FOREWORD

As the Senior Portfolio Leader for Development in Gwynedd Council, it is my pleasure to present to you the MENTERRA Product Packages.

Combining the Welsh word "menter"(enterprise) and the Latin "terra"(land), MENTERRA was the name given to this pioneering land-based initiative. In 2003, Gwynedd Council secured a £2.6m Objective One funding package through The Welsh Assembly Government, the WDA (which is now incorporated into the Assembly), University of Wales Bangor, and Gwynedd Council itself to launch this ambitious 3 year project (which was extended to a 4 year term). The objectives were: -

- To establish the potential for agricultural innovation in Gwynedd
- Expand the economic basis of the industry
- Identify production opportunities and new processes
- Develop new agricultural enterprises
- Identify future target markets
- Establish procedures to undertake future crop research and create new enterprises

Since the project was established, it has given some 50 Gwynedd farmers an ideal opportunity to collaborate in the development of a range of crops that are different to those normally seen locally. Amongst these were **Crambe, Camelina** & **Linseed oil crops, Soft Fruit, Exotic Mushrooms**, and the first attempt in Britain to grow **Salicornia** away from its natural habitat. Advancing the development of this crop now forms part of a Trans European project, which will also research the environmental benefits. There was an attempt to improve upon the **Omega 3** fatty acid level in lambs, but without doubt, the outstanding success was seen with the **Naked Oats** and **Barley** growing trials and these crops have been the subject of very promising assessments over the last months of the project.

With the project now drawing to a close, it is time to reflect on what has been achieved from the investment, the innovative research and development work, and the commitment of the group of farmers and smallholders with an interest in diversification and trialling. Without doubt, one of the most important outputs of the project was the establishment of the **Agricultural Innovation Centre** at Henfaes near Abergwyngregyn, which was opened in 2004. This building, together with the expertise of the staff, will be a valuable long-term asset for the industry. The project also proved that a different range of crops could be successfully grown in Gwynedd and by now, armed with the knowledge gained from the research and the growing trials, it is encouraging to see two groups moving forward towards establishing co-operative businesses, in line with one of the project objectives, to further develop their produce and market it more effectively.

The Product Packages summarise all the findings and conclusions of the research trials, giving clear guidelines to those farmers who wish to further develop these crops. It is hoped that they will encourage those of you who have followed developments from the sidelines to consider taking advantage of new openings for producing different crops, to help secure prosperity within the agricultural industry in Gwynedd and to help sustain a strong economy and community in our rural areas.

If you would like more information, you can also visit our web site on
www.menterra.org

Councillor Dafydd Iwan
Portfolio Leader – Development
Gwynedd Council

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INTRODUCTION

This publication has been produced by MENTERRA, a Gwynedd multi partner agri-innovation initiative. It outlines the range of considerations facing individuals or businesses that intend to grow and profit from the cultivation and commercialisation of oil seed crops. It aims to explain how to produce quality food grade crops in Gwynedd and examines which markets in particular should be targeted to maintain competitiveness. The package will detail why camelina and linseed in particular, were selected within the Menterra project and provide an informative introduction to partial or complete diversification options.

The information aims to highlight key requirements for growing and harvesting oil seed crops, quality considerations, information regarding new and emerging markets and possible routes to market for the crop.

The oil crops were selected for inclusion in Menterra because they offer Gwynedd farmers the opportunity to diversify into a niche market by supplying among others, the growing functional food industry. This relatively new market has developed substantially over the past 5 years and further growth is predicted as consumers become increasingly selective in their choice of food and other day-to-day products.

Experimental work was conducted at the Henfaes Research Station during 2004 and the crops were also grown on a number of selective farms throughout Gwynedd. The approach provided a means to evaluate the varieties available and ascertained the performance of linseed, camelina and crambe to determine their agronomic requirements.

Crambe was piloted on a semi commercial scale but as yields were substantially less that expected, it has not featured to the same extent as camelina or linseed in this publication. It was selected as one of the most promising oil crops due to its high yield of erucic acid. The product is used in plastics manufacturing as a lubricant or ‘anti slip agent’. In addition to acid production, crambe oil has excellent lubricating properties and has a range of potentially valuable applications as petroleum product replacements in environmentally sensitive applications such as forestry and marine engineering.

Linseed and camelina on the other hand did grow better in Gwynedd, providing the platform for further experimental work to determine the impact of omega 3-oil supplement as a finishing feed for mountain lambs.

Origins and Uses of Linseed

Linseed is the seed product of *Linum usitatissimum* L. also commonly known as flax. The plant has been cultivated for thousands of years, being one of the 'Near East package' of six crops that founded agriculture in the Fertile Crescent; the others being einkorn wheat, emmer wheat, barley, lentils and peas. Plant breeders have developed two main types of specialised cultivars, seed flax (linseed) for oil production and fibre flax for the bast fibres in the stem.

The linseed plant is an annual with a thin, erect and wiry stem. Linseed varieties tend to be shorter with more branches than fibre flax plants. The flowers are usually self-pollinated and produce a rounded fruit capsule that retains the seed until threshed. The seeds are oval and flattened about 4-5mm long, are usually brown but golden varieties have also been developed.

Origins and Uses of Camelina

Camelina (*Camelina sativa*), a member of the mustard family, is a summer annual oilseed plant. Camelina, like oats and rye, is considered a secondary crop because it first appeared as a weed of flax and cereals, before being domesticated as agriculture spread into Eastern Europe where its tough qualities were appreciated.

The plant grows between 30-90 cm tall, has branched stems that become woody at maturity, and produces abundant small pale yellow flowers. The seeds are yellow to yellow-brown with a very low thousand-grain weight of about one gram. False flax and Gold of Pleasure are the popular names for c*amelina sativa*.

The crop was probably never widely grown in the British Isles but was popular in Eastern Europe and Russia up to the early 1940's with some production lasting up to the 1950's. Camelina was replaced with the introduction and widespread use of oilseed rape, probably due to difficulties associated with hydrogenating the highly unsaturated oil for margarine.

Over 50% of the fatty acids in cold pressed camelina oil are polyunsaturated. The major components are alpha-linolenic acid (omega-3-fatty acid, approx 40%) and linoleic acid (omega-6 fatty acid, approx 15%). These fatty acids are known to reduce the LDL-cholesterol level in the blood and are good for heart and cardiovascular health. The oil contains many natural antioxidants, such as tocopherols, which make the oil stable and is well suited for use as cooking oil. The vitamin E content of Camelina oil is approximately 10mg/100g. Because of the health effects, technical stability and almond-like taste and aroma, camelina oil has an exciting future in the kitchen and on the plate.

