**Final Report Summary - SWAFAX (Seaweed derived anti-inflammatory agents and antioxidants)**

Executive Summary:

The project has explored a range of processing methods to extract and fractionate polyphenols from *Ascophyllum nodosum*. It is clear that the extraction and fractionation procedures can have a marked effect on total polyphenols and on anti-oxidant activity. The sample extracted with ethanol/water and fractionated to provide a product with predominantly high molecular weight polyphenols had the highest level of polyphenols and the greatest antioxidant activity as assessed by FRAP and TEAC methods. Water extraction alone was the least effective method of extracting polyphenols. A food grade seaweed polyphenol extract (SPE) containing a mixture of low and high MW polyphenols was produced for use in 2 human intervention studies. Several extracts, including the food grade SPE, were tested in in vitro assays for bioactivity. When used in the in vitro Comet assay for assessing single strand DNA breaks, the high MW extract (after simulated digestion and gut fermentation followed by dialysis to simulate absorbed metabolites) significantly protected human lymphocytes from DNA damage induced by hydrogen peroxide. Similarly, the digested and fermented high MW fraction, representing polyphenol metabolites generated by gut bacteria, was able to protect human intestinal cells from induced DNA damage.

In vitro assays to assess effects of the digested and fermented extracts on markers of inflammation in blood revealed dose-related decreases in the pro-inflammatory cytokine IL8 and increases (non-significant) in the anti-inflammatory cytokine IL10, indicating overall potential anti-inflammatory activity of the Ascophyllum extracts.

A bioavailability study was conducted in 24 male and female volunteers over 24 h after consumption of the SPE. HPLC analysis revealed the presence of a variety of metabolites in urine from 15 volunteers out of 24 and in plasma from 14 out of 24. There was considerable inter-individual variation in metabolism and most of the metabolites were found in samples collected at 8-24h.

In a chronic (8 week) human dietary intervention study in 80 male and female subjects given the food grade SPE, the effects seen were less dramatic than in vitro, and although there were beneficial trends with some endpoints, significant effects were only apparent in analyses of subsets of the complete cohort. After consumption of SPE there was a non-significant decrease in total oxidant capacity in plasma, this became significant when a subset of subjects with a high initial level of peroxides were investigated. Similarly there was a decrease (non-significant) in the level of DNA damage in lymphocytes in subjects given SPE capsules. However in a subset of obese subjects, a significant 23% reduction in lymphocyte DNA damage was seen.

It seems likely that the lack of statistical significance of several of the beneficial trends seen in the main dietary intervention trial was a consequence of the high level of inter-individual variation in absorption and metabolism of the polyphenols that was apparent from the bioavailability study. Such interindividual variation has been seen with many other polyphenol rich plant sources.

Project Context and Objectives:

Reactive free radical damage (due to endogenous or exogenous factors such as chemicals, smoke, radiation, pollution and diets) to cellular macromolecules is thought to be involved in the aetiology of many chronic degenerative diseases including...
cardiovascular disease, cancer and neurodegenerative disease. Furthermore, there is a growing body of evidence that chronic, low-grade inflammation is also an important factor in the aetiology of such diseases possibly by increasing DNA damage and cell proliferation.

Epidemiologic studies have shown a diet rich in plant food protects against chronic degenerative diseases and many studies have highlighted a potential role for phenolic compounds which provide antioxidant and anti-inflammatory properties and are increasingly being shown to have an important role in influencing critical cell signalling pathways.

Fruit and vegetables, cocoa, red wine and grape juice derived polyphenols have been extensively studied for effects on chronic diseases. A less well known, but nevertheless rich source of polyphenolic compounds is seaweed. In Ascophyllum nodosum, a common brown alga in the British Isles, polyphenols have been reported to comprise up to 14\% of the dry weight of the plant (Ragan & Jensen (1978). The types of polyphenols in seaweeds show similarities to those found in land plants and include phenolic acids, tannins and flavonoids. And appear to be particularly abundant in certain red algae such as Gelidium elegans, Gracilarua asiatica and Gracilaria texorii). In the brown seaweeds in contrast, phlorotannins are the main group of polyphenols. The phlorotannins are unique to seaweeds.

