly formats like fortified carrageen powder sachets, ready to consume drinks or “carrageen tea bags” should be made available to improve the likelihood of achieving increased sales and consumer demand for such products. This situation is common for many seaweed products and convenience products are quite rare in the seaweed sector. It is necessary to support the industry to innovate new products and formats such as “ready to eat” snacks and drinks, vitamin and mineral fortified products, culinary and foodservice ingredients such a stocks, soup bases, vegetarian foods and appealing novel alternatives to popular Asian products like Nori, Hijiki etc.

Figure 8. Asian Seaweed Products.
Left: Dehydrated Hijiki granules, Right; Dehydrated Seaweed soup

5.8 Scientific Marketing and Functionality

There must be a science-based approach to the development and marketing of novel seaweed products. Currently seaweed products are marketed as lifestyle and gourmet foods and little effort is made to capitalise on the nutritional content of seaweed.

In order for the sector to broaden the appeal of their products, credible scientific data on nutritional content and the potential benefits of consuming seaweed must form the basis of marketing seaweed products throughout the existing retail network.

5.9 Niche Marketing and Product Differentiation

Seaweed products are unlikely to make significant crossover from niche markets to conventional markets because of production constraints. The public profile of seaweed is rather low and some consumers may have a negative perception of the flavour of seaweeds.

It appears likely that seaweed will continue to be a niche product. Therefore, efforts should be made to capitalise on niche markets as much as possible. There are a number of possible niches in the food market that may offer growth opportunities for seaweed producers.

5.10 Vegetarian food manufacturers, restaurants & retailers

The Vegetarian Society of Ireland (VSI) estimates that 4% of the Irish adult population (approx. 136,000) are vegetarians or vegans. (Source; Colm O' Brien VSI, pers. comm) A survey by the Food Standards Agency in 2009 found that 3% of UK respondents were vegetarians and another 5% of respondents consumed a partially vegetarian diet. This data suggests that there may be over 3.13 million vegetarian consumers in Ireland and the UK combined and that this may be an ideal market for seaweed producers to target. Carefully targeted marketing through manufacturers, retailers and restaurants, combined with communications initiatives through lifestyle-specific press, such as magazines and websites, may boost sales to this potentially receptive sector.

5.11 Healthfoods & Health Stores

According to the UK National Association of Health Stores, there are over 1,000 Health stores in the UK (source; www.nahs.co.uk) and the Irish Association of Health Stores has stated that its members run approximately 100 shops and that there are a further 100 non-member health stores in Ireland. (Source; Jill Bell, IAHS, pers. comm.) Health stores are already a significant market for seaweed products, but, it appears that seaweed producers have not fully exploited the domestic market and have not achieved the level of sales that might be expected.

Health Stores are generally quite open to introducing domestic products. This is mainly due to a willingness to support indigenous industries and the low carbon footprint of the products. To develop the Health Store market fully, seaweed producers must assist retailers to introduce their products more effectively to the general public. The production and distribution of consumer focused information material (leaflets & store displays) and the implementation of a promotional campaign would be affordable for even small companies.

The seaweed sector should make efforts to improve the profile of its products amongst health store owners by holding demonstrations at large events like the annual "Rude Health" event in Dublin. The 2010 event had over 200 exhibitors and over 5,000 attendees. Exhibition space generally costs €700 to €1,000 for this event.

By fully exploiting opportunities in the health store market, many producers could achieve a significant increase in sales. Many seaweed producers have reported that their total base of retail customers is approximately 60 to 80, this could be significantly improved upon with promotional effort within Ireland

5.12 Farmers Markets & Whole-food Markets

There has been significant growth in the number and size of Farmers Markets and Whole-food markets in Ireland and the UK. These markets often have a strong focus on unprocessed, natural foods, regional produce or specialities. There are over 130 farmer's markets operating in Ireland and a further 60 or so country markets (Stephanie Moe, Bord Bia pers. comm.). These markets appear to be growing significantly, in terms of size, number, distribution and customer base. Seaweed products may be well received in such markets if efforts are made to highlight the health and nutritional benefits of seaweeds and if promotional events such as cooking demonstrations, tasting and distribution of free samples and information are held at busier markets in larger urban areas.

