IENICA

Interactive European Network for Industrial Crops and their Applications

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Summary Report for the European Union 2000-2005

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~ INTRODUCTION ~

An Interactive European Network for Industrial Crops and their Applications, IENICA began in February 1997 under the Fourth Framework Programme, FAIR (FAIR-CT96-1495). IENICA saw a great many achievements in its original three years, perhaps most significantly the European overview published in August 2000, which gave *"the first ever concrete review of the industrial crop situation in Europe"* (Ciaran Mangan, DG Research, CEC Brussels, IENICA Scientific Officer). This report was based on 14 individual state reports from the project partners (EU-15 except Luxembourg), which identified markets and constraints for non-food crops.

In addition, an industrial crop website was established (**www.ienica.net**) which made a wide variety of non-food crop information freely available to the public, and three major industry-focussed conferences were held. These conferences covered Natural Fibres (Denmark), Vegetable Oils (the Netherlands) and Speciality Chemicals (France).

In April 2000 IENICA received continuation funding (QLK5-CT-2000-00111) under the Quality of Life Programme of Framework Programme 5 which provided for a further three years of activities in this area. The original partner states remained in the project and were joined by a number of the European Union accessing states, as well as some 'associated' states. In addition, Bulgaria joined the project in a separate contract at a later date. 26 countries have therefore been involved in the new IENICA project:

Austria, Belgium, Bulgaria, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Republic of Ireland, Israel, Italy, Lithuania, the Netherlands, Poland, Portugal, Romania, Spain, Sweden, Switzerland, UK, plus the USA and Canada.

Source: **www.brocku.ca/maplibrary/ fortopo/euroname.html**

The major activity of this new IENICA has been the preparation of national status reports by the accessing and associated states. These have, for the first time, assessed the status of non-food crop developments and markets in these countries. In addition, the 'original' partner countries have updated their national reports, and together this gives a complete overview of the new enlarged Europe.

This report collates and analyses the information provided by IENICA's partners and updates the summary published in 2000.

The national reports and summary have been major elements of IENICA's tasks, but have not been the only activities:

- The original website has been modified and considerably extended and is now a valuable resource for all with an interest in non-food crops

- Quarterly newsletters have continued to be published, with articles from projects partners and others

- An agronomy booklet has been published, with generic guidelines on a range of non-food crops

- Four Market Data Sheets have been published, with information on raw material specifications for: bast fibres; oleochemicals; essential oils; biolubricants

- Pan-European conferences (BioPlastics, UK, February 2002 and GreenTech, the Netherlands, April 2002) and regional seminars (Italy, May 2003 and Germany, September 2003) have been held successfully

Together, these activities have addressed the overall aim and the objectives of IENICA as set out at the start of the project:

Aim:
The IENICA project seeks to achieve enhanced technology transfer and market orientation in order to extend sustainable and economically viable non-food products from plants, through positive interaction and collaboration at all stages in the production-supply-processing-market chain.

Objectives:
- To facilitate interaction and interchange of information through an interactive network linking key individuals from industry in particular, to government and scientists/technologists in EU member, accessing and associated states. Quantification of market size and confirmation of market specification for raw materials are particular targets. This will extend the successes of the previous IENICA project into accessing and associated states, whilst extending and validating progress in EU-15 states.

- To disseminate unpublished data which identified opportunities, challenges and constraints for industrial crops on a country by country basis in EU-15, so that market development can begin in a structured way and in a way which recognises user needs and market demands. The IENICA project will act as the European Gateway facility for all data on non-food crops and this will be made available free o charge through its dedicated Internet site.

- To identify the strengths of accessing and associate states in EU in terms of industrial crops, industrial products and their markets and link this data into existing networks and market assessments. These will be actively disseminated throughout the EU and at the same time, existing EU-15 information will be further proactively promulgated.

- To allow an enhanced efficiency of use of limited RTD funding by identifying true market potential and thereby helping scientists and research funders to focus and achieve maximal value for money in research through closely targeted spending of limited resources.

At the start of the project, IENICA was consolidated with another European project – INFO*RRM*: Industry Network for Renewable Resources and Materials – to become INFO*RRM*-IENICA. INFO*RRM* was a two year project, which recognised that the vast range of activities and websites (both national and EU) involving the many products, services and opportunities in the non-food crops arena are not integrated nor is it easy to search across them. INFO*RRM* became a strategic gateway to aid the navigation of these resources (**www.industrialcrops.eu.com**).

Structure of Report

This report is structured in the same way as the last IENICA summary, published in 2000. Based upon the data and information provided by the 'new' country's national reports and the original partners' update reports (as well as data from other sources, where appropriate) it looks at non-food crops across Europe according to end-use sector, namely oil crops, fibre crops, carbohydrate crops and crops with speciality uses. It discusses the elements of science and technology; identifies, discusses and attempts to quantify markets, and considers barriers and constraints to development and uptake.

In most cases, it has been necessary to discuss the original and new countries separately i.e. the changes which have occurred in EU-15 in the last four years, plus the status of the non-food crops situation in the new states.

Where data is given for EU prior to 2004 it is assumed that 'EU' means EU-15, if not otherwise specified.

Annexes F-O give the country statistics provided by each of the newly accessed states. Annex P gives references for all chapters of this report.

Non-Food Crops

As identified by the previous IENICA summary, industrial raw materials can be sourced from a very wide range of plant species. In fact, all plants have the potential to provide non-food products in some form – whether it be their primary metabolites as bulk materials (e.g. oil, carbohydrates); their secondary metabolites for speciality products (e.g. chemicals, pharmaceuticals) or the remaining biomass as a source of energy. The plant database on the IENICA website lists over 100 plant species with known or potential industrial applications.

The national reports produced for IENICA demonstrate the very wide range of plant species in Europe which are at the commercial, pilot or interest stage.