GROWING LINSEED

Soil & Climate

Linseed can be successfully grown in a variety of soil types and is suited to all regions of the UK. However, due to difficulties in producing a suitable seedbed, thin soils or those with poor structure such as heavy clays should be avoided. Linseed straw is very difficult to cut when even slightly damp. Wetter or later areas may experience harvesting problems, especially fields next to the sea, where mist or spray may prevent the straw drying. Linseed is fairly tolerant of drought conditions provided its taproot can access water. Optimal pH is between 6.0 -7.0.

Varieties

There is a wide range of linseed varieties available, a selection of which was tested as part of Menterra, along with fibre flax and dual-purpose varieties. As would be expected, the seed yields of the flax varieties were much lower. Dual-purpose varieties had low seed yields, and incidentally poor fibre yields as well (see the *Guide to Growing Flax and Hemp in Wales* available at www.flaxandhemp.bangor.ac.uk). The stand retting technique, recommended to achieve quality fibre, requires desiccation with herbicide before the seed is fully developed, and much seed is lost as the crop rets. Therefore, despite the obvious attractions of producing both seed and fibre from the same crop, the best option is to select either a specialist linseed variety or a fibre flax variety and manage it accordingly.

The Descriptive List of Linseed Varieties is produced by the Home Grown Cereals Authority and is available at www.hgca.com. The list contains yield, oil content and agronomy data. When using the lists to assess suitability for Gwynedd, particular attention should be paid to earliness of maturity. For example, 'Juliet' is the highest yielding variety on the list, but also the latest to mature, which may cause harvesting difficulties.

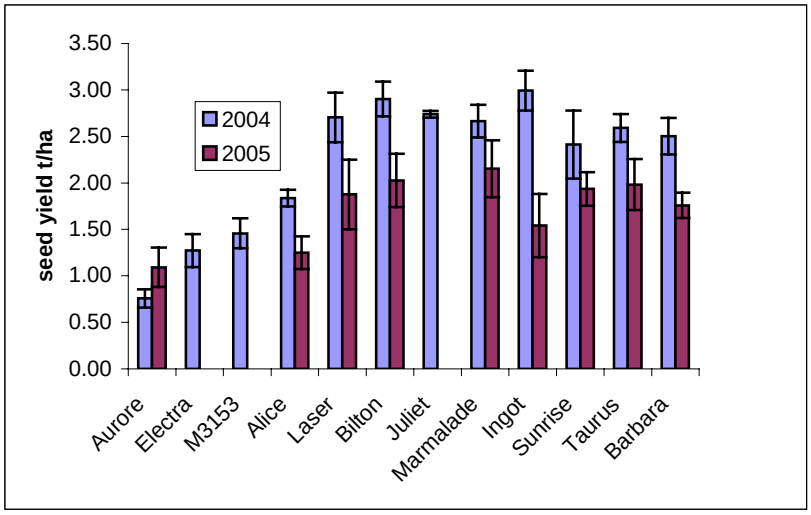

figure 1: Seed yields of flax (Aurore, Electra), dual-purpose (M3153, Alice) and linseed varieties, (Electra, M3153 and Juliet) were not grown in 2005. Ingot and Marmalade are golden varieties.

If Linseed is grown under contract, the purchaser will usually specify the variety before sowing, and often supply the seed as part of the contract.

Rotation

The main threats are *Sclerotinia sclerotiora* infection (other hosts include oilseed rape, peas spring beans and hemp) and wilt (*Fusarium oxysporum*) requiring a four-year break in the rotation. Perennial grass weeds also present problems due to the poor competitive characteristics of the plant. These are best controlled using glyphosate (e.g. Roundup) before ploughing.

Seedbed and Sowing

Despite the tolerance of a wide range of soil conditions, linseed establishment can be problematic. Seedbed preparation is crucial as it is essential to provide a firm, fine and moist environment into which the small seeds (TGW 8-10g) can be shallow-drilled. Ideally, the seedbed should be rolled before and after drilling to ensure good soil contact with the seed. Care should be taken not to over-work fine soils, as if capping occurs linseed emergence will be severely restricted.

The optimal sowing period is between mid-March and mid-April, although acceptable yields can be obtained from sowings up to the end of April. Earlier sowing is usually preferable, but is no advantage to be obtained from early drilling into a cold, poor seedbed. Sowing depth should be as little as is necessary to ensure good contact with moist soil – ideally 15 mm, but deeper (no more than 25-30mm) where the seedbed is drier than optimal. Row spacings of 8-18cm are acceptable, with narrower rows giving better plant distribution. Sowing rates should be directed at establishing about 400-500 plants/m^2, (approximately 50kg/ha assuming 60-80% establishment), which is optimal for seed yield. Lower seed rates encourage weed competition and increased branching, resulting in uneven seed development, whilst higher rates are likely to increase lodging and disease vulnerability.

Crop Nutrition

Fertilisers should be applied to the seedbed prior to drilling in accordance with the following DEFRA recommendations, taken from RB209, which is available at:

www.defra.gov.uk/farm/environment/land-management/nutrient/fert/rb209/Index.htm

Soil Index	*0*	*1*	*2*	*3*
N (kg/ha)	80	40	0	0
P_2O_5 (kg/ha)	100	75	50	50
K_20 (kg/ha)	90	65	40	0

figure 2: Fertiliser requirements for linseed.

Weed Control

Due to its uncompetitive growth habit, effective weed control is crucial to linseed production. Cultural methods should always be used to reduce weed problems as far as possible. An example is the stale seedbed technique, where a seedbed is prepared

in advance of sowing to encourage weeds to germinate, which are then destroyed by cultivation or herbicide. Further wide spectrum weed control can be obtained through use of a herbicide, after the plant has developed two proper leaves. Current options include metsulfuron methyl (e.g. Ally) and bentazone (e.g. Basagran). Metsulfuron methyl is cheaper and has a wider spectrum of controlled weeds; however there may be residual damage to some sensitive non-cereal crops sown during 16 months following application to the linseed. Growers should consult the current edition of the UK Pesticide Guide, or the Pesticides Safety Directorate at www.pesticides.gov.uk for details of currently approved products.