Figure 9. Market Stall at English Market, Cork Source; www.englishmarketcork.ie

5.13 Functional Food & Beverage Manufacturers

In recent years, sales of functional foods & beverages (i.e. foods & beverages that have an intrinsic, additional health benefit beyond the provision of nutrients) have grown significantly. The world functional food market is believed to be worth between US$30 billion and US$47 billion annually (Siró et al., 2008).

Seaweed products may hold potential in such a market particularly for polysaccharides (such as fucoidan), dietary fibre and vitamins and micronutrients (iodine, selenium etc.) Seaweeds are also a source of thickening and texture agents (alginates) in foods and beverages.

Some companies are already exploiting seaweed extracts in functional foods, Diana-Naturals have marketed an anti-atherosclerosis capsule manufactured from *Fucus vesiculosis*. AHD international, an American Company, have marketed Fucoxanthin from *Undaria pinnatifida* as a micro-nutrient supplement that can be added to functional beverages etc. There may be opportunities for Irish seaweed producers to exploit Irish seaweeds for the manufacture of Fucoidan and Fucoxanthin.

At present, there are only a small number of Irish seaweed companies actively pursuing opportunities in the functional foods market. In order to increase the likelihood of achieving success in this sector, companies should consider either joint ventures with other innovative companies to jointly manufacture and market products like snacks, beverages, fortified mineral waters and capsules.

The functional foods sector is competitive and few Irish seaweed companies are now in a position to develop retail products without significant support or collaboration with large scale food manufacturers. It seems more likely that the industry will seek opportunities in the supply of prepared ingredients to domestic and overseas manufactures.

Key points

- A number of areas are identified for support:- increasing production capacity, improving processing capability, supporting new product development, provision of consumer information and in-store promotional material and improving the profile of seaweed amongst retailers.
- Workshops and training courses should be delivered to facilitate companies in acquiring new skills and capabilities, in processing and business.

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6 A Marketing Strategy

6.1 Branding and Product Differentiation

In order to capitalise on any new markets for seaweed in the long term, Irish seaweed producers should be carefully considering branding and differentiation strategies for Irish seaweeds. By promoting "seaweed" as a generic ingredient, manufacturers and producers may allow competitors to enter the market with another "seaweed" product and to compete aggressively on price. This would, in all likelihood, damage revenue and sales of any Irish products. It is recommended that Irish producers differentiate their products down to species level and actively market their products as containing Irish marine extracts. Where possible, they should focus on the unique qualities of the specific seaweeds or where appropriate, the limited global distribution of the species e.g. *Palmaria* which is mainly concentrated in Northern Atlantic areas with sparse distribution elsewhere (source; www.algaebase.org). Failure to do this, may simply facilitate competitors to benefit from promotional or marketing efforts by Irish companies.

Scientific data on water quality should be gathered from a number of sources in order to highlight the unpolluted nature of the waters from which most Irish seaweed is harvested. There is extensive data on various water quality indicators available from a number of sources including, the Environmental Protection Agency (EPA), Sea Fisheries Protection Agency and local county councils. Reports like the EPA bathing water quality reports and updates of the classification of various shellfish production water provide a platform for Irish companies to promote the production environment as a further selling point for Irish seaweed.

6.2 Organic Certification

The European Union has set down organic regulations (Council Regulation 834/2007) that allow farmed or wild collected seaweed to be classified as organic. The standards that are set out concentrate mostly on issues such as water quality in production areas, managing stock sustainability and tracing the source and origin of seed stock. These regulations appear to present no significant problems to Irish producers and the new regulations present Irish seaweed producers with an opportunity to enter this strong and growing market. It is recommended that Irish producers are supported in their efforts to obtain organic certification in order to broaden the appeal of their products, establish environmental credentials and achieve a premium on as many sales as possible. Organic certification should provide opportunities in

areas such as organic cosmetics, prepared foods and flavourings. The seaweed industry must continue to work closely with bodies such as the Organic Trust, Irish Organic Farmers and Growers Association (IOFGA) and the International Federation of Organic Agriculture Movements (IFOAM), in order to obtain this certification.