Some of the species are of interest/are cultivated solely for one non-food application (e.g. flax); some have a range of non-food applications or the by/co-products can be used to add further value to the primary use (e.g. hemp); some are grown for food purposes and their by-products have non-food applications (e.g. wheat, potatoes). As will be shown, developments are occurring in all of these areas – new crops for non-food applications are being introduced and new products are being investigated.

The previous report identified very large markets for many of these products and with the accession of a number of countries into the European Union, the non-food crop industry is likely to see some significant developments. The new countries bring with them huge areas of land and non-food crops cultivated; new skills and knowledge (particularly in the area of speciality crops, for example) and new markets. In turn, the original EU-15 countries have a lot to offer, particularly in terms of technology, research and the latest market developments. This combination suggests that EU-25 (which will increase even further in the coming years) can potentially be a significant force in the global industrial crops arena, and significant future developments are inevitable, though progress in some areas is slow at present.

Enlargement

On the 1st May 2004 ten new countries entered into the European Union, enlarging the EU area by more than 700,000 square kilometres, the culmination of a long process of preparation and negotiation: Cyprus, the Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia and Slovenia. Bulgaria and Romania will join the Union in 2007, providing they meet the required standards of readiness in time. Turkey and Croatia have also applied for membership, although negotiations have not yet taken place.

This enlargement sees an increase from 15 to 25, and *"has its roots in the collapse of communism, symbolised in the fall of the Berlin Wall in 1989, which offered an unexpected and unprecedented opportunity to extend European integration into central and eastern Europe*"[1].

The economic impact of enlargement will be significant as a bigger and more integrated market boosts economic growth for new and current members alike. The newly accessed states stand to benefit from investments from firms based in western Europe and from access to EU funding for their regional and social development. Integration of their economies with the rest of the EU is already underway, as trade agreements, negotiated and applied in advance of membership, have already removed virtually all tariff and quota barriers on their exports to current member states.

The enlargement of the EU by ten countries will have significant impacts, as mentioned. Table 2 estimates the impact of expansion from EU-15 to EU-25:

Table 1 Impact of Expansion from EU-15 to EU-25

	Increase
Population	20%
Economic product	5%
Overall area	23%
Agricultural area	30%
Agricultural workforce	50%

Source: European Commission

The importance of agriculture in the new states is shown in Table 3.

Table 2 Relative Importance of Agriculture

Agricultural share of:	**EU-15**	**CEEC-10**
Economy	2%	4%
Employment	4%	13%

Source: European Commission

[1] **www.europe.eu.int**

The European Commission also notes that:

- Several of the newly accessed states, in terms of GDP per head, are as wealthy as Greece, Spain and Portugal were at accession

- The rate of growth of the new countries is likely to be double that of the existing EU-15 and will consequently have a major influence on demand

- One of the major threats to EU crop prices is the volatility of production in the accession countries and the former Soviet Union

As reported earlier, of the newly accessed/accessing countries, Bulgaria, Cyprus, the Czech Republic, Estonia, Hungary, Lithuania, Poland, and Romania are partners in the IENCIA project.

Legislative Infrastructure

The renewable raw materials industry is subject to a large number of regulations, agreements and legislature which can impact upon the uptake of non-food crops and products both positively and negatively. These are discussed by sector in the following chapters. There is also some discussion of them in the previous summary report (trade agreements, EU policy and the Common Agricultural Policy) and so will not be repeated here. However, since the last report was written, changes have been seen in these areas. Perhaps most significant are the recent reforms of the CAP.

The reforms, adopted in June 2003, have completely changed the way the EU supports its farm sector. Fundamentally, the vast majority of subsidies will be paid independently of production. The new 'single farm payments' will be linked to the respect of environmental, food safety, animal and plant health and animal welfare standards as well as the requirements to keep all farmland in good agricultural and environmental condition – "cross-compliance". The intention is that, by severing the link between subsidies and production, EU farmers will become more competitive and market oriented, while still being provided with the necessary income stability. The different elements of the reform will enter into force in 2004 and 2005.

The newly accessed states will receive the full benefits of the CAP market measures from the date of entry. Table 4 shows estimated CAP expenditure in 2005 for the accession countries (compared with the UK in 2002):

Table 3 Estimated CAP expenditure 2005 for the Accession Countries compared with UK 2002 (million Euros)

	CAP – Pillar 1	Rural Development	Total
Czech Republic	278	161.6	439.6
Estonia	50.4	44.8	95.2
Hungary	416.9	179.4	596.3
Latvia	46.6	97.7	144.3
Lithuania	124.1	145.7	269.8
Poland	906.8	853.6	1,760.4
Slovakia	121.1	118.3	239.4
Slovenia	65.3	83.9	149.2
Cyprus	20.8	22.2	43
Malta	1.8	8	9.8
TOTAL	**2,032**	**1,715**	**3,747**
UK (2002)	3,480.8	161.8	3,642.6

Source: European Commission

This shows that expenditure in the newly accessed states will mainly be on rural development.

Rural development is a key element of the development of the countryside. Consideration must be given to a wider remit than just agriculture; the rural economy and rural employment are impacted on by wider issues than those of agriculture alone.

"Without a living countryside, farming has no future, and without farmers the rural areas do not have one either. A meaningful rural development policy should of course improve the competitiveness of agriculture, in particular in the new Member States. But it has also become clear in our discussions that we need diversification, modernisation, investment and jobs outside the farming sector if we want to have living and sustainable rural communities". Franz Fischler[2]

The European Commission has a range of rural development policy, for both EU-15 and the accession countries, under its 'Second Pillar' of the Common Agricultural Policy, including Sapard (Special accession programme for agriculture and rural development), Leader+ and a range of Commission Regulations[3].

Bioenergy

Whilst the IENICA project does not specifically include crops for energy, it is difficult to address the subject of non-food and industrial crops without touching on this area. If nothing else, this is largely because energy is often an application for the by/co-products of agricultural production for food or non-food purposes; not just a market for specific energy crops alone. In addition, the by-products from biofuel production can be used for industrial purposes; glycerine from biodiesel production, for example, can be used in applications such as surfactants and solvents, and gluten from the production of ethanol from wheat can be processed into plastics.