The bioactivity of seaweed polyphenols has received relatively little attention. There are reports of reactive oxygen species scavenging and inhibition of lipid peroxidation in extracts of some brown seaweeds Preliminary work in our laboratory has revealed potent antioxidant activity of Ascophyllum nodosum extracts, and a recent study indicated that that phlorotannins found in brown seaweeds are potent anti-inflammatory substances. Although limited, these reports suggests that the potential antioxidant and anti-inflammatory benefits of seaweed-derived polyphenols are worthy of investigation and may yield highly bioactive components with commercial potential for food and even pharma applications. The present proposal is a focused investigation designed to provide strong scientific evidence for health promoting activity of a seaweed polyphenol extract in human volunteers, and additionally to provide information on the antioxidant and anti-inflammatory potential of a range of novel seaweed extracts that can be further exploited by the SME partners.

Objectives

The overall objective of the proposal is to provide the SME partners with the information, expertise and capacity to develop polyphenol extracts with valuable biological activities and to exploit the commercial possibilities of these extracts. In order to achieve this aim a number of technological and scientific problems need to be solved and these are addressed within the current proposal. The objectives may be summarised as follows

1. To prepare a food grade polyphenol extract of Ascophyllum, plus novel polyphenol extracts of other seaweed varieties.
2. To characterize the extracts in terms of their polyphenol profiles.
3. To evaluate the biological activity of the food grade seaweed polyphenol extract in terms of the bioavailability of its components, plasma antioxidant capacity, reduction of oxidative damage to DNA, modulation of inflammatory responses and reduction on chronic, low level inflammation in vivo.
4. To screen the novel seaweed extracts for antioxidant and anti inflammatory activity in vitro.

Project Results:

Please see attached document

Potential Impact:

A pdf version of this has been uploaded since the tables and figures have not formatted correctly here

The overall aim of the Project was to provide the SME partners with information, knowledge and capacity to develop seaweed polyphenol rich extracts, with valuable biological activities, and to exploit the commercial possibilities of these extracts. This was to be achieved through the following specific objectives:

• Preparation of a food grade polyphenol rich extract from Ascophyllum nodosum and a series of novel bioactive rich extracts
from Hebridean and Irish Ascophyllum nodosum of relevance to the partner SMEs

• Characterization of the extracts in terms of their polyphenol profiles, key bioactives and major structural components
• Evaluation of the biological activity of a food grade seaweed polyphenol extract in terms of the bioavailability of its components, plasma antioxidant capacity, reduction of oxidative damage to DNA, modulation of inflammatory responses and reduction on chronic, low level inflammation in vivo
• Screening of the novel seaweed extracts for antioxidant and anti-inflammatory activity in vitro
• Transfer technology and plan for exploitation of novel seaweed extracts

Drawing on intellectual property at CEVA (Center for Study and Promotion of Algae, France) a food grade polyphenol rich extract from Ascophyllum nodosum was produced, and the method optimized in the lab for novel polyphenol rich extract preparation. In addition, several new methods were developed and optimised in the laboratory for novel polyphenol extract preparation. One of these three methods was then validated on the pilot scale for the production of novel polyphenol rich extracts, and specified as a proposed scaled up production process which was then transferred to the SMEs. A study of the Japanese market for polyphenols and seaweed extracts carried out at an early stage within the Project highlighted the relevance of fucoidan and fucoxanthin rich extracts to the SMEs. It was thus possible within the original scope of the project to produce extracts for testing that included one fucoxanthin fraction and a number of others high in fucoxanthin and with significant fucoidan content. A single blend of two of the polyphenol rich extracts was used to generate capsules (100 mg polyphenol) for in vivo studies. All eleven extracts were subject to in vitro screening and characterization (% composition, heavy metals and microbial quality). Results obtained from the analysis of urine and plasma samples from the bioavailability study on healthy adults indicate the presence of a range of metabolites. Anti inflammatory effects of the food grade seaweed extract were observed in the acute and chronic intervention studies, and also during in vitro screening of a number of novel seaweed polyphenol extracts. A protective effect against DNA damage was observed in vitro and in vivo.

The exploitable results relate to antioxidant and anti inflammatory activities of seaweed polyphenol extracts, processing technology and market data supporting commercial applications. This document aims to provide a comprehensive plan for how the research results and technologies can best be used and exploited within the personal care, health supplements and food and beverage markets