Pests

During the Menterra linseed trials, there were no observed pest attacks, nor on flax crops grown in recent years in Gwynedd. It is recognised that linseed is not usually pest prone, however Flea beetles, often harboured by weeds (e.g. Charlock), can cause characteristic 'shot hole' damage to leaves and may be a serious pest during crop establishment. Flea beetles were observed at Henfaes but not in significant numbers to cause serious damage, which may be due to the limited area of cultivation.

The use of lamda-cyhalthrin (Hallmark) as a spray to treat flea beetle is allowed under a Specific Off Label Approval (SOLA). However seed dressing are often more effective in being less dangerous to non-target insects and use much less active ingredient. SOLA is also available for Chinook (beta-cyflutrin + imidacloprid), a seed dressing developed for oilseed rape, which may also benefit linseed. For up-to-date information on SOLAs consult:
https://secure.pesticides.gov.uk/offlabels/offlabellist.asp.

Linseed is much more resistant to wire worm than cereal crops and potatoes, and therefore it may be sensible to follow ploughed down pasture that may harbour large numbers of this pest.

Disease

The use of fungicide treated seed (e.g. thiabendazole/ thiram, prochloraz or iprodione) is recommended for controlling seedling diseases. Seed treatment should be applied by an approved seed supplier. Potential problems in the mature plant are grey mould (*Botrytis*) and blight (*Alternaria linicola*), which may occur at flowering in wet years, although again no problems have been recorded in recent flax crops.

The only disease observed during growing at Henfaes was powdery mildew in July 2006 on severely drought stressed flax, planted in compacted soil around the field margins.

Harvesting and Combine Settings

The crop matures in late August/September. Desiccation with diquat (e.g. Reglone) or glyphosate (e.g. Roundup) can assist harvesting both through drying out green fibrous stems, overcoming uneven seed ripening and killing weeds which hold moisture in the lower canopy. Diquat is a contact herbicide and works faster than glyphosate, however some contracts (whole seed e.g. for sprinkling on bread) may state that only glyphosate should be used, as diquat can dull the appearance of the seed. Desiccation can take place as soon as the seeds can be rattled inside their capsules. Spraying is best done in early morning, avoiding hot afternoons especially when using glyphosate as the plants will be 'shut down' and fail to absorb the chemical. At least 10-20 days are necessary between spraying and harvesting to ensure the crop is fully senesced.

Photograph courtesy: Dr Edward Dickin and Dr Jim Dinnock

figure 3: Illustrations of linseed in growth and the harvested seed.

Although linseed is an easy crop to grow, harvesting can be problematical. Spring sown linseed's late maturity means that combining takes place in September when the shortening days and heavy dews restrict combining hours, as linseed is almost impossible to cut when green or damp. In arable areas of England autumn sown varieties have never reached popularity, as spring sowing allows problematic autumn germinating black-grass to be controlled. It may be advantageous to autumn sown linseed in Gwynedd where black-grass is not present, and the long dry days in July will benefit harvesting.

A combine harvester with sharp knives is necessary to deal with linseed's fibrous stems. Keep up a high cutter knife speed and cut as high as possible with a low reel speed to avoid stems wrapping on the combine table. The concave should be set to 5mm at the front and 3mm to the rear, with a high drum speed of between 1000 and 1200 rpm. Sieves may need to be closed to avoid seed loss, and wind speed over sieves kept low. Care must be taken to ensure that trailers and grain handling machinery are leak-proofed, as the small slippery seeds flow very easily.

Storage and condition

Moisture content of 8% is necessary for prolonged storage and to maintain oil quality drying must take place at a maximum of 65°C. The small size of the seed limits airflow, so for on-floor drying the recommended maximum storage depth is 80cm.

Beware – never stand on bulk linseed, as you will rapidly sink in!

GROWING CAMELINA

Soil and Climate

Camelina is suited to most soil types. It is drought tolerant, especially later in the season, and so can be grown on poorer soil types. The crop can be winter sown but this is best avoided in areas, which may be subject to late spring frosts. Frosts can damage the flowers and prevent seed formation destroying the whole crop.

Varieties

Camelina is very much a neglected and forgotten crop; hence the number of varieties is limited. The variety used in the Menterra trials is 'Calena', a spring variety from Austria. Seed is available from merchants specialising in alternative crops, such as Springdale Crop Synergies, or direct from the supplier e.g. Samena Handels GmbH in Austria. IENICA (www.ienica.net/crops/goldof pleasure.pdf) states that GIE SPRINT registered a winter variety 'Epona' and a spring variety 'Celine' in France. However this company appears to have ceased trading and supplies of these varieties are uncertain.

Despite not being developed specifically for the UK, Calena gave reasonably good yields of 1.8 t/ha in 2004, 1.3 t/ha in 2005 and 2.6 t/ha in 2006. Yields of all spring oilseeds were poor at Henfaes in 2005 due to a cool May and drought in June, leading to poor early growth, reduced branching and premature flowering of drought stressed plants

Rotation

Camelina will work well on most livestock and mixed farms as a break crop, and since it is a low input crop, it complies with the Welsh Assembly Governments' drive for more sustainable production systems. It is common good practice not to follow on from other closely related crops such as rapeseed. The stubble can be left to provide erosion control when establishing autumn-seeded crops in minimum cultivation systems.

Seedbed and Sowing

The drill depth should be approx 1-2cm, row spacing 12-14cm. Modern pneumatic drills set to oilseed rape settings can achieve even shallow sowing. Problems may be experienced when using older gravity fed drills, as the seed is very small and flows too quickly. One of the farm triallers mixed the seed with the fertilizer, broadcast with a fertilizer spinner and then rolled. This produced an evenly established and very successful crop. Pneumatic grassland seeders such as those produced by Einbock would be another possibility.

The sowing date ranges from end March to end April/early May, which gives a harvest date between mid August to early September. The best time to sow is when

the soil has warmed to about 10˚C, in Wales this can be between mid April and mid May. There is no yield penalty from sowing up to mid May, however the harvest becomes later in September. Studies at UWB have shown that there is little benefit achieved from winter sowing.

The seed rate of around 7kg/ha gives a plant population of around 220-250 plants/m^2. Due to its small size it is recommended that the seed is sown into a moist seedbed or when rain is expected. The crop germinates quickly and is visible within 5-7 days.