It is important to note that the biofuels industry in EU-25 is developing rapidly (considerably so in some countries); liquid biofuels, and rapeseed for biodiesel, most particularly. Whilst the members of IENICA have not covered energy specifically in their national reports, it is inevitable that this subject has been mentioned and this has given a brief overview of the industry. The biofuels industry in EU-25 is led by Germany, where very significant activities are taking place, with a great deal of support from FNR - Fachagentur Nachwachsende Rohstoffe e.V. (Agency of Renewable Resources)[4]. More than 600,000 ha of oilseed rape are used for the production of rape methyl ester and it is estimated that nearly 23% of German diesel consumption could be covered by energy plants (2 million ha). The main focus of German development activities, however, are Biomass-to-Liquid (BTL) fuels, and it is estimated that 10% (6 million tonnes) of current Germany fuel consumption could be substituted by BTL fuels; FNR have significant activities in this area.

France is also a major producer of biodiesel – currently processing 350,000 tonnes of rape methyl ester from 260,000 ha.

The European Biodiesel Board[5] gave estimates of EU biodiesel production in 2002 and 2003 (Table 5). It noted that production more than doubled between 1998 and 2002 and 2003 production has increased by 35% when compared with 2002 production.

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[2] The European Conference on Rural Development, Salzburg, November 2003
[3] For further information on EC rural development policy, see **www.europa.eu.int**
[4] **www.fnr.de**
[5] **www.ebb-eu.org**

Table 4 EU Biodiesel Production Estimates 2002 & 2003 ('000 tonnes)

Country	Estimate* Production 2002	Estimate* Production 2003
Germany	450	715
France	366	357
Italy	210	273
Austria	25	32
Denmark	10	41
UK	3	9
Spain	/	6
Sweden	1	1
TOTAL	**1,065**	**1,434**

Source: European Biodiesel Board

Other data, as reported in the IENICA national reports, includes:

- *Austria*: Approximately half the sunflower grown on set-aside land is used for biodiesel (approx. 1,100 ha in 2002) and more than 75% of all set-aside land for non-food crops is rapeseed for biodiesel. In total, approximately 85% of oilseed production is for biodiesel: approximately 8,300 tonnes (this is around 2% of the gasoil consumption in Austria).

- *Belgium:* All the non-food production of oilseed rape is sold to German oil mills and this seems to be used exclusively for biodiesel production.

- *Denmark*: One mill processes rapeseed into biodiesel. All this is exported, primarily to Germany, as there is no domestic tax exemption on biodiesel. 10-15 ha of miscanthus is grown for energy.

- *Finland*: 2,000 ha (10,000-16,000 tonnes) of Reed Canary Grass is grown for bioenergy and paper applications.

- *Greece*: The good future potential for biodiesel from sunflower might increase the production of this crop, and also open the way for other industrial uses (e.g. biolubricants). Limited quantities of cotton seed oil are extracted and some (20,000-30,000 tonnes per year) is used for crude biodiesel, processed through combustion at the crushing/pressing/extraction plants. Sorghum is also grown for energy and olive residues and wastes are being investigated for biofuels.

- *Ireland*: Biofuels is the main area of activity in the area of non-food/industrial crops. Camelina has been grown successfully in Ireland for biodiesel.

- *Italy*: The main use of oilseed rape is for biodiesel and energy is the main sector of interest in the non-food crop area.

- *Sweden*: Oilseed rape is used for fuel. Reed Canary Grass is also used as a fuel raw material and this sector is rapidly expanding.

Activities are also occurring in the bioethanol industry – from sugar beet and cereals; though development is much less advanced than biodiesel, commercialisation has occurred.

The newly accessed states also have a developing biofuel industry, as briefly reported by the IENICA members:

- *Bulgaria*: Oilseed rape will be used for the production of biodiesel in the near future; a new factory with a capacity of 3,000 tonnes of biodiesel per year has recently started, and this currently uses mainly used vegetable oils. Sugar beet and some cereals are used for the production of ethanol: 2,000 tonnes of sugar beet molasses are used. The renewable energy industry needs further support and encouragement.

- *Czech Republic*: Domestic consumption of biofuel is 9.7% of the total diesel consumption in the Czech Republic (227,000 tonnes production in the Czech Republic; 232,000 tonnes imported). Existing manufacturers are not able to satisfy the demand for biofuel and must be enlarged. Government programmes are in place to support the industry; 2003 was the third year of this and the production of methyl esters increased by 67% compared with 2001. Ethanol is also of interest; in 2001 a grant was established for the production of 100,000 hectolitres of bioethanol from agricultural crops in the Czech Republic. Ethanol from sugar beet is at the interest stage. The main industrial application of wheat is the use of saccharose for bioethanol: 25,000 ha and 200,000 tonnes of cereals for the production of 600,000 hectolitres of bioethanol. The main potential after 2010 will be wood and cereal straw, but energy crops are likely to be important in the longer term (after 2020). Chicory is being investigated for bioethanol production.

- *Estonia*: The intention to establish new biodiesel activity from rapeseed was unsuccessful, due to a lack of legislation (taxes and quality standards). There has been much R&D into cost, cost-effectiveness and appropriate production technologies.

- *Lithuania*: A few hundred tonnes of oilseed rape were processed domestically for biodiesel in 2003. Recently, processing capacities have been constructed and biodiesel can be produced in significant amounts, if the economic environment is favourable; they are preparing for production in 2004. It is possible that some farmers may use mustard seed together with rapeseed for biodiesel production on a small scale. Grain is considered an importance source for bioethanol production; ethanol in transport is likely to be a major development in the near future. Willow for fuel has been investigated for there is no commercial production yet. Straw fuel was started in 1996 and there is around 5 MW of straw-fired boilers: approximately 7,500 tonnes per year of straw is used. The slow development of legislation reduces the interest for initiation and limits development.