1 Contribution at the European level of the SWAFAX project work programme impacts

1.1 Economic Impact for SMEs

The pre-competitive SWAFAX research applies to the production of seaweed polyphenol rich extracts on a pilot scale and further demonstration will be necessary to prove techno-economics, characterize seaweed polyphenol extracts and broaden their acceptance by potential personal care, health supplement and food and beverage customers. Each SME will continue to drive exploitation of the project deliverables independently to improve and augment their existing product offerings, but where mutual benefit is identified for co-exploitation, 2 or more SMEs will work together. In the event that one or more of the SMEs identify opportunities to license the SWAFAX developed seaweed polyphenol extraction technologies, then the SMEs will agree the terms and give a percentage to CEVA. It is envisaged that products based on seaweed polyphenol extraction technology will be introduced progressively, starting within 6 to 9 months following completion of the project. The degree and rate of expansion will depend on the economies of scale in seaweed polyphenol extract production at the Hebridean Seaweed Company, pricing policies, barriers to market entry and consumer acceptance. Consumer acceptance of seaweed as a human food and in heath supplements is high in Asia, and this will be an important target geographic market (Japan in particular) for creation of value from the SWAFAX results by SMEs. It is recognised that it will be necessary to obtain regulatory approval under FOSHU for inclusion of a seaweed polyphenol extract in food and beverage products for antioxidant effects. It is recognised that publication in high impact scientific journals of beneficial effects of the specific seaweed polyphenol extracts will be an important aspect of marketing new products for the SMEs.

According to FAO, world production of seaweeds stood at 19 million tonnes (wet weight equivalent) in 2010, with 95.5% cultivated and 4.5% harvested in the wild. According to CEVA, China towers over other seaweed producers at 64% of supply in a world market valued at 7.4 billion US$ in 2008, where the human food segment occupied 65% of that value and the colloids segment another 30%. European seaweed production, at around 1.3% of world supply, is focused around Norway and France,
with a significant contribution from Ireland. Core markets for EU seaweed are agriculture, nutrition and health, and cosmetics, whilst emerging markets lie in bio-refining, green materials and bio-energy. The SMEs plan to realise commercial value within the core markets of nutrition and health (health supplements, and food and beverage) and cosmetics (personal care). More specifically the SMEs (Hebridean Seaweed Company Ltd., Outer Hebrides of Scotland: HS; Marigot Ltd, Ireland:MT and Mesosystem S. L., Spain: MS) will use the SWAFAX project intellectual property (IP) to:

1. manufacture a range of seaweed polyphenol extracts for sale into the personal care market in Asia (HS);
2. develop new personal care products incorporating seaweed polyphenol extracts (HS; and MS) and manufacture them for sale in Asia and Europe
3. develop seaweed polyphenol health supplements and manufacture them for sale in Asia (HS; and MT)
4. develop a wholly seaweed derived antioxidant and mineral formula product for the food and beverage market in Asia (MT)

1.1.1 Personal care market

Hebridean Seaweed Company Ltd. is the largest industrial seaweed processor in Great Britain. The company manufactures seaweed products for use in the animal feed supplement, soil enhancement, alginate, personal care and nutraceutical sectors. During the SWFAX project HS identified a cosmetics company in Japan seeking supply of a polyphenol rich extract from the Hebridean seaweed, Ascophyllum nodosum. Characterization of this extract, preliminary testing for skin whitening and an initial extract product specification were drawn up. HS wishes to further explore this and other potential opportunities for seaweed polyphenol extracts in the Japanese cosmetics market - the world’s second largest market (47 billion US$ in 2011 of which skin care represents 45% of the value) – which is actively changing. Main market trends include aging as the strongest characteristic of the Japanese society today (with a growing proportion of men ready to pay a premium price for products that can visibly reduce the extent and signs of aging) and a continued interest for whitening products. While the competition is getting fiercer, the current Japanese market is full of opportunities to increase sales, even for newcomers or small and medium-sized companies. This remark also applies to overseas cosmetic brands, which are becoming increasing popular among Japanese consumers. Another prominent feature in the current market is the success of overseas organic brands which fits well with HS. HS already has two personal care products on the market in the UK and it also aims to use SWAFAX IP to create another personal care product for the UK market and to enter the Japanese market with its own personal care products.

HS recognise that it is particularly important to have their polyphenol extracts scientifically well documented for the Japanese market. This will be addressed through further characterization work after the project, taking on board seasonal influences, with the support of Colin Hepburn (consultant and previously an employee of CyberColloids) and CEVA. HS has additional Japanese market research results tailored to its requirements from the study conducted by Galloway & Associates during the SWAFAX project. HS also recognises it must meet the requirements laid down for cosmetics within the Pharmaceutical Affairs Act, which are now consistent with international standards. Whilst individual product approval is not required, the ingredients in a product must already be approved in Japan.