Crop Nutrition

The crop is not a 'hungry' plant and requires a maximum of 75kg nitrogen/ha; pilot experiments at Henfaes have shown no yield benefit in increasing N applications above this level. This is best applied as 35kg N/ha in the seedbed, with the remainder applied at the 4 leaf stage of growth. The crop is not responsive to P and K applications, providing soil indices are maintained above 2. If P or K is required it may be applied in the seedbed.

Weed Control

The crop is fast growing and competes well against weeds when an even crop is established. A good seedbed, warmth and moisture will enhance the competitiveness of the crop; hence a later sowing date may be advantageous by providing a better chance of achieving these conditions. If weeds are known to be a problem, a herbicide can be applied pre-emergence of the crop to assist with the early stages of establishment. During the trialling period, Alpha Trifluralin 48 and Treflan, both containing trifluralin, were the only products approved for use on Camelina. Unfortunately trifluralin does not control the brassica weeds, such as charlock, which are a common problem in Gwynedd. Since then and as of spring 2007, it has been announced that trifluralin herbicide is to be withdrawn. Growers should therefore consult the current edition of the UK Pesticide Guide, or the Pesticides Safety Directorate at www.pesticides.gov.uk, for details of currently approved products.

Pests

During the Menterra camelina trials, there were no observed pest attacks. The crop is fast growing minimising the need for flea beetle control. Again a SOLA for Chinook may be useful in the future. Seed eating birds may cause slight damage to very ripe crops so scaring devices might be useful.

Disease

Camelina is not susceptible to many diseases. Downy mildew (peronospora) is sometimes a problem in late sown crops. This disease was observed at Henfaes in 2005 and on two of the three trialling farms in 2006. There are no fungicides currently registered for use on Camelina, so legally no fungicide can be applied. If

Camelina becomes more widespread it would be worth obtaining SOLA for products such as Folio Gold (chlorothalonil + metalaxyl-M), currently used to control downy mildew in field beans.

figure 4:
Downy mildew on Camelina at Henfaes in 2005.

Harvesting and Combine Settings

The crop is less susceptible than oilseed rape to pod shatter and seed loss, and can stand undamaged for up to 6 weeks after full maturity. However it is always good practice to harvest the crop as soon as possible to preserve quality. The crop may be direct cut using a standard combine with a 3mm lower screen. If necessary the crop can be desiccated to even up ripening using glyphosate. Camelina may also be swathed and allowed to ripen before harvesting. Camelina has no fibre in the stem, so is much easier to combine than linseed. Combines and trailers should be carefully sealed, as the small seed can be lost from any openings. Average yield is approximately 0.5 – 1.0 t/acre (1.25 – 2.5t/ha).

figure 5:
Mature Camelina crop near Aberdaron. At maturity, pods will be brown, and stems straw-coloured.

Storage and Condition

Camelina seed ***must*** be carefully dried (max temperature 43°C) and stored to avoid deterioration of the oil. The seed will deteriorate rapidly in warm damp conditions, developing off-flavours tainting the oil. The seed should be dried down quickly after harvest to around 8% moisture.

Cost of Production

Fixed costs will vary between farms but need to be considered when establishing crop profitability.

In terms of variable costs, the availability and need for contractors will be determined by the farms' existing machinery base and it may be suitable under certain conditions for farmers to pool their resources and share some costs between a pre-identified group. It is important to ascertain accurate costs of production per unit from sowing to post harvest, with the need for storage facilities also being considered and reflected in these costs.

COMMERCIAL OPPORTUNITIES

UK Production of Linseed and Camelina

Linseed cultivation was encouraged in the 1990s by a favourable subsidy regime, but since the 'Agenda 2000' reforms the popularity of this crop has fluctuated. At the time of writing, the short-term prospects for linseed are on a downward trend due to a poor UK harvest in 2006 (resulting from a cold spring and summer drought), poor prices (a good harvest in Canada) and good prices for oilseed rape (a rival break crop).

Camelina is already grown as an oilseed, but only to a limited extent in the UK (e.g. in Devon and Reading). UK yields from winter-sown plots show a 30-40% yield advantage over spring-sown plots.

Further information regarding the commercial potential of linseed and camelina crops in the UK can be found at:
http://www.nnfcc.co.uk
http://www.premiumcrops.com

Market Potential

Both linseed and camelina are rich in omega 3 fatty acids. The health advantages of Omega-3 essential fatty acids are well documented and are of particular relevance in the current health-driven consumer marketplace.

Whilst there is definite long term potential in the lubricant and bio-fuel uses of these crops, any short-term market potential is likely to come from increased use within functional foods.

Environmental conditions will influence the total oil content as drought stress or disease may decrease oil levels. As a general rule a healthy un-stressed crop will contain seeds with higher oil content. Premature desiccation will result in decreased oil content. Presumably oil content will vary between camelina varieties, but our trials only used Calena due to the difficulty of sourcing seed.

Vegetable oils are composed of tri-glycerides, which are large molecules consisting of a group of three fatty acids (hence the 'tri') bound to a glycerol (type of alcohol) molecule. Fatty acids are long chains of carbon atoms, with hydrogen atoms, and it is the proportions and type of fatty acid present that determine the property of the oil.

Unsaturated fatty acids can be classified according to the position of the first double bond. The double bond of mono-unsaturated fatty acid is found on the ninth carbon, hence these are sometimes called omega 9, e.g. oleic acid found in olive oil.
In fatty acids with two double bonds the first is on the sixth carbon, so are omega 6 e.g. linoleic found in sunflower oil; and where there are three double bonds, the first is on the third carbon, therefore omega 3 e.g. alpha–linolenic acid (ALA) found in linseed.

Total oil content of linseed varies between the varieties, with the flax and dual-purpose varieties having the lowest oil content.