Figure 10. A selection of products from Maine Coast Sea Vegetables, US.

Left to Right; Kelp snack bar, dried Alaria, Nori granules, dried kelp, kelp granules, Dulse granules, dried Dulse. Note that the majority of these products are certified organic (OCIA).

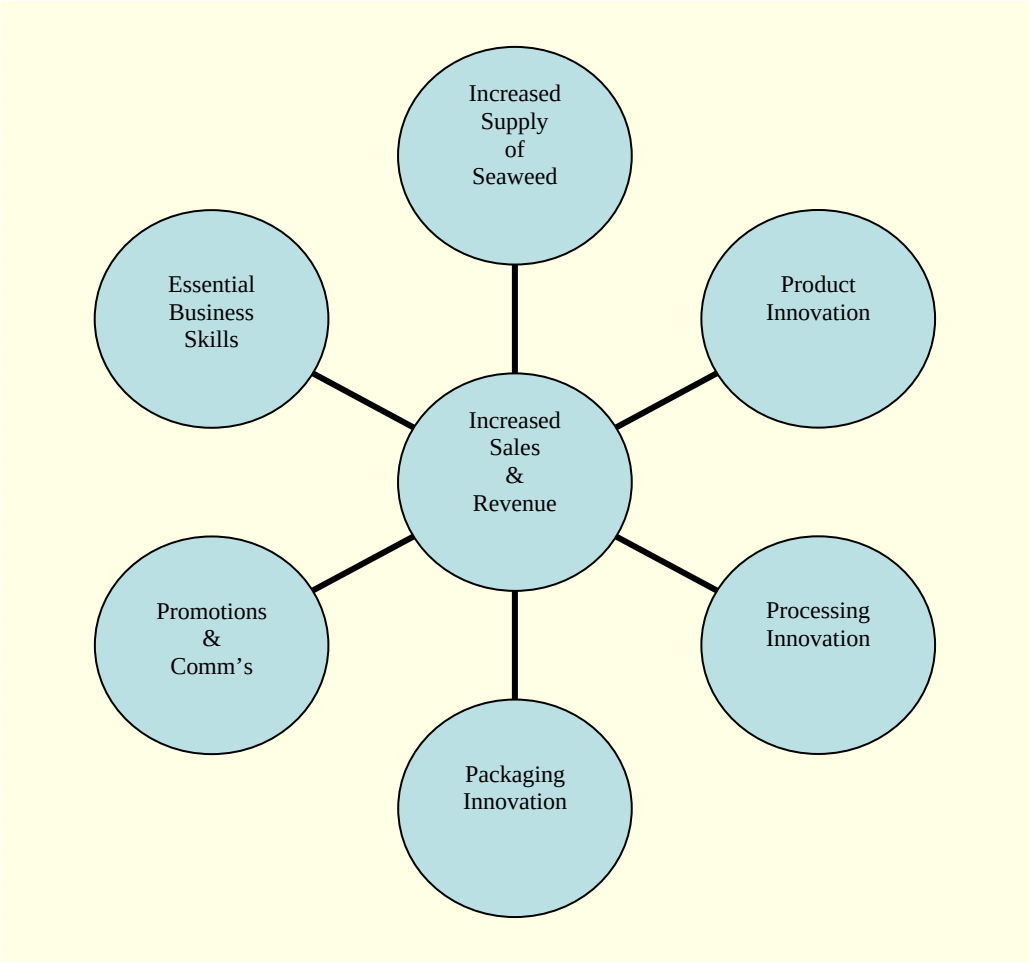

Figure 12. Priorities for the development of the Irish seaweed industry

Table 4 Possible Innovation partners for the Irish Seaweed Industry		
Name	Location	Capabilities
Seafood Development Centre Bord Iascaigh Mhara	Clonakilty, Co. Cork	Product Development, Processing kitchens. Training. Scale-up.
The Food Technology Centre, St Angelas College	Lough Gill, Co. Sligo	Product Development, Taste testing, Nutritional Analysis.
The Food Hub	Drumshanbo, Co. Leitrim.	Incubation units, Product Development, Manufacturing capabilities.
Spice O' Life Ltd.	Dunmanway, Co. Cork	Contract Manufacturing, Taste testing, Product Development.
The Organic Centre	Rossinver, Co. Leitrim	Training, market information.
Dunhill Cusine	Dunhill, Co. Waterford	Product Development, Contract manufacturing (mainly ready meals)

Key points

- A variety of innovation partners exist in Ireland. Linkages must be made by industry with these agencies in the areas of product development, contract manufacturing, nutritional analyses, marketing and business development skills.
- Irish seaweed suppliers must focus on the product's unique selling points (USP). They must differentiate their product to species level and actively market their product as containing Irish marine extracts.
- Provenance and source of raw material must be backed up with scientific data.
- Organic creditation should be investigated with the relevant agencies, to enhance consumer awareness and appeal.

7 Macroalgal Requirements for the Irish Aquaculture Industry

Macroalgal grazers have come to the fore in Irish aquaculture in recent years with the development of multiple recirculating aquaculture systems. These enable greater control of water parameters than traditional flow through or sea-based culture environments.

7.1 Abalone and urchins

Three species of grazer are currently grown in these environments, the abalone *Haliotis discus hannai* and *Haliotis tuberculata* and the sea urchin *Paracentrotus lividus.*