- *Poland*: The prices of liquid biofuels are still higher than petroleum-based fuels and this is the main barrier to their development. There has been some decrease in excise duty and exemptions (ethanol and rape methyl esters – waived from excise tax). However, potential producers do not use them due to *'the lack of long-term quarantine of decreased excise duty for such fuel'*. Since 1993 ethanol as an additive to fuel has been produced on an industrial scale in Poland. The maximum was in 1997 (110 million litres); it has decreased since then to 48.3 million litres in 2000. The decrease is due to limited demand of major fuel producers. In 2000, 176,000 tonnes of rye; 118,000 tonnes of potatoes and 39,000 tonnes of molasses were used for ethanol. There is research and increased interest in rapeseed for biodiesel. It is likely that approximately 6,000 tonnes of oilseed rape oil will be used in 2004.

- *Romania*: The Romanian Society for Biofuels, established in 2003, has recently made an agreement with a German-American consortium to cultivated sorghum on 500,000 ha, for technical ethanol and pulp.

- *Switzerland*: In 2000, 4,700 tonnes of rapeseed oil was used for biodiesel. 1,300 ha of oilseed rape is grown for biodiesel.

Table 6 shows some of the natural driving forces for bioenergy development in the newly accessed states.

Table 5 Natural Driving Forces for Bioenergy Development

Country	Import dependency >50%	Cultivated land >40% of territory	Woodland >30%	Bio-energy
Cyprus	✓			?
Czech Republic		✓	✓	YES
Estonia			✓	YES
Hungary	✓	✓		YES
Latvia	✓		✓	YES
Lithuania	✓	✓	✓	YES
Malta	✓			?
Poland		✓	✓	YES
Slovakia	✓		✓	YES
Slovenia	✓		✓	YES

Source: EC Baltic Renewable Energy Centre **www.ecbrec.pl**

The EC Baltic Renewable Energy Centre sets out some of the strengths of bioenergy in the accessing states:

- Huge and unexploited bio- resources availability at lower than in EU-15 cost (land and labour)
- Current surplus of agricultural production and opportunities for energy crops production
- Attractive short term options for heat and Combined Heat and Power (CHP) production: coal to biomass (co-firing) or biomass instead of imported gas (oil)
- Better and better policy and legal framework driven by the EU regulations
- Strong agriculture and agro-industry lobby

It also gives some weaknesses:

- Continuing unstable legal framework and taxation
- Infant bio-energy industry and little capacity for, and experiences with, more advanced technologies (for bio-electricity and biofuels)
- Fossil fuels still subsidised and some overcapacity existing in power systems
- Risk associated with land competition (food or energy) and uncertain pattern of agricultural production in the accessing countries and unknown model of future food demand (protein-reach or vegetarian diet?)
- Limited own financial resources and weak technical infrastructure for large scale bio-energy production

Protein Crops

Covered by the previous IENICA report in a dedicated chapter, protein crops are not considered in such depth here.

Proteins are biopolymers of amino acids and are therefore diverse in molecular structure, including highly polar, water-soluble to hydrophobic insoluble molecules. Proteins can vary from being rigid to flexible in structure and have similar mechanical properties when used to produce non-food products as have existing polymers. It is mainly structural or storage proteins such as collagen, keratin and seed proteins which are of interest for commodity applications. In the plant kingdom these are sourced commonly from seeds (e.g. soyabean and pea proteins, wheat gluten) and tubers (e.g. potato proteins). These proteins are traditionally valued for their functional properties e.g. the viscoelastic properties of wheat gluten.

The production of protein-based plant products for non-food markets can be based upon fractionation of existing crops (e.g. wheat, barley), by current or newly developed processes (e.g. peas, soyabean) or by extracting protein from existing low value by-products (e.g. rapeseed meal). Currently, soyabean and wheat proteins represent the most important resource for protein production with some emerging availability of pea proteins and cotton seed proteins and very recently rapeseed proteins.

It was noted in the previous report that the use of protein derivatives from plants has not been subjected to the breadth of exploitation as other non-food crop market sectors. In 2000 (when the last report was published), the production of protein isolates and concentrates was 1 million tonnes per year and it was suggested that this tonnage will undoubtedly increase.

Markets for plant proteins include coatings, plastics, adhesives, cosmetics and encapsulation agents. In the previous IENICA report, the most promising areas for EU produced non-food proteins were thought to be in packaging and labelling, controlled release of pharmaceuticals or chemicals, adhesives and cosmetics. However, the likelihood of competition for markets between proteins and other non-food products (e.g. starch derivatives) must be recognised. Key development will probably occur with proteins from plants as secondary products. Moreover the EU is deficient in food and feed proteins.

IENICA

~ OIL CROPS ~

Introduction[6]

"In concepts for new products the price, performance and product safety criteria are equally important and have a correspondingly high importance right at the start of product development. To ensure a high degree of product safety for consumers and the environment, renewable resources have often been shown to have advantages when compared with petrochemical raw materials and can therefore be regarded as being the ideal raw material basis. Results from oleochemistry show that the use of vegetable fats and oils allows the development of competitive, powerful products, which are both consumer-friendly and environment-friendly."

Karlheinz Hill, Cognis, Germany

In 2003, approximately 330 million tonnes of oilseeds, and approximately 100 million tonnes of vegetable oils, were produced worldwide[7]. In recent years, the amounts produced have continuously increased by around 3% per year[8]. It is predicted that this trend will continue in the medium and long terms. Four main vegetable oils dominate the industry, accounting for around 82% of worldwide vegetable oil production in 2003:

- ***Soya oil***: 31% of world oil production in 2003: 31 million tonnes. There has been a steady increase in production, from 22m tonnes in 1997/1998.
- ***Palm oil***: 28% of world oil production in 2003: 28 million tonnes. There has been a steady increase in production, from 17.7 million tonnes in 1997/1998.
- ***Rapeseed oil***: 14% of world oil production in 2003: 14 million tonnes. Production has remained relatively constant in the last 6-7 years, between 11 and 14 million tonnes.
- ***Sunflower oil***: 9% of world oil production in 2003: 9 million tonnes. Production has remained relatively constant in the last 6-7 years, between 7.5 and 9.5 million tonnes.