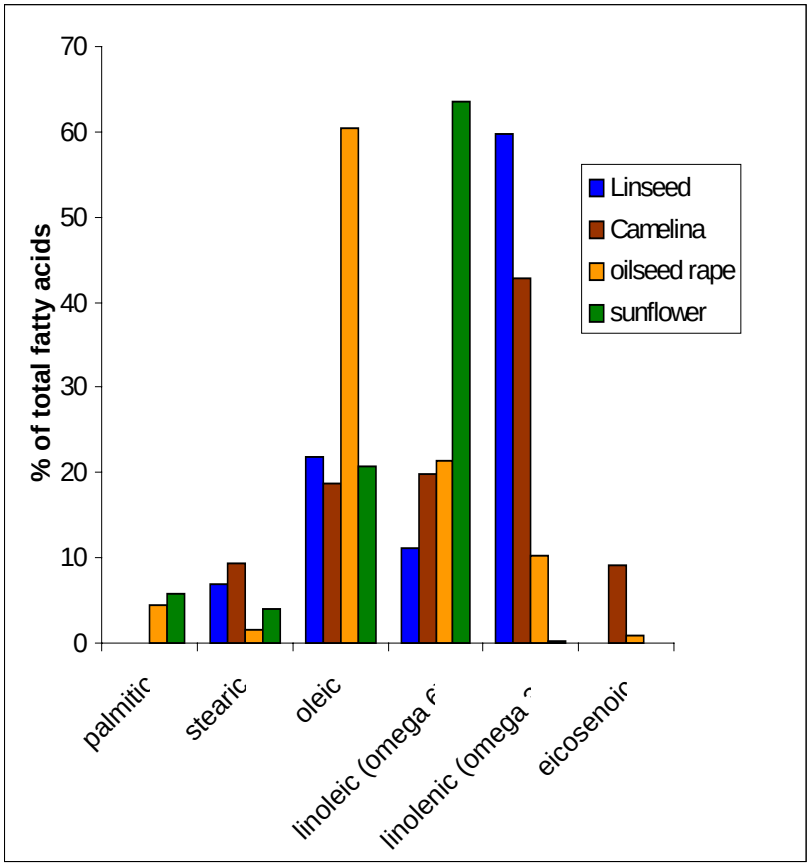

figure 6: Fatty acid composition of linseed (Barbara grown at Henfaes), Camelina (Calena grown at Henfaes), compared with oilseed rape and sunflower (values from Salunkhe, Chavan, Adsule & Kadam (Eds) 1992, World Oilseeds, AVI Books: New York)

Again, as with total oil content, the proportion of omega 3 may vary between camelina varieties, but further tests would be needed.

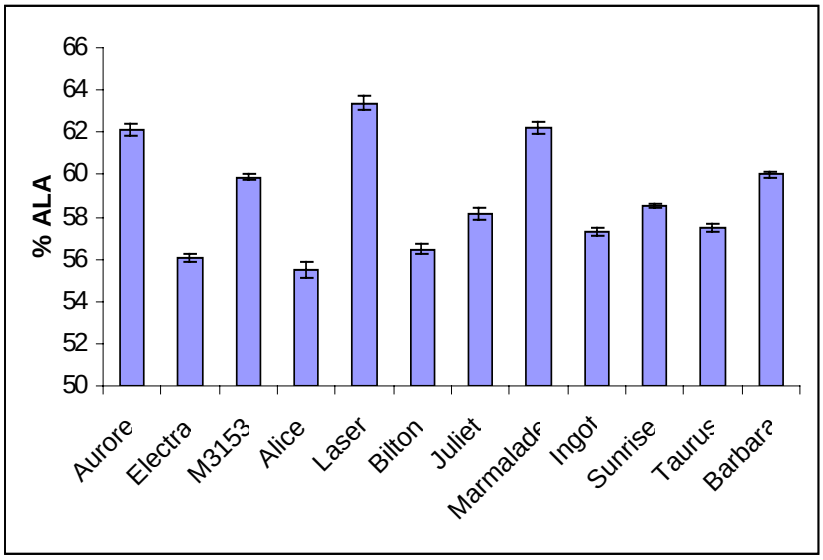

figure 7: Alpha-linolenic acid ALA (omega 3) as the percentage of total oil of flax (Aurore, Electra), dual-purpose (M3153, Alice) and linseed varieties grown at Henfaes in 2004.

Uses of Linseed

Linseed represents only 1% of the world supply of oilseeds, but is considered to have high potential for increased industrial use, as well as for human food and animal feed markets

Nutritionists classify fatty acids as essential or non-essential. The human body is unable to make essential fatty acids, so must obtain them in the diet. As Omega 6 and omega 3 are essential, they need the same biochemical machinery in the body to process them and hence they compete with each other. Therefore the proportion of omega 3 to 6 is important. In the western diet, there is far too great a proportion of omega 6, especially from sunflower oil.

The traditional source of Omega 3 is from Fish Oil. Fatty fish such as Salmon, Mackerel and Herring naturally contain high levels of Omega 3 and people who regularly eat fresh examples of these fish have normal omega 3 levels. Linseed is a source of Omega 3 fatty acids.

A good source of accurate information on the Internet is www.lipidlibrary.co.uk. Information on some other sites is often incorrect or produced with the aim of selling supplements.

Oil Composition
Linseed and camelina oils are by far the richest plant sources of omega 3 (see figure 7). Rapeseed has lower levels of omega 3 and sunflower almost none. Sunflower also has very high levels of omega 6, which may be metabolised to produce chemicals that irritate the blood vessels, causing furring of the arteries.

Linseed oil is superior to camelina in having a greater ratio of omega 3 to omega 6. However camelina oil is more stable, due to its natural antioxidants, which also have health benefits in their own right. These tocopherols are types of vitamin E, and are used in skin creams to encourage the healing process.

Uses of Camelina

Food Use
As with linseed, camelina contains above average levels of omega 3 fatty acids. Recent Danish research "DIETARY FATTY ACIDS AND AMINO ACIDS OF *CAMELINA SATIVA* SEED" **(**J. Zubr 2002), highlighted the nutritional potential of camelina, through providing omega 3 at a level exceeding a diet based on tolerable fish fat levels.

Camelina Ltd established by the University of Helsinki in 1999 to market a range of products from pure oil, salad dressing, relish to seeds and crushed oilseed cake, has recently been acquired by the Raisio group to provide camelina in it's range of '*Benecol*' low-cholesterol products.

Whilst the health effects will appeal to a certain percentage of the population, camolina's technical stability and almond-like tasty aroma may also be recognised by a larger market in the near future.

figure 8: Camelina oil by Calon Lân used as a salad dressing

Cosmetics, skin and body care products, soaps and soft detergents
Much of the camelina currently produced is used in the preparation of cosmetics and paints. The low oxydability of alpha-linolenic acid can be exploited. Traditional uses of the oil include as an illuminant and for cosmetics purposes.