HS is acknowledged as being important to the Highlands and Islands region of Scotland and the company has built a strong positive relationship with Highlands and Islands Enterprise (HIE) in its achievement of high growth over the last 5 years. The HIE will be an important part of the support network in enabling HS to establish factory scale production of seaweed polyphenol extracts for use in personal care and other markets. HS has an existing stock of frozen seaweed and a working relationship with CEVA which would enable HS to immediately supply small volumes of extracts to potential customers at the end of the project. So it is not anticipated that factory scale production would be in place until 2015.

The Japanese cosmetics market is in a stable condition but with continuous realignment of distribution channels, all cosmetics producers need to enhance and restructure the management of their sales channels. Specialty stores are the leading channel due to consumer convenience and low prices while sales through department stores is slowing down. Shiseido, Kao (and Kanebo), Kose, and Pola dominate the cosmetics market in Japan. HS will need to work with an importer cosmetics company when looking to launch its skin care product on the Japanese market. HS is likely to seek further professional support and plan to build on existing websites, promotional literature and trade show attendance to promote their extracts for the personal care
HS has produced confidential growth plan financials for the new extract and personal care products, and a 14% profit before tax is estimated as the return on these new sales over a period of 5 years.

Mesosystem’s (MS) R&D department specialises in the generation of new products based on their specialist knowledge and innovative technology. The MS line of products created is based on selection of specific nutrients and plant extracts whose effectiveness and safety offer real benefits. Currently the portfolio includes 200 products in various categories: solar protection, body, face, mesotherapy, lymphatic drainage, cavities, skin marks, pigmentation, scars, acne, anti-aging and others, with operational centres in Portugal and Spain.

In 2010, the world’s largest cosmetics market, Europe, was valued at €66.6bn and it has been growing constantly since the industry’s full post-recession recovery in 2011. A typical product’s life cycle lasts less than 5 years, therefore cosmetics manufacturers have to reformulate 25% of their products every year to keep up to the industry’s pace of this highly competitive market. Skincare, the largest European cosmetics market segment, has very good growth prospects and is seeing increasing demand for natural cosmetics and sustainable products. MS has identified the opportunity to use novel seaweed polyphenol rich extracts to improve an existing antiaging skincare product and to develop a new skincare product for the European medical cosmetics market. Using SWAFAX seaweed polyphenol extraction IP and its own innovation network in Spain and Portugal, MS will secure the extracts, reformulate an existing product, formulate a new medical cosmetics product and test them. It will integrate these products into its existing production facility and deliver them through its distribution channels in Europe. A 15% profit before tax is estimated as the return on these new sales over a period of 5 years.

1.1.2 Health supplements market

The dietary supplements market in Japan was valued at 7.5US$ billion in 2000 but with the per capita consumption at only one sixth the level found in the United States, the potential for continued growth in that market was enormous. Value sales of vitamins and dietary supplements rose by 1% in 2011. In the same year, a study among older adults (55-75 years) in Japan reported that 45.8% took supplements on a weekly or daily basis, with the prevalence higher for women (52.5%) than for men (41.7%). Many types of miscellaneous supplements were consumed. The most popular supplement was vinegar for both men (11.0%) and women (15.2%), followed by energy drink (8.5%) for men, and multivitamin (8.5%) for men and vitamin C (8.3%) for women. The findings suggested an increasing trend of dietary supplementation by Japanese older adults when compared to previous studies.

HS has identified the opportunity to produce a seaweed polyphenol capsule for the dietary supplements market. In Japan, there are no regulations which define a food supplement. Food supplements fall under the category of “food” and are regulated in the same way as food products. General regulations on food labelling (Food Sanitation Act and Law Concerning Standardization and Proper Labelling of Agricultural and Forestry Products) are applied to the labelling of health food products, the same as other food products. Also, under the Health Promotion Act, health food products which comply with the specifications and standards established by the Minister of Consumer Affairs Agency of the Government of Japan and are labelled with certain nutritional or health functions can be labelled as “Food with Health Claims.” These food products are categorized into two groups, according to differences in purpose and function:

a) Foods with Nutrient Function Claims (FNFC): Foods that are labelled with the functions of nutritional ingredients (vitamins and minerals)

b) Foods for Specified Health Uses (FOSHU): Foods which are officially approved to claim physiological effects on the body and approved by the Minister of Consumer Affairs Agency of the Government of Japan.

Care has to be taken with ingredients, as only those substances that are on a “positive list” covering synthetic and natural origin additives can be used in supplements marketed in Japan.