In addition, a number of other oil crops are produced around the world, including peanut, cottonseed, palm kernel, coconut, linseed, groundnut and corn oil. The production of most of these has remained relatively constant and accounted for approximately 18% of worldwide vegetable oil production in 2003[9].

Fediol data shows that, in 2003, EU-15 produced 4.1% (13.6 million tonnes) of total worldwide oilseeds production and 8.6% (8.6 million tonnes) of total worldwide vegetable oil production (see below), and Eastern Europe produced 1.8% (5.8 million tonnes) of total worldwide oilseeds production. See figures 1, 2 and 3.

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[6] Key references for this chapter are:
- Fediol (EC Seed Crushers' and Oil Processors' Federation - **www.fediol.be**)
- The American Soybean Association (ASA - **www.asa-europe.org**)

[7] Fediol and the ASA
[8] Hill, K (2000) *Fats and Oils as Oleochemical Raw Materials* Pure Appl. Chem., Vol 72, No 7 pp 1255-1264
[9] See **www.fediol.be** for detailed information on the worldwide production of the main oilseeds, the main vegetable oils and oil consumption of selected countries.

Figure 1

Oilseeds Production of the European Union, 2003
Total Production: 13.6 million tonnes

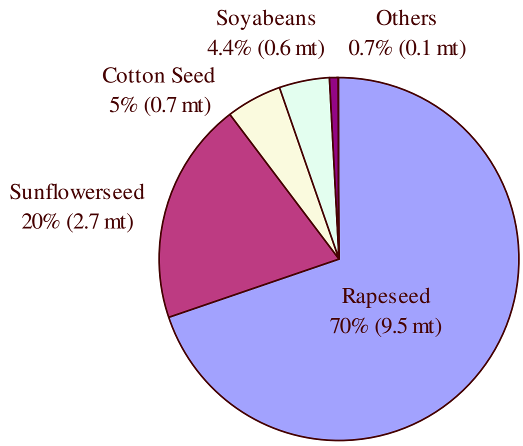


Figure 2

Vegetable Oil Production of the European Union, 2003
Total Production: 8.6 million tonnes

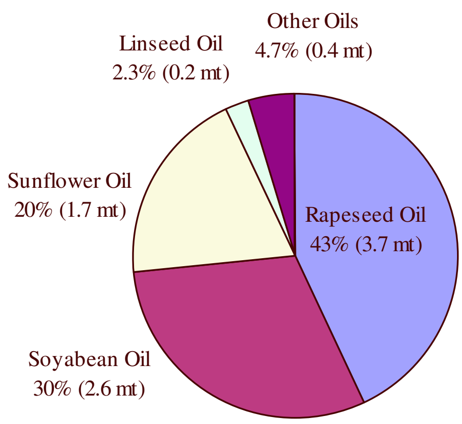
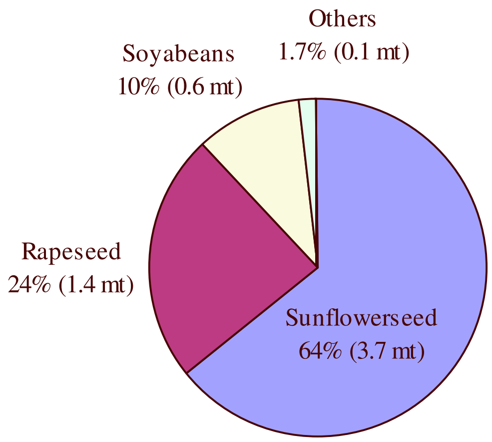


Figure 3[10]

Production of Oilseeds in Eastern Europe, 2003
Total Production: 5.8 million tonnes



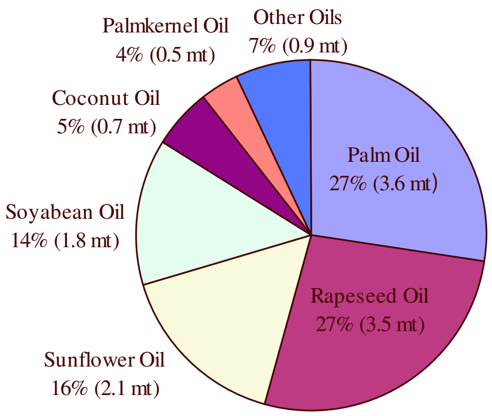
Vegetable oil production in EU-15 in 2003:

- Rapeseed oil: 3.7 million tonnes (43%)
- Soya bean oil: 2.6 million tonnes (30%)
- Sunflower seed oil: 1.7 million tonnes (20%)
- Linseed oil: 0.2 million tonnes (2.3%)

The data also shows that 13.1 million tonnes of oil was consumed in the European Union (assumed to be EU-15) in 2003, broken down as shown in Figure 4.