Adjuvant in agrochemicals
Camelina has also been found to be a potential low cost crop for green manuring. Its stems can be used to make brushes, packaging and thatching temporary buildings. Additional uses for the green crop as fodder and the seed for fattening poultry, whilst the protein rich pressed cake is a valued livestock feed. The oil can also be used as adjuvant oil for

agrochemical sprays. It can also be used as an inexpensive cover crop and for ornamental plantings.

Organic Feed for Animals

Following the oil production process, the remaining meal is compacted into 'Press cake'. This pelleted by-product still contains useful quantities of oil and high levels of protein and is commonly used in animal feed. There are reports in the farming press that 'red tape' due to farm assurance regulations may be a problem if selling press cake produced by an on-farm oil press. Current regulations are designed for large-scale commercial operations, and are too expensive and heavy-handed for small producers. This situation is being reviewed in light of the growing popularity of on farm pressing.

At present, camelina cannot be used for animal feed, as it is on a list of banned plant products in the EU. It was placed on this list some time ago due to (unfounded) concern about the glucosinolate content. Glucosinolates are not harmful; in fact they are the anti-cancer compounds in brassicas such as broccoli.

It is anticipated that as camelina becomes a more widely grown crop, the regulations will be reviewed. However until the law is changed it is illegal to use camelina in animal feed.

Photograph courtesy: Dr Edward Dickin and Dr Jim Dimmock

figure 9: Camelina seed, press cake and oil.

Under the Menterra programme, scientist at UWB undertook two sets of experiments, feeding a combination of diets including linseed oil to Welsh Mountain lambs. The aim of the research was to supplement the finishing diet of Welsh Mountain lambs with enhanced levels of alpha-linolenic acid in order to raise levels omega-3 fatty acids in the meat. The trial concluded that there was no improvement in meat quality to be gained by feeding the chosen breed (with a supplement or grass) after bringing them off the mountain. Weight gain from such feeding appears to be by accumulation of mainly saturated fat. A larger framed more muscular breed, for example a Texel, would possibly give different results.

Bio-fuel

Camelina press cake has the potential for use in pellet-fired boiler applications, either straight or combined with wood chips, or composting material. A Coed-Cymru initiated trial, found that the addition of camelina press cake improved the production of wood chip pellets, by acting as a binding and lubricating agent.

Bio-diesel

Camelina could be an ideal low-input crop suitable for bio-diesel production. To be an environmentally sound option, bio-diesel must stand up to a life cycle analysis of the environmental impacts of all aspects of production. At present many bio-diesel crops have little overall benefit, causing almost as much pollution in their production as is saved by their use as an alternative to mineral diesel. Tropical palm oil is the cheapest source of bio-diesel, but creating plantations often involves destruction of rainforest. Oilseed rape is the major oilseed in the UK, but requires large inputs of fertilizer N and pesticides. These, and N especially, require large amounts of fossil fuel energy in their manufacture and transport.

The table below compares oilseed rape and camelina; figures are typical values taken from HGCA Recommended List, RB209 and the Menterra trials. Despite a lower yield and oil content, the output efficiency of camelina, measured as oil produced per unit of N, is better than oilseed rape. It should also be considered that the data for oilseed rape are for a crop treated with herbicide, fungicide and insecticide, in contrast to the camelina, which is untreated. If camelina was grown using farm yard manure, green waste compost or treated sewage sludge to provide its modest N requirements, then the environmental balance sheet is even more favourable.

	Yield t/ha	% Oil	Oil yield kg/ha	Fertilizer N applied	kg oil per kg N
Oilseed rape	4.5	44	1980	200	9.9
Camelina	2.2	35	770	70	11

Figure 10: Comparison of yield, nutrition and oil properties for camelina and oilseed rape.

At the time of writing fresh unprocessed oil (unlike used chip oil or methyl-ester) does not qualify for the reduced tax rate as bio-diesel. However this may change, and anyone wishing to produce bio-diesel within the law should contact the Inland Revenue for up-to-date advice. Using untaxed bio-diesel on the road is an offence.

Potential Use as Lubricating Oil

A decade ago, virtually the only plant-matter-derived products on the market were adhesives and lubricating oils and a handful of intermediate chemicals. Today, plant-derived products compete in just about every major product category, entering the market by displacing some petroleum-derived product in a portion of its market, and then gradually increase their market share. An example of this is crambe, which yields some 9% more oil than is popular relation rapeseed, but is currently stifled due to lack of processing sites, whilst the Menterra trials did not prove successful for growing in Gwynedd, it is possible that with improved variety selection this may be a potential oil crop of the future. The oil produced from both Linseed and camelina, is considered too ‘light’ for use as lubricant in their natural state, processing cost are currently prohibitive in this area.

Admittedly, most plant-derived consumer products are not yet competitive with their petrochemical counterparts. But the price premium for plant-derived products has dramatically diminished. Even when their costs are higher, plant-based products are gaining market share as a result of a combination of "green" consumerism and government regulation. A number of plant-based products have established their reliability and quality, not to mention environmental value.

Four drivers for change were identified by Springdale Crop Synergies Ltd (http://www.springdale-group.com):

It is estimated that around 800,000 tonnes of lubricants are used in the UK each year, whilst the EU market for lubricants is estimated to be 4.9 to 5.1 million tonnes per annum. Of these, over 580,000 tonnes are unaccounted for after use and are presumably lost in the environment. Further to this, it is estimated by the European Environmental Agency that around 260,000 tonnes of oil-based lubricants are lost in the North Sea each year. It therefore seems logical that oil-based lubricants are perceived to have the greatest competitive advantage in total loss systems e.g. chain bar oils, two stroke marine engines, drilling muds, agricultural greases and possibly in applications where the risk of loss is high (e.g. certain hydraulic systems). In such cases their negative impact on the environment is much less than that of mineral oil-based lubricants.

The drivers for adoption of vegetable oil derived lubricants are:

- Regulatory issues
- Price
- Performance
- Need or wish to change sourcing to renewables
- Environmental impact and image
- Contract specifications

Hydraulic fluids are seen as 'high risk loss' situations as the systems operate at high pressure often in environmentally sensitive areas such as forests and watercourses. In the UK the total hydraulics market amounts to 120,000 tonnes per annum, only 1% of this is accounted for by biolubricants.

Chainsaw oils also represent a 'total loss' system. UK consumption is estimated at 500 - 600 tonnes per annum, currently only 75% of the oil used for these applications is biodegradable, and this figure is expected to reach 95% by 2010.