HS aims to align with the vitamin and minerals category, and take advantage of the Government allowance that consumers in
Japan may import for personal use a four-month supply of nutritional supplements. This has given rise to a major mail order channel of distribution, particularly via the internet. An online retailer in Japan such as kemo.com could be a suitable channel of distribution. HS is likely to seek further support from Galloway & Associates and plan to build on existing websites, promotional literature and trade show attendance to promote their seaweed polyphenol capsule for the dietary supplement market in Japan. A 15% profit before tax is estimated as the return on these new sales over a period of 5 years.

Marigot (MT) has been at the forefront of marine multi-mineral technology and innovation by adopting an in-depth scientific approach to the research, including clinical studies, and market development of Aquamin™. From its application and development laboratory AquaminTM has been successfully trialled and incorporated into a wide range of food products as a source of mineral enrichment, fortification, or buffering aid based on its unique physical and structural properties. MT’s product innovation strategy is focused on today’s healthy lifestyles, as exemplified by its recent introduction to the market of Aqua PT Nature’s Calcium, Green Tea and Pine Bark Extract (775 mg x 120 capsules per tub), an innovative health supplement which has anti-inflammatory qualities; reducing pain and stiffness to result in improved mobility and walking distance. MT aims to develop a similar product to Aqua PT where calcium is combined with a seaweed polyphenol extract. MT already has an online sales capability for Aqua PT and would aim to use it also for this new product. MT’s commercial manager in Asia would promote this product in Japan, although sales would also be sought in Europe. A 15% profit before tax is estimated as the return on these new sales over a period of 5 years.

1.1.3 Food and beverage market
MT’s commercial manager in Asia has identified an opportunity for a wholly seaweed derived antioxidant and mineral formula product for incorporation into food and beverage products in the Japanese market. The Japanese functional foods market is the most developed in the world as illustrated by the cutting-edge innovations that continue to deliver more sophisticated and niche health benefits. In terms of size on an international scale, Japan’s functional products market is second only to the United States, and is valued at US $19.6 billion annually. The important role of food in curing or preventing illness has long been recognized in Japan, and has facilitated the development of the functional food market as consumers have been encouraged to look after their own health, and proactively combat disease. Japan’s aging population and the increasing prevalence of lifestyle-related health issues have put a growing emphasis on FOSHU products, as well as foods that are rich in antioxidants with more indirect health claims such as boosting the immune system, or containing cancer-preventing elements.

MT will source a seaweed polyphenol extract made using SWAFAX IP. MT has a strong R & D capability to enable it to formulate a wholly seaweed derived antioxidant and mineral formula product and evaluate it. A 15% profit before tax is estimated as the return on these new sales over a period of 5 years.

1.2 Effect on Competitiveness of SMEs
Encouraging and challenging agri-food and drink companies, particularly small and medium sized enterprises (SMEs), to consider the benefits of exporting and building it into their business strategies is essential. Research shows that exporting companies tend to enjoy increased levels of growth, productivity and innovation in addition to other positive effects including improved business resilience and increased profitability. This belief in exporting is shared by all 3 SMEs and the SWAFAX project has enhanced their capability to access the Japanese market. All three SMEs are committed to innovation as the basis of maintaining their competitiveness, and during the SWAFAX project all experienced growth and increased profitability. For example, between the 2010 and 2012 Marigot increased its sales by 44% and profit before tax by 55%. Also during the SWAFAX project all three SMEs have made further investments in research and innovation to underpin future new product offerings.

Whilst the SMEs recognised the opportunities that successful introduction of seaweed polyphenol extract process technology, and the associated bioactive products for the personal care, health supplements and food and beverage markets, particularly in Japan, would give them, they would not have had the resources or know-how to do this directly without participation in the
SWAFAX project. The role of CyberColloids should be particularly highlighted in validating a seaweed polyphenol extract process technology on a pilot scale and specifying a proposed scaled up production process, thus providing the SMEs with a strong technology platform upon which to create value within their businesses through seaweed polyphenol extracts. Furthermore, significant scientific evidence was transferred to the SMEs to substantiate the use of the seaweed polyphenol extracts within the high value personal care, health supplements, and food and beverage markets. The role of CyberColloids should also be highlighted in transferring SWAFAX project results, including Japanese market and commercial applications data, to SMEs through detailed quarterly reports which were written to aid interpretation and the thinking of SMEs on how the results could be used to create value in their businesses. The personal care, health supplements and food and beverage applications, as outlined in 1.1.1 and 1.1.3 are forecasted to command profit margins before tax of 14% or 15%, which will make a highly significant contribution to the competitiveness of HS, Marigot and Mesosystem. Human health is an important driver for innovation within all three SMEs. The SWAFAX project has significantly increased the bioactives capability within all three SMEs through knowledge gained from the leading European nutritional scientists, the 3 successful dissemination events at Coleraine (June 2011), the “Route to market opportunities for participating SWAFAX SMEs” workshop at Porto (November 2011), the “SME Exploitation of SWAFAX Results” Discussion Forum at Stornoway (June 2012) and the http://seaweedforhealth.org website.