Figure 4[11]

Oil Consumption of the European Union, 2003
Total Consumption: 13.1 million tonnes



[10] Bosnia-Hercegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia-Montenegro, Slovakia, Slovenia
[11] Fediol

Annex A shows the largest oilseeds and oil import/export flows in 2003. It shows that[12]:

Oilseeds

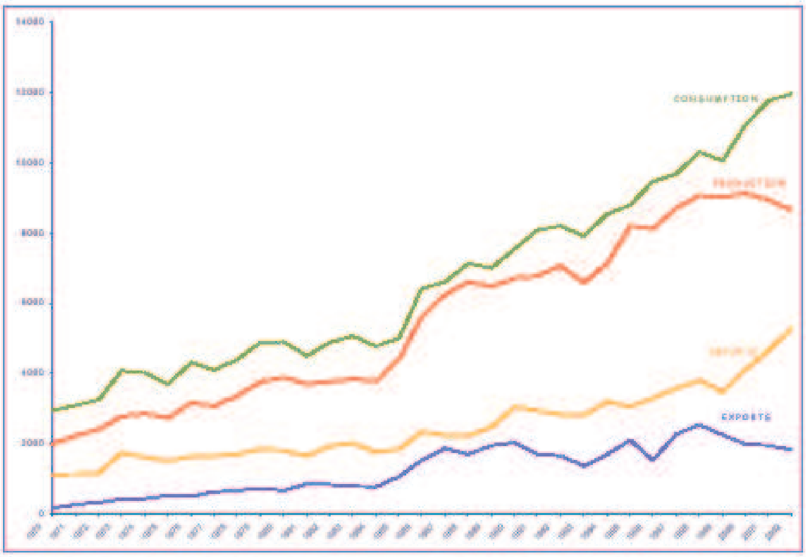
Soyabean: The EU is a major importer of soyabeans, importing 26% (15.3 mt) of total world soyabean exports.
Rapeseed: Both the EU and Central Europe each exported 3.4% (0.2 mt) of total world rapeseed exports, and the EU imported 7% (0.4 mt) of total world rapeseed exports. This is a dramatic decrease from 2002, when the EU exported 17% (0.8 mt) and imported 15% (0.7 mt) and Central Europe exported 12.5% (0.6 mt).
Sunflower seed: The CEEC countries exported 41% (1.3 mt) of total world sunflower seed exports and the EU imported 60% (1.9 mt) of total world sunflower seed exports.
Cottonseed: The EU imported 12.5% (0.1 mt) of total world cottonseed exports
Groundnuts: The EU imported one third (0.5 mt) of total world groundnut exports

Oils

Palm Oil: The EU imported 17% (3.7 mt) of total world palm oil exports.
Soyabean Oil: EU-25 exported 13% (1.2 mt) of total world soyabean oil exports.
Sunflower Oil: The EU exported 4% (0.1 mt) and imports 21% (0.6 mt) of total world sunflower oil exports. The CEEC countries exported 7.1% (0.2 mt) of total world sunflower oil exports.
Coconut Oil: The EU imported 37% (0.7 mt) of total world coconut oil exports.
Rapeseed Oil: The EU exported 15% (0.2 mt) of total world rapeseed oil exports. This is a decline from 27% in 2002.
Palmkernel Oil: The EU imported 29% (0.5 mt) of total world palm kernel oil exports.

The above data is summarised in Figure 5, which illustrates how consumption of vegetable oils and fats has increased, but production has decreased since the late 1990's, reflected by an increase in imports and a decrease in exports.

Figure 5 Evolution of EU-15 Consumption of Vegetable Oils and Fats



up to and incl. 1972 : EC-6; from 1973 incl. : EC-9; from 1986 incl. : EC/EU-12; from 1995 incl. : EU-15

Source: Fediol

[12] Where figures are for EU, this is EU-15

Science and Technology

See Annexes B and C for statistics on the oil crops described below, sourced from FAOSTAT data, 2004 (Annex B) and Fediol data 2002 and 2003 (Annex C).

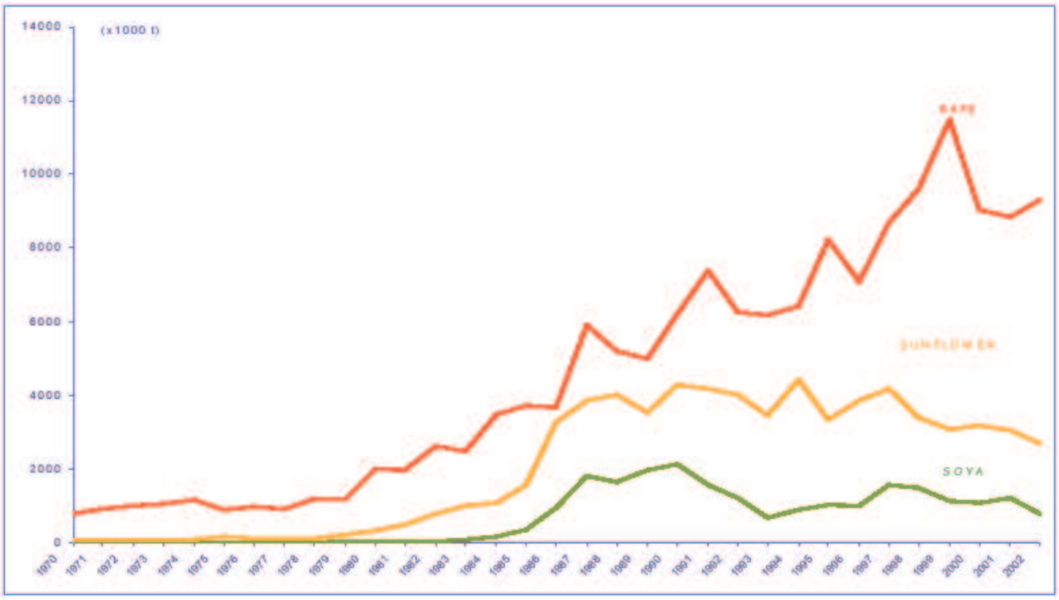
Whilst European oilseed production is dominated by oilseed rape (*Brassica napus*) and sunflower (*Helianthus anuus*) a number of other oilseed crops are produced, and this range has increased with the accession of the new European states.

In 2000 IENICA showed that oilseed rape dominated in most northern European countries and sunflower in most central and southern countries, and that although the largest proportion of oil produced was used for food purposes, a significant proportion was used for non-food. Soya bean (*Glycine max*) cultivation was shown to be increasing in southern Europe, although little for non-food production at that time; the area of linseed (*Linum usitatissimum*) was shown to fluctuate and was largely subsidy driven, and considerable quantities of, primarily tropical, oilseeds were imported to supplement European production.