As service contracts, within the public sector, are increasingly specifying bio lubricants as the preferred product when working in environmentally sensitive areas, the market will make biodegradable materials more competitive.

Potential Use of Linseed and Camelina as Bio-fuel

At the time, of writing fresh unprocessed oil (unlike used chip oil or methyl-ester), whilst potentially suitable for bio-fuel use, does not qualify for the reduced tax rate as bio-diesel. However this may change, and anyone wishing to produce bio-diesel within the law should contact the Inland Revenue for up-to-date advice.

Oil Storage and Shelf Life

One of major problems of extended oil storage life is rancidity. Oxidation of unsaturated free fatty acids not only produces offensive odors and off-flavor limiting their use, but can also decrease nutritional quality through the formation of secondary reaction products. Rapeseed oil contains a high amount of unsaturated free fatty acids, and its oxidative stability decreases rapidly, particularly with the temperature.

Heat, light and exposure to oxygen are the greatest factors of accelerating rancidity of stored oils. For better preservation, rapeseed and canola oil should be packaged in dark, opaque, airtight containers. Cooking oil should be stored in cool, dark area. Generally, cooking rapeseed oil has a shelf life of about one year; canola oil may have a shelf life of more than one year.

Presence of heavy metals in edible oils is known to have deteriorating effect on stability of these oils. The adverse effect of heavy metals on stability of these oils are due to the absence of antioxidants or stabilizers. Therefore, technology of oil production should avoid addition of heavy metals to oil during processing.

Formulation of the oil products may be improved by incorporation of antioxidants and stabilizers. Packaging and storage conditions (such as light and temperature) have to be optimal to increase shelf life.

Rapeseed/canola oils are usually packed in bottles (for cooking oil purpose) and in cans, paperboard, plastic (for shortenings and margarine purposes respectively). Most canned packages are vacuum packed or nitrogen-packed. Liquid oils have been packed in blow-molded bottles or molded polycarbonate bottles, PVC plastic containers with cap closures such as screw thread, and flexible cartons such as "Tetra-Paks".

Why Commercialise Linseed and Camelina in Gwynedd?

Farm and experimental plot trials have proven that both crops can be grown successfully in Gwynedd. The agronomic guidelines should be followed to ensure maximum yield, aiming for high quality food grade crops. Care must be applied at key stages, especially drying the camelina post harvest. This section aims to outline which trends in particular need to be followed or even anticipated and identify which markets should be targeted given the crops' specific characteristics.

A SWOT analysis conducted in the UK and published by IENICA (Interactive European Network for Industrial Crops and their Applications) reveals the following strengths and opportunities linked to the production of camelina:

Strengths

- lower primary production costs
- appropriate scale conventional processing technologies are available
- new processing technologies/facilities in the UK
- UK centres dedicated to substantiating medicinal claims
- Specialised UK pharmaceutical companies actively involved in the commercialisation of phytochemicals
- The recent UK development of Gamma Linoleic Acid (GLA) from evening primrose exemplifies the possibilities for the industry

Opportunities

- potential to broaden UK crop base – biodiversity
- potential to replace imports of "natural" materials ranging from aromatherapy products to dyestuffs
- growing crops for some markets is unlikely to take up large areas of UK arable land, but could provide profitable enterprises from some growers plus up and down stream benefits
- consumer appetite for functional foods increasing

Route to Market

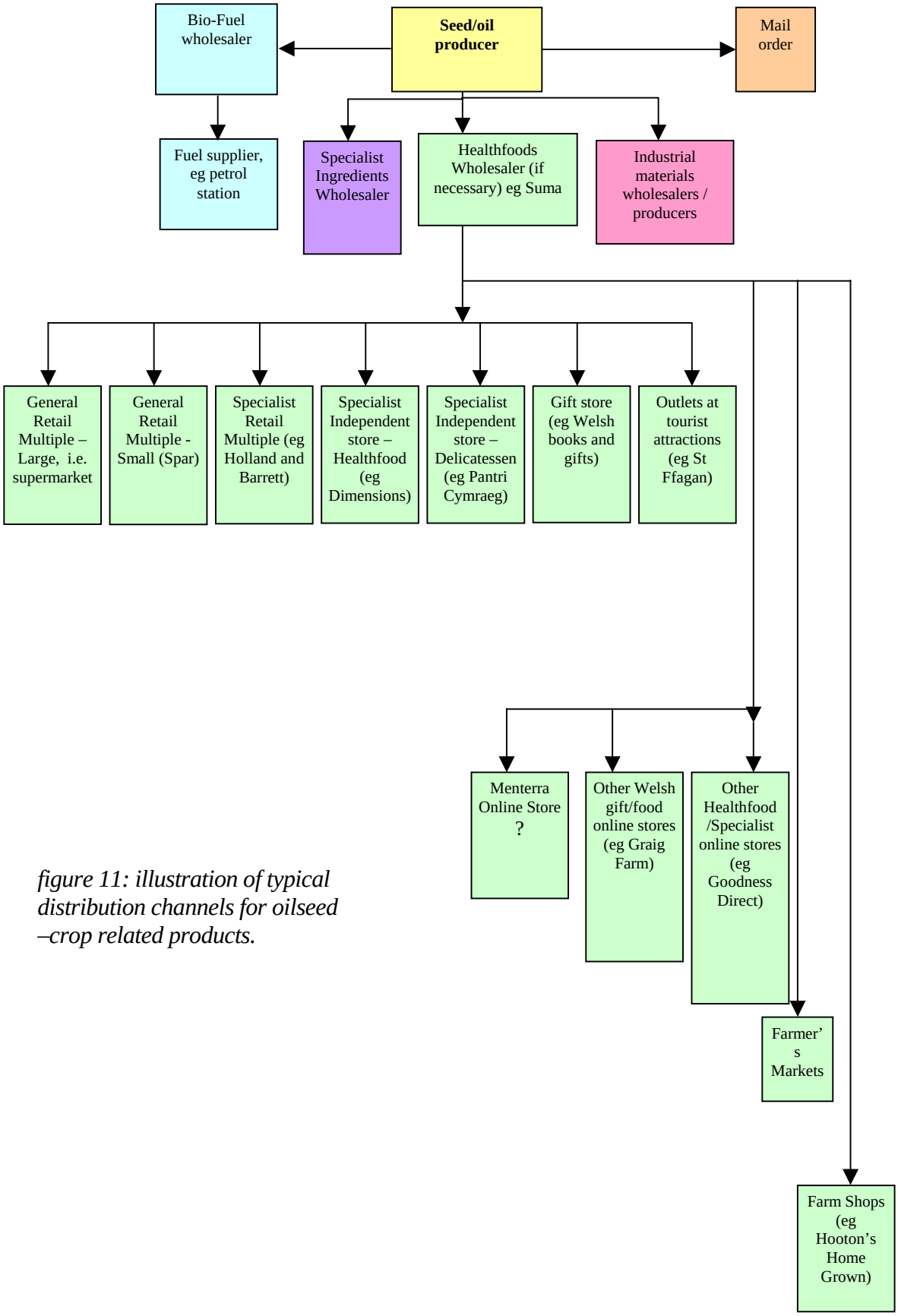

figure 11: illustration of typical distribution channels for oilseed –crop related products.