1.3 Economic justification of the HYFFI project
It was anticipated that the total investment of €1,046,089 in the SWAFAX project will be recovered in three years after project completion through commercial exploitation of seaweed polyphenol extract processing technology by the SMEs in the personal care, health supplements, and food and beverage markets. The forecasted sales for improved existing and new products, arising from SWAFAX project IP, which are confidential, reflect a payback of the investment within 3 to 4 years. SWAFAX enabled HS to network with people from the seaweed industry, who they would otherwise have been unlikely to meet, and to obtain detailed analysis about their product composition and other scientific data that they were then able to supply to new potential customers. As a result of this HS has gained new customers in both the human food and personal care sectors. SWAFAX allowed Marigot and Mesosystem direct access to scientific expertise and networking opportunities within the Universities of Reading and Ulster. Such access to excellence in science is invaluable to both SMEs. In addition, Marigot has just submitted an application in partnership with Ulster, through the Intertrade Ireland FUSION programme, for a product innovation project focused on the Asian market. Successful introduction of the seaweed polyphenol extract technology by the SMEs is anticipated to lead to longer term adoption of the technology by others SMEs in the European and international seaweed industry.

1.4 Contribution towards Community societal objectives
Any change that has a positive impact on a sustainable food system is of relevance to all European Government agencies and companies involved in the agri-food industry. HS is a true model of sustainability, harvesting a renewable resource in an environmentally responsible way creating much needed year round jobs on the Isle of Lewis. This made the company a clear winner of The Crown Estate, Marine Business Award in 2010. In addition, the development of seaweed polyphenol extract processing technology within the SWAFAX Project for the personal care market will make a contribution to human skin care in Europe, including medical applications. Furthermore, the development of seaweed polyphenol extract processing technology for health supplement applications and food and beverage use will have a positive impact on human health through new scientifically well documented antioxidant and anti inflammatory products, add volume to manufacture in Europe and increase exports from Europe to Japan.

In conclusion, the SWAFAX project has had positive effects on a range of Community societal objectives including a more sustainable food system, increased employment and improved health. For those aging consumers, a quality of life benefit as well as health benefit will be provided.

1.5 Effect of Transnational technological cooperation
The SWAFAX Project brought together leading European nutrition and hydrocolloids research, technology and development (RTD) performers, and innovative, non-competing SMEs in the business of supplying seaweed derived products to European
and international markets. The complementary expertise of the three RTD performers, and their past experience of working together, helped to maximise the value of the SWAFAX project work undertaken.

While some innovations can be developed and introduced at a single SME level, this opportunity for adding value to seaweed was best implemented by a group of European SMEs. Under these circumstances, the SMEs looked towards CyberColloids to take the lead in developing the seaweed polyphenol extract technologies, and towards the two universities in how best to conduct the scientific studies to support the personal care, health supplement and food and beverage market opportunities. Operation of all three SMEs and CyberColloids in international markets, and both universities in international collaborations, helped to steer the direction of the research and to ensure SMEs had maximum opportunities to service international markets. Transnational technological cooperation was further enhanced by three dissemination events organised by CyberColloids and the University of Ulster which enabled the transfer of knowledge to the SMEs in the UK and Ireland, and from research scientists at UK, Irish, German, French and Icelandic institutes and universities. It would not have been possible to achieve all the benefits from the work undertaken in a single EU state.

2 Dissemination and Exploitation of Project Results and Management of Intellectual Property

2.1 Project results and IPR

The SMEs decided to allow independent exploitation of the IP generated within the SWAFAX project, where each SME has equal rights for internal use of the IP for future product development and sales, without the need to pay the other SMEs a royalty. A legal document is being put in place by the SMEs governing ownership and usage of the SWAFAX IP.

Section B 3.1.2 in Grant agreement no: 262519 laid down the arrangements for IP ownership and usage which were and ratified by all partners. Under item 3 pertaining to background IP it states: “All Background Intellectual Property Rights used in connection with the Project (see Table 1) shall remain the property of the party introducing the same, access rights, if necessary will be on fair and reasonable conditions to be agreed. After the end of the project, SMEs and RTD performers will grant access rights on a fair and reasonable basis to the background needed to use the foreground”.