Whilst the relevant importance of the different crops has not altered – oilseed rape and sunflower are still the most significant – the level of cultivation in some of the EU-15 countries has actually decreased, whilst in others it has significantly increased. This is largely dependent on the development of the biofuel industry, as outlined in the introduction to this report.

Figure 6 shows the evolution of the production of the main oilseeds in EU-15, since 1970.

Figure 6 Evolution of EU-15 Main Oilseeds Production



up to and incl. 1972 : EC-6; from 1973 incl. : EC-9; from 1986 incl. : EC/EU-12; from 1995 incl. : EU-15

Source: Fediol

Oilseed rape (*Brassica napus*):

As shown in Figure 6, overall cultivation of oilseed rape has decreased since 2000. Other than seasonal factors, this is largely due to the reductions in EU support (via Agenda 2000) which are considered to no longer compensate for the inferior price given for non-food uses. Fediol data suggests that approximately 23% of the rapeseed grown in the EU (assumed to be EU-15) is for non-food uses.

The most significant changes to oilseed rape cultivation, however, can be seen in those countries with a developing biodiesel industry and this may be reflected in the upturn since 2001 shown in Figure 6. In France, for example, the oilseed production has increased by more than 65% since 1997. The rapeseed area is now over one million hectares and biofuel processing activity currently yields 350,000 tonnes of rapeseed methyl ester, from 260,000 ha of cropland. In turn, this generates significant quantities of glycerine, around 35,000 tonnes of which finds outlets in the surfactants and solvents industries, plus others. A similar story can be seen in Germany, where rapeseed is the most important agricultural crop. 650,000 ha is used for the production of biodiesel (90%, for RME), oleochemicals, lubricants and hydraulic fluids (together, 10%). Figures suggest[13] that France accounted for 11% and Germany 9% of worldwide rapeseed production in 2001.

Oilseed rape production in the newly accessed states varies significantly between counties, in terms of cultivation area and applications for food/non-food. The Czech Republic is the largest producer for non-food uses: 312,000 ha, primarily for non-food products (biofuels, crude glycerol, lubricants, detergents). Bulgaria, Estonia, Hungary, Lithuania, Poland, Romania and Switzerland also all cultivate rapeseed, but by far the majority is used for food applications, and only small proportions are processed for biofuel. It is important to note, however, that there is significant interest and developments in biodiesel production in the new European states, and many have processing facilities nearing commercialisation.

Sunflower (*Helianthus anuus*)[14]:
Grown in Austria, France, Germany, Greece, Italy, Spain and Portugal the area of sunflower has seen a general decrease since the results of the last IENICA report were published and, as Figure 6 shows, since the early 1990's. The main reason for this was the change in the CAP in 1992. Before that time, sunflower seed was paid to farmers at a higher price than the world price, and the price of sunflower was higher than that of oilseed rape, so it was of great interest to farmers. After 1992, farmers are paid on the world price basis and they received a complementary payment on an acreage basis, and this 'acreage payment' is the same for oilseed rape and sunflower. So, the interest in sunflower declined in areas where the yield of oilseed rape is higher than that of sunflower. In addition, the information from CETIOM in France is that the sunflower crop suffered a very severe attack of *Phomopsis helianthi* in 1993 and 1994. At that time, resistant cultivars were only grown on a very limited acreage and there were very low yields in 1993. In 1995 resistant cultivars and fungicides were applied on a large scale, and the impact of the disease has not been so dramatic since 1996. It is reported that, in Italy, the area planted to sunflowers in 2004 is forecast at 69,200 ha, down 54% on the area in 2003 – around 150,000 ha[15]. This decline is expected to be partially offset by an increase in average yields, due to favourable weather this year.

The largest proportion of the sunflower grown is still for food purposes; Fediol data suggests that only around 6% of the sunflower seed produced is for non-food uses. However, whilst the overall area has decreased, the area on set-aside land in a number of countries has actually increased.

Sunflower is a more significant oil crop in the newly accessed states, with large areas cultivated in Bulgaria (736,000 ha in 2003), Hungary (418,000 ha in 2002) and Romania (1.2 million ha in

[13] Cyberlipid Center, **http://www.cyberlipid.org**
[14] Some of the information in this section is sourced from Personal Communication with Andre Pouzet of CETIOM in France.
[15] AgraEurope (**www.agra-net.com**)

2003). Whilst the vast majority is used for food purposes at present, considerable potential exists for these production levels to meet future demands for renewable feedstocks.

Other Oil Crops:
Four years ago IENICA suggested that only two new species were moving towards commercialisation: Crambe (*Crambe abyssinica*) and Calendula/Pot Marigold (*Calendula officinalis*).

Whilst market achievement of Crambe has not been made to a great extent since that time in Europe, commercialisation has occurred in the UK[16] and the crop has been commercially produced since 2001. The area grown has increased from approximately 500ha in 2001 to nearly 3,500 ha in 2003. The area is expected to increase, with a potential market in the UK for 20,000 ha.

Calendula is also nearing the commercialisation stage in the UK[17], with large-scale trials currently taking place. *Calendula officinalis* breeding is taking place in the Netherlands; recent interest has centred on the seed oil of Calendula for industrial use. The seed contains 40-46% oil of which 50-55% is highly conjugated calendic acid and 28-30% is the non-conjugated linolenic acid (both C18:3)[18]. The oil could have applications in the manufacture of paints and coatings, personal care products and some industrial nylon products.