The abalone *H. discus hannai* and the seaurchin have a preference for brown macroalgae and commonly eat *Laminaria,* whereas the abalone, *H. tuberculata* has a preference for red weed, most notably *Palmaria palmata*

7.2 Dietary needs

There are currently two formulated diets that are readily available for the purposes of Abalone aquaculture, the Skretting Halo diet and Le Gouessant. There are alternative international suppliers from outside Europe, including Adam and Amos and Abfeed, but these diets are designed for the Australian and South African abalone respectively and their efficacy has not been proven for *H. discus hannai* or *H. tuberculata*. The formulated diet from Skretting comes in only one size and is therefore not useful for all sizes of abalone. The diet from Le Gouessant comes in multiple sizes from powder to large chip but has been designed specifically with *H. tuberculata* in mind.

Protein percentages vary from 24% to 35% and the protein source is mostly fish meal based. Because production of these foods is small on a global scale the prices fluctuate based on the prevailing fishmeal price. Other protein sources are being investigated. Due to its higher protein content the Feed Conversion Ratios (FCR's) tend to be better than macroalgal diets ie more animal is produced per kilogram of formulated feed than seaweed. The price of feed delivered varies between €1,500 and €3,000 per tonne.

7.3 Seaweed requirements

The estimated wet weight of *Laminaria* required for the Irish abalone industry growing *H. discus hannai* is between 645t and 860t based on an FCR of 15-20:1 and an annual harvest of 43t. For an estimated annual harvest of 37t of *H. tuberculata* the required volume of *Palmaria* required would be between 555t and 925t based on FCR's of 15-25:1

With a predicted annual harvest of 27t of sea urchins the algal requirement is 400t to 540t based on an FCR of 15-20:1. The species requirement is approximately a 50:50 split between *Laminaria* and *Palmaria*.

The nutritional qualities of macroalgae change throughout the season. The protein content of *Laminaria* can vary from 8-14% and that of *Palmaria* from 12-21%. The protein energy ratio affects the FCR's and subsequently the required amount of algae to get animals to market size.