An unusual situation arose in SWAFAX as Background IP belonging to CEVA became Foreground IP belonging to the SMEs (See Figure 1). This Background IP was used by CEVA, as subcontractors in the project, to produce extracts for the in vivo studies conducted at the Universities of Ulster and Reading. This Background IP was also granted by CEVA to CyberColloids to produce other extracts for the in vitro studies at the University of Reading. A legal document is being put in place outside the SWAFAX project by the SMEs, CyberColloids and CEVA governing access to the Background IP belonging to CEVA.

Table 1: Access rights to Background IP owned by the consortium partners

<table>
<thead>
<tr>
<th>Partner</th>
<th>Background IPR</th>
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<tbody>
<tr>
<td>UR</td>
<td>‘know how’ in the areas of: i) Phytochemical absorption, metabolism and bioavailability; ii) Design and conduct of human intervention trials for assessing health benefits of dietary components; iii) Assessment of antioxidant and anti-inflammatory activity of dietary components, especially phytochemicals; and iv) Health claim legislation.</td>
</tr>
<tr>
<td>UU</td>
<td>‘know how’ in the areas of: i) Phytochemical absorption, metabolism and bioavailability; ii) Design and conduct of human intervention trials for assessing health benefits of dietary components; iii) Assessment of antioxidant and anti-inflammatory activity of dietary components, especially phytochemicals; and iv) Health claim legislation.</td>
</tr>
<tr>
<td>CC</td>
<td>‘know how’ in the areas of: i) Seaweed extracts manufacturing techniques and chemistry; ii) Processing pilot plant design and configuration; iii) Manufacturing process design and implementation; iv) Sales and marketing networks; and v) End use product development.</td>
</tr>
<tr>
<td>HS</td>
<td>‘know how’ in the areas of: i) Seaweed growth cycles and selection for maximum polyphenol concentrations; and ii) Ascophyllum processing techniques.</td>
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<td>MT</td>
<td>‘know how’ in the area of nutritional seaweed based product development.</td>
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<tr>
<td>MS</td>
<td>‘know how’ in the area of well-being and personal care products which could incorporate polyphenols.</td>
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Figure 1: Use of background IP and how it forms part of the generated foreground IP
The uniqueness of the IP generated for 2 of the 3 methods in seaweed polyphenol extraction was discussed by the consortium. Whilst the processes were possible candidates for patent protection, the SME's decided not to pursue this route as they felt it was problematic given the level of disclosure required. Furthermore, the SME's decided not to pursue patents for the unique IP generated as a result of the studies carried out by Reading and Ulster, where product (extract) characteristics could be related to the uniqueness of the raw material source, characterisation technique and some of the processing know-how.

Project results acquired by the SMEs are shown in Table 2. A confidential technology transfer document, and not patenting, has been agreed as the type of exploitation for novel seaweed polyphenol extracts. Scientific documentation of the health benefits of the extracts is best served by peer review scientific publication subject to restricted (non confidential only) disclosure of extract processing technology. The SMEs have gained extensive market intelligence within the SWAFAX project to support the use of their brands (e.g. Hebridean and Aquamin) for introducing improved and new products based on seaweed polyphenol extracts.

Table 2: Project results acquired by the SMEs

<table>
<thead>
<tr>
<th>Project</th>
<th>Result (No.)</th>
<th>Result (Description)</th>
<th>Type of exploitation</th>
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<tbody>
<tr>
<td>(Marigot)</td>
<td>(Hebridean Seaweed Company)</td>
<td>Type of exploitation (Mesosystem)</td>
<td>Confidential info. (Technology transfer document) Confidential info. (Technology transfer document) Confidential info. (Technology transfer document)</td>
</tr>
<tr>
<td>1 Novel seaweed polyphenol extracts</td>
<td>2 Antioxidant/anti inflammatory effects in vitro</td>
<td>3 Beneficial effects in intervention study</td>
<td>4 Market analysis and feasibility</td>
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<tr>
<td>(company source specific)</td>
<td>(company source specific)</td>
<td>(company source specific)</td>
<td>Trade mark</td>
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2.2 Dissemination and Use

2.2.1 Web-based management and dissemination system

The University of Reading developed and maintained a web-based knowledge management and dissemination system at http://seaweedforhealth.org to support the SWAFAX Project partners and their activities, and to publicize the activities of the consortium. The web-based system includes a public section and a confidential domain. The public web pages provide i) information on the partners and their expertise; ii) a seaweed for health forum; iii) publications; iv) news and events; v) a gallery of relevant photos; vi) a contact communication channel; and vii) non-confidential Project findings. The restricted area of the website is accessible only by the partners via user names and passwords. This restricted area enabled geographically dispersed project team members to efficiently share and exchange information, and to discuss and jointly modify project resources, in real time.