Linseed/flax oil production is relatively small in the EU (compared with the production of rapeseed and sunflower particularly) but has remained at a more or less static level since the 1980's. Worldwide production of linseed oil was approximately 634,000 tonnes in 2003 and European production accounted for around 38% of this (240,000). There has been a decline in European linseed production since 2000, however (from 760,000 tonnes in 1999 to 117,000 tonnes in 2002[19]), largely as a result of the introduction of Agenda 2000, which decoupled crop specific payments. There was a slight increase to 163,000 tonnes in 2003. The linseed/flax oil which is produced is used largely for non-food applications, including paints, coatings, timber protection products, inks, soaps, detergents and linoleum. Much of the requirement for linseed oil is currently met by imports. The largest area of linseed is in France, followed by the UK, Belgium, Germany and Spain. Linseed is also cultivated, although in small amounts, in the Czech Republic, Estonia (where it is the only oil crop for non-food purposes), Hungary, Lithuania, Romania and Switzerland it is processed largely for non-food purposes i.e. wood impregnation products.

Camelina (*Camelina sativa*) is grown on small, scattered acreages throughout Europe, including in Austria, Belgium, Denmark, Finland, France, Germany, Italy, Netherlands, Spain and the UK. No significant developments have been reported for this crop since the original IENICA report was prepared, although there is increasing interest in its use as a liquid biofuel (Camelina methyl ester has properties similar to rape methyl ester) and there are a number of activities in this area. Much of the current production is for personal care products, cosmetics and paints.

European production of cotton seed oil currently accounts for just over 1% of worldwide production[20] and is grown mainly in Greece (350,000 ha in 2003, as reported by FAOSTAT, 2004), as well as in Spain and Israel. The Greek IENICA report outlines that cotton-seed oil is of

[16] Springdale Crop Synergies Ltd (**www.springdale-group.com**)
[17] Springdale Crop Synergies Ltd
[18] Springdale Crop Synergies Ltd
[19] FAOSTAT data, 2004 (covering all IENICA partner countries)
[20] FAOSTAT data, 2004

low quality and thus finds only low-grade uses (e.g. as paint solvent) – in very limited amounts – and as a fuel (crude bio-diesel) in more substantial amounts (20-30 kt/year), processed through combustion at the crushing/pressing/extraction plants. It suggests that the strong animal feeding limitations (e.g. gossypol) of cotton seed oil could act as a positive factor for driving other industrial uses, should the technologies and markets be in place.

Olives are grown in Greece but are still prohibitively expensive as an industrial non-food feedstock. However, there is some interest in olive kernel oil from the pressed olive cake for soap production (1,000-2,000 tonnes/year) and significant R&D activities into olive residues and wastes as biofertilisers and biofuels and the fractionation of high added-value polyphenols from olive mill effluents.

European soyabean production is largely for food uses, and is grown in a number of countries, most significantly in France, Italy and Romania. There have been variations in the cultivation area on a country by country basis in recent years, with some states seeing an increase in area, and some a decrease (see Annex B). The decrease in the Italian acreage (a decrease of 35% between 2001 and 2003) is linked to the changes in EU policy: in reality, the subsidies do not compensate for the inferior price given for non-food destinations. Therefore, the farmer does not have any economic incentive to produce in the non-food sector and thus does not take this possibility into consideration. Around 50% (10,500 tonnes) of the Romanian crude soyabean oil production is used for the production of resins for paints.

Other oil crops cultivated in the newly accessed states include:

Poppy (*Papaver somniferum*). The Czech Republic is one of the world's foremost cultivators of *Papaver somniferum*, producing around 38% of total worldwide production and 64% of total European production in 2003: around 18,000 tonnes from 30,000 ha, exporting around 15,000 tonnes. Poppy is also grown in France, as well as smaller amounts in Austria, Germany, Hungary, the Netherlands and the UK.

Jojoba (*Simmondsia chinensis*). Jojoba is grown and harvested in desert climates. The major worldwide production areas are the USA, Mexico, Costa Rica, Australia, Brazil and Paraguay. Commercial plantations also exist in Argentina, Egypt, Israel and Peru. In 1999-2001 Israel produced one third of the world production of Jojoba. All of the jojoba grown in Israel is exported; there is no known domestic use. The total worldwide area covered by the crop is currently around 8,500 ha. The total world market potential for Jojoba oil at prices of US $4–6 per kg has been estimated to be 64,000 tonnes[21], and the projected uses are cosmetics, 18%; pharmaceuticals, 23%; lubricants, 15%; wax replacement, 15% and other uses, 29%.

The previous IENICA findings reported that considerable scientific activity has taken place throughout Europe into crops for non-food applications. This continues to be the case for a number of reasons: as the demand for 'green', environmentally-friendly products increases; the need to find alternative options for farmers becomes ever more important; new legislation impinging on industrial practices continues to come into force. National Governments, the EU and private organisations continue to fund R&D into new oil crop species, and the improvement of existing and traditional crops. However, R&D spending is not in balance with market uptake. Whilst there are a number of species which could potentially produce interesting oils for industrial applications (as identified in the earlier report) the problem remains that most are wild

[21] IENICA Report for Israel, 2004

species and have major cultivation problems and/or marginal oil production potential. Progress is being made in the investigation of some of these, including[22]:

- Ethiopian mustard (*Brassica carinata*)
- Caper spurge (*Euphorbia lagascae*)
- Sweet sorghum (*Sorghum bicolor*)
- Castor (*Ricinus communis*)
- Honesty (*Lunaria biennis*)
- Cuphea (*Cuphea* spp.)
- Rain daisy (*Dimorphotheca pluvialis*)
- Safflower (*Carthamus tinctorius*)
- Meadowfoam (*Limnanthes alba*)
- Stokes' aster (*Stokesia laevis*)

In accessing EU-15 the new states bring with them a wide range of R&D activities, looking into many different areas of non-food oil crop production and end-use applications. These include:

- Breeding programmes to develop new varieties; disease resistance, oil quality, quantity and characteristics
- Investigation into and development of 'new' species i.e. Camelina (*Camelina sativa*), Calendula (*Calendula officinalis