Assuming the above seed inputs are realised and the predicted tonnage is harvested, utilising an all macroalgal diet, the required tonnage of *Laminaria* will be between 850 and 1,130 tonnes per annum. Between 750 and 1,200 tonnes per annum of *Palmaria* will also be required.

Key points

- Ireland's abalone and urchin farmers have an existing combined seaweed requirement of circa 2,000 tonnes of *Laminaria digitata* and *Palmaria palmata* at full production capacity.
- In order for this demand to be met, licences must be forthcoming in respect of applications made for seaweed aquaculture sites.

8 Research and Development

8.1 Recent International Scientific Research

In the last four to five years, commercially relevant seaweed research has reflected global trends. International concerns about oil reserves and increased demand for oil based products, amongst other reasons, has dramatically increased the interest in fuels derived from sustainable resources (biofuels). Algae (macro and micro) are seen as viable producers of bioethanol and biodiesel as second or third generation alternatives to sugar cane and rape seed oil etc. Global fisheries have reached their limit and the aquaculture industry is driving forward as the main future provider of fish protein. Seaweed culture is recognised as an extremely important economic activity within the aquaculture area.

These issues have been reflected in the presentations given in recent international conferences on seaweed. During the Applied Phycology Conference held in Galway in June 2008, biofuels were the 'hot' topic, with production values and photobioreactor systems for micro and macroalgae especially, vociferously debated. Even since this conference, the general impression within the research community is that many of the basic ideas on algal cultivation and lipid extraction have been taken up and protected by private companies, to protect their intellectual property.

The International Seaweed Symposium, held in Tokyo in August 2009, was a more diverse conference, with many more research topics covered. However, of all the macroalgal studies, there were strong presentations on climate change-based research from the Antarctic. What was concerning was the amount of change that may be around the corner for more temperate climates, such as those found in Ireland. For example, increasing ultra violet exposure with a decreasing ozone layer and rising seawater temperatures may deleteriously affect the seaweed populations here. There were also several interesting presentations on molecular work carried out on a variety of seaweeds, and how developments within the last few years within this discipline will have a very positive effect on the potential for breeding new strains of seaweeds.

Closer to home, organised by Enterprise Ireland, and hosted by the Marine Institute, the Seaweed Research Symposium introduced an Industry Led Research Programme (IRLP) for 'Bioactive Compounds from Seaweed'. This one-day symposium in January 2009 gathered together researchers from across the island of Ireland alongside industry representatives to talk about the current state of

seaweed research, and where the future of this research may lie. The main focus of the day was on the potential of bioactive compounds, and the presentations from the guest speakers reflected this approach.

As the first of three international speakers, Dr. Philippe Potin (Station Biologique de Roscoff, France) highlighted his work on kelp species, in particular, *Laminaria*. He presented an argument for the use of kelp as a good source of bioactive compounds, followed by challenges in optimised production. Bottlenecks exist however, such as optimisation of desirable traits/compounds, e.g. by population and quantitative genetics. Dr. Elena Ibañez (IFI-CSIC, Spain) delved more deeply into the extraction processes, and presented three methods, including Supercritical Fluid Extraction (SFE), Pressurised Liquid Extraction (PLE) and Subcritical Water Extraction (SWE). Overall, the methods are fast, selective, green and cost-effective, with the added advantage of not using organic solvents in the procedure. A short communication from her research group on the use of PLE (Plaza et al., 2009) is a very good introduction to results obtained with a macroalga common to rocky shores of Ireland.

Finally, Dr. Alan Critchley (Acadian Seaplants Ltd., Canada) who has great experience and knowledge of global seaweed industries, focused on the source of these bioactive compounds in terms of resources. The relative merits of the production of seaweed from wild stocks or cultivated means was discussed, and the importance of sustainable harvesting was stressed. Extensive harvesting may be appealing as it is cheaper than algal cultivation, but it is not without its own challenges. Looking to the future, he anticipated climate change events having an impact on seaweed resources, and noted that further research into these effects would be valuable. To view these presentations, see Marine Institute webpage link in the reference section.