Key Steps for Processors in Assessing the Route to Market

The development pipeline is a process used in all new product development activities when taking product concepts or ideas and converting them into fully commercially viable products which the consumer is prepared to buy in an identified market. At various stages of the pipeline decision hurdles exist to ensure that all relevant information is available and risk is known to make an informed decision prior to committing to any expenditure. It is important to factor into a project timescale the research element; gathering market information and data to enable identification of a product that fulfils a consumer need or fills a market gap. The diagram below shows the pipeline process. The process can be as simple or complex as required to fit the size of opportunity and / or the financial investment required to action. Whatever the size of opportunity, it is good discipline to follow this type of procedure to facilitate good decision making throughout the project.

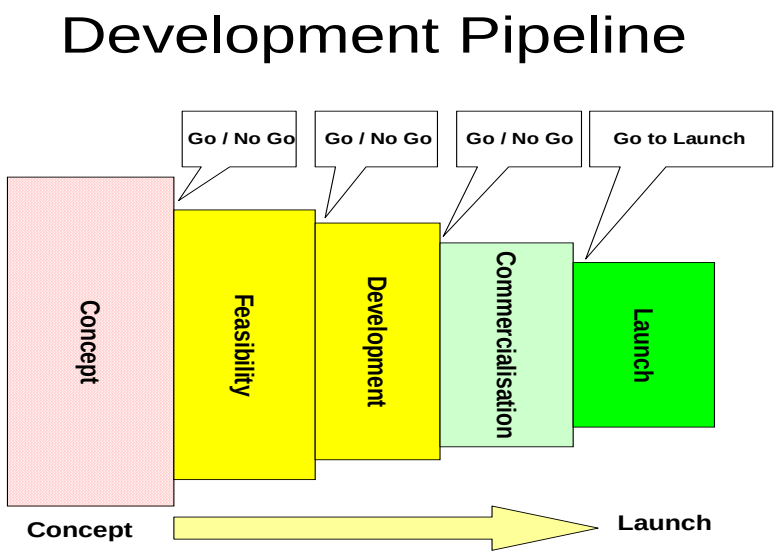

figure 12 : *The development pipeline process in diagrammatic form*

- Define the product concept based on market research
  - ↳ Identify product to fit a market gap / consumer need.
- Conduct feasibility
  - ↳ Provisional product costings and capital expenditure
- Develop product / process / package
  - ↳ Identify and develop processing requirements and packaging to create product offering.
- Develop or identify supply chain
  - ↳ Purchasing requirements, internal and external contracting for ingredients and services required.
- Establish Bill of materials
  - ↳ Highlight cost of goods and services. Provides valuable information to establish selling price to achieve target margins.

Key Players - Potential Partners and Competitors

Globally, Canada remains the world's largest producer of linseed and is the only real exporter. According to DEFRA, UK linseed production increased from 55,000 tonnes in 2003 (at a value of £5.9M) and has increased to 76,000 tonnes by 2005. Whilst worldwide exports of linseed are in decline, diversification of its uses has grown causing an increase in imports. Linseed development work in Hungary, particularly for winter sowing, has increased Northern European yields. Despite these advances and the potential to grow locally, the EU is still a major net importer.

Camelina at present has a very limited market, although the potential is there for it to become substantial. Cold pressed, it is a pleasant tasting and healthy oil, which can be sold as food oil in the UK and Europe due to past precedence. Camelina ltd. as part of Raisio in Helsinki and SPRINT-Limagrain (France) are working hard promoting the seed and the oil, to gain consumer acceptance in the marketplace.

The European market for Camelina is still undeveloped, although Australian and Canadian companies are actively stimulating the market by exploiting new opportunities to grow specialist crops and export them abroad.

For more information: http://www.rirdc.gov.au/reports/NPP/02-026.pdf
(Report of Australian crop specialist exploiting market possibilities in Europe.)

Calon Lân was established in 2006 to market alternative foods with healthy benefits and as such is the first company in the UK to sell pure camelina oil for culinary uses. The company's initial focus is to develop the market for camelina oil whilst medium term efforts will concentrate on growing the crops locally. In June 2007, the company will launch two other products, a pesto sauce and an innovative dip called *Twca* made from camelina seeds. Together with linseed and avocado oil, it forms a range of healthy products, which offer something different for the consumer. Additional information can be gained from www.bwydcalonlan.com

The existing market for omega 3 products is dominated by the fish industry and significant competition can be expected from these organisations. The market for linseed-based products is much weaker than the fish industry.

The real potential opportunity lies in the emerging cattle feed market, which is yet to become established. An additional opportunity exists in using linseed to produce a vegetarian alternative to fish based Omega 3 supplements, but it is too soon to assess value of omega-3 related supplements. Some activity and R&D already exists in this area in the UK (www.oilthecogs.co.uk), retailing supplements made from linseed. Competition also exists from supplements made from marine algae.

IMPORTANT INFORMATION

This information is produced for guidance only, all crops are subject to seasonal variation and recommendations are based on knowledge currently available and results of field trials for the Menterra project. Any products mentioned are for illustration and are subject to change, other suitable products are available. The organisations participating in this project can bear no responsibility for damages or losses resulting from the use of the above information. If the grower has any remaining doubts about any aspects of the crop production, he/she should consult a professionally indemnified agronomist.

All agrochemical products must be handled and applied strictly in accordance with manufacturer's recommendations. Growers should consult the latest edition of the UK Pesticide Guide, or the Pesticides Safety Directorate at www.pesticides.gov.uk, for details of currently approved products specific to each crop.