2.2.2 Training to enhance innovation capability

Bespoke training in seaweed polyphenol extract processing technology was provided by CyberColloids to HS. CyberColloids ran a half day training workshop in Porto on “Route to market opportunities for participating SWAFAX SME’s”, which covered i) Japanese market potential for polyphenol extracts focused on the requirements of SWAFAX SMEs; ii) Developing your Business with Polyphenols; and iii) What are the next steps for creating value from SWAFAX IP? In addition, CyberColloids and the
University of Ulster ran a “SME Exploitation of SWAFAX Results” Discussion Forum for the SMEs.

2.2.3 Market analysis and feasibility
Early in the project CEVA presented an excellent overview on “EU market opportunities for seaweed in food and nutritional products” to the Consortium. Then Galloway and Associates were commissioned to carry out a market study for polyphenol rich extracts in Japan. First clarification of the positions of SMEs and their needs within the market study was obtained, then the study was undertaken using a combination of local desk research in Japan, interviews and meetings with industry opinion leaders, relevant company executives and trade journalists in the market and finally the findings were detailed in a report with recommendations for the SMEs. CyberColloids also carried out research and reported in detail to SMEs on “Commercial applications of phlorotannins and fucoidans” and “Market Products with Fucoidan”. Hebridean Seaweed Company, Marigot and Mesosystem also carried out market analysis and business planning exercises for the introduction of new products based on SWAFAX IP to the personal care, health supplement and food and beverage markets. Summaries from their work can be seen in sections 1.1.1 to 1.1.3.

2.2.4 External dissemination of the results to the scientific community
After approval by the SMEs results from the bioavailability study were presented in a poster by the University of Reading at the 2011 International Conference of Polyphenols and Health in Barcelona, Spain. CyberColloids gave an oral presentation at the 2011 Alg’n’Chem conference in Montpellier, France on the anti-cancer compounds in seaweeds, including the SWAFAX extracts. The University of Ulster presented a poster on the effect of seaweed derived polyphenols on inflammation and oxidative stress at the 4th C-TRIC annual Translational Medicine Conference in Londonderry, UK in May 2012. Work is in progress by both universities to produce two joint publications in peer reviewed journals based on in vitro and in vivo Project results. For exploitation reasons, there is also a limit to what can be said in the publications about the processing technology used to prepare the study samples. Publications will be sent to the SMEs for their approval 45 days before submission, and the consent of the SMEs will be obtained for scientific publication.

2.2.5 ‘Third party’ SME workshops and networking events
Three successful ‘third party’ SME workshops and networking event took place in June 2011 at the University of Ulster, Coleraine:
“Market Opportunities for Seaweed: Polyphenols and other interesting bioactives” Knowledge Club Event
• 43 participants from Carbon Zero NI, CEVA, CAFRE, CC, Fraunhofer Institute, HS, Invest NI, IT Tralee, James Hutton Institute, MT, Marine Institute, Matis, Northern Ireland Food and Drink Association, Sheffield Hallam University, University College Cork, University of Limerick, UR, UU and Voya
‘Bioactives from Seaweed, and Innovative Ingredients in Salt Reduction’ Conference
• 38 participants from CEVA, CyberColloids, Food Standards Agency, Fraunhofer Institute, IT Tralee, James Hutton Institute, Marigot, Marine Institute, Matis, Queen’s University Belfast, Sheffield Hallam University, Spanish Point Sea Vegetables, University of Limerick, UR, UU and Voya
‘Seaweed Culinary Event with Prannie Rhatigan’
• 27 participants from CEVA, CC, Fraunhofer Institute, James Hutton Institute, Marine Institute, Matis, Sheffield Hallam University, Spanish Point Sea Vegetables, UR & UU

These were reported within the consortium by the University of Ulster and CyberColloids, and publically by University of Reading at http://seaweedforhealth.org. In addition, the University of Ulster published an article on the first event within the Institute of Food Science and Technology “foodnet” Newsletter (September 2011) and the SWAFAX project within its Faculty of Life and Health Sciences Newsletter (June 2011)

List of Websites:

www.seaweedforhealth.org/swafax
Related information

**Result In Brief**
Seaweed extracts to promote wellness

**Documents and Publications**
final1-25-pg-swafax-report3007a.pdf

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