8.2 Irish Scientific Research

The NutraMara initiative was launched in April 2008 and is led by Teagasc Ashtown Food Research Centre. The work programme aims to identify novel marine food ingredients and products with focus on these three main marine sources:

- Fish processing waste streams or raw materials
- Under utilised species of fish and seaweed including microalgae and microalgae
- Aquaculture

NutraMara utilises the expertise of up to 30 individual scientists (research officers and postgraduate students) from seven different institutes across the island of Ireland including Teagasc Moorepark

Food Research Centre (Teagasc MFRC), University College Cork (UCC), University College Dublin (UCD), NUI Galway (NUIG), University of Limerick (UL) and University of Ulster (UU).

The objectives for the consortium include the:

- Creation of a strong, interdisciplinary research association, capable of exploiting marine biodiversity as a source of material.
- Establishment of new research venues in marine functional foods – linking indigenous and multi-national food and pharmaceutical industries with researchers at state and higher education research institutions.
- Engagement in priority research activities such as complete extraction, biological and chemical characterisation of polyphenols, peptides, polysaccharides, amino acids, polyunsaturated fatty acids, protein hydrolysates and materials with antioxidant, probiotic or prebiotic properties and to conduct dietary intervention studies on characterised marine bioactives.
- To develop model foods enhanced with marine origin bioactives and capabilities to process marine-based materials for use by the functional ingredients sector.
- Development and implementation of training programs aimed at providing inter-disciplinary skills critical to the food industry sector.
- Securing research funds from national and international sources that will enable the NutraMara consortium to expand its research base in relevant areas to the advantage of Ireland's food, food ingredients and pharmaceutical sectors.
- Ensuring that commercially valuable results of the research programme are appropriately protected and made available to Irish industry for efficient and effective commercialisation.
- Promotion of organisational connections and linkages, both within and beyond the participants in the programme, within and among campuses, industry, other research bodies and international collaborators.

8.3 Seaweed breeding program

While the whole genome of the brown alga *Ectocarpus siliculosus* has been sequenced (Charrier et al, 2008; Cock et al. 2010)) and much molecular work has been carried out in Europe on a variety of macroalgal species, very little research has focused on developing a breeding programme for large-scale culture of valuable seaweeds. Friedlander (2008) acknowledges that genetic improvement of *Gelidium* sp. (an agar-producing red alga) is likely to be the only way to increase growth rates of the seaweed and therefore increase the yield of agar. Gjedrem (2000) notes that the domestication and improvement of fish species is many decades behind those of farm animals, and that the efficient conversion of food to biomass must be maximised to contend with the demands of an increasing human population. Seaweed aquaculture faces exactly the same challenges, especially in the anticipation of new active compounds being identified and required by industry. It is not unreasonable to assume that strains of seaweed could therefore be selected for to express larger amounts of these desirable compounds than their wild counterparts could produce, making the extraction process more efficient. In Asia, strains of species such as *Laminaria japonica* were selected for their temperature tolerance of different coastal waters, and indeed, work is still ongoing in this area (Pang et al., 2007). In Europe, this type of knowledge may also become important if climate change predictions are correct, and seawater temperatures rise. It is extremely unlikely however, given public perception of GMO crops (Genetically Modified Organisms) that GMO seaweeds (e.g. Gao et al., 2005) will be acceptable as the debate continues.

8.4 Environmental Assessments of Habitats

A close relationship between environmental authorities/agencies and University research groups should be developed to establish robust assessment protocols, if not already done within Ireland. Joining of forces with respect to biological knowledge, site knowledge, manpower, statistical analysis, long-term monitoring etc. would increase understanding of the intertidal and subtidal environments, and the prevention of over-exploitation of the seaweed resource.

8.5 Prediction of climate change effects

A large amount of *Ascophyllum nodosum* is already hand-harvested around the West of Ireland. Climate changes that would affect water temperature, pH etc. may have a damaging effect on the standing stock of *A. nodosum*. From a commercial viewpoint, this has a knock-on effect on harvesters, producers and consumers of the different end products. It is important to be able to predict what may happen to seaweed farms in the future too. For example, *Palmaria palmata* is a cold temperate species, and its southernmost limits of distribution are in the North of Portugal. Around Ireland, winter temperatures are suitable for the growth of the alga, but summer temperatures can occasionally be too high. Incremental changes in water temperature during the summer would make the growing season shorter for this alga, and potentially quite a few other species too. As mentioned above, a breeding programme may be of benefit to identify temperature tolerant strains.

8.6 Integrated Multi-Trophic Aquaculture (IMTA)

Evidence of cultivation of several different marine/freshwater species in ponds (also known as polyculture) can be traced back 5000 years in China. Within the last 15 years, the concept has become popular in the West, with the open-sea culture of finfish, shellfish and seaweed being trialled mainly in Canada and Norway (Chopin et al., 1999, Neori, 2008). This is commonly known as Integrated Multi-Trophic Aquaculture (IMTA). Within the system, species occupying the highest trophic level (e.g. salmon) excrete dissolved and particulate waste, and particulate waste from food to the environs of the culture site. Shellfish, e.g. mussels, filter the particulate waste stream, removing it from the site, and using it as a nutrient source. Finally, seaweed takes up the dissolved nutrients released from the fish. In this system, the environmental impact of the fish farming is greatly reduced, and three crops or products are obtained from the same area from the cost of one.

8.7 Algae for Biofuels

Again, this is another fledgling industry alongside that which will develop for bioactive compounds. In recent years, huge amounts of capital have been poured into biofuels research, based on productivity predictions made by research groups worldwide, and the fear of depleting fossil fuel reserves etc. For examples, see the conference program from the 11th International conference of Applied Phycology, held in Galway http://www.conference.ie/Conferences/menu.asp?menu=295&Conference=41). While developing a sustainable fuel and associated technology from seaweed is an interesting and potentially

lucrative area of research to be involved in, caution should be exercised, as not all calculations of biomass productivity stand up to scrutiny. It should be noted that seaweed crops used towards the creation of biofuels will have an intrinsically low value to compete with other biomass such as soya or maize, and so that fuel prices at the pumps are competitive with petroleum based fuels. Therefore, cultivating seaweeds purely for biofuel production should be considered extremely carefully, as it is unlikely to be economically viable to do so. No matter what the end product for the cultivated/harvested seaweed biomass will be, there is an issue of waste management that occurs in many industries now, from finfish aquaculture to milk production.

By-products must be disposed of in an environmentally sustainable way. As all seaweed production has an associated cost attached, it is worth considering developing the industry in such a way that as many different compounds and applications can be extracted from the same biomass as possible. Seaweed cultivation is always going to be more expensive than harvesting, therefore the following scenario is suggested to maximise the profit from one crop of seaweed:

1. Grow seaweed in an IMTA system. Finfish production provides enough nutrients so that the growth of seaweed is unlikely to become nutrient limited. The seaweed will use these nutrients that would otherwise be lost to the environment. As an additional benefit, this use of seaweed may make the image of finfish aquaculture more responsible and sustainable. In Denmark, growing seaweed as way of bioremediation near finfish cages actually allows the owners to increase the capacity of the fish farm (Dr. S. Holdt, personal communication).

2. Extract valuable compounds from this biomass. The return for this biomass is most likely increased if a suite of bioactive compounds is extracted from the biomass. This can occur alongside established extractions of alginates (if it is a kelp species such as *Laminaria digitata*)

3. Waste biomass – use for biofuels or horticulture. The remains from the valuable industries will be broken down into bioethanol, methane or biodiesel, depending on the process. Alternatively, the biomass could be used as a fertiliser, which is another well-established industry, or composted and used to enrich soils/mulches/composts/sold as garden products.

Key points

- In the last four to five years, commercially relevant seaweed research has reflected global trends and commercial interests, for example, research into biofuels, bioactive compounds for medicine and extracts for ‘functional’ food production.
- In Ireland, the NutraMara will provide a significant body of knowledge and this shall be available to a cross section of the seaweed industry.

- There may, however, be a need for further more specific analysis tailored to individual company needs at a later date.
- Going forward, it is envisaged that research will necessarily focus on some key aspects as follows; seaweed breeding programmes to augment supply of identified desirable compounds; commercially driven harvesting trials as a matter of urgency to identify recovery and growth of harvested seaweed areas, and algae for biofuel production.

9 Conclusion and Recommendations

The Irish seaweed industry has been given an ambitious target, to increase its value by €12 million per annum by 2020. The current annual value of Irish production is €18 million and the bulk sale of agri-products developed from wild kelps is the mainstay of the sector. Achieving greater value in the sector can only come about from efforts made by industry in association with the agencies and the research providers. The industry is made up of a dispersed group of companies ranging in size, from a relatively few large ones to a greater number of small ones. Approximately 185 full time equivalents are employed in the seaweed industry in Ireland. All the marine agencies have an interest in the sector and various committees have existed and worked together to support the sector. Seaweed is a naturally available resource and culture techniques exist. BIM was instrumental in further developing and applying in the commercial environment for the first time in Ireland, culture techniques for *Alaria esculenta.*The details of the technique are available in the Aquaculture Explained manual, Cultivation of brown seaweed, *Alaria esculenta* (2006). The project, PBA/SW/07/001 (01) 'Development and demonstration of viable hatchery ongrowing methodologies for seaweed species with identified commercial potential', aims to commercialise hatchery techniques for *Palmaria* and *Laminaria digitata.* While the *Laminaria* technique which borrows from the technique developed for *Alaria,* is proving to be successful, *Palmaria palmata* is proving to be more difficult to manipulate successfully in the hatchery. At the current time, growing *Palmaria* in tanks on land is proving to be more successful.

On the market, technology and product development side of things, a number of key issues deserve mention. As a relatively dispersed group, the seaweed industry would benefit from coming together to liaise with each other to identify common needs and to discuss how to approach the relevant agencies for help in the identified areas. Automation needs, technology trials, product development and manufacturing processes and training requirements are all identified in this report as being important to the further development of the seaweed processing sector.

As its stands, Ireland is known for producing agri and horticultural products. Ireland is also known, but less so, for cosmetics and food products. To capitalise on the potential for increased profitability, the existing Irish seaweed sector needs to move down the value chain into the identified opportunity areas. The nutraceutical, pharmaceutical and cosmetics industry represent greater profit opportunity than the agri-products and horticultural products sector. To achieve this, the sector, in association with the agencies and research providers, needs to identify specific market opportunities, innovate and introduce greater automation, including new processing and packaging technology. Linkages through the relevant

state development and research providers must be maintained to ensure that research is industry led and relevant.

Ireland has a clean, green image that should be capitalised on in the seaweed sector. Ireland's food industry and more specifically in this case, the aquaculture sector, trades heavily on its organic status. Provenance in the food sector is a winning concept. Ireland is the largest producer of farmed organic salmon in the world. The whole idea of farmed organic seaweed needs to be investigated, in particular where Irish abalone and urchin producers are looking for organic accreditation. The opportunity to farm seaweed and supply it directly into a farmed abalone or urchin environment is extremely attractive. The weed stays fresh on the line until needed. It is harvested on a 'just in time' basis, it is accessible to the farm and it is extremely cost effective to grow.

Key points

- Industry needs to come together with innovation partners to identify needs and work on new product development, automation, technology transfer and business skills.
- Industry must seek to generate greater value from existing seaweed processing activity.
- Industry must seek to apply 'organic status' to product to leverage greater profitability.
- Seaweed industry must continue to attend International events to establish and maintain overseas market linkages.
- Industry and relevant agencies and regulators must work together on licensing of aquaculture sites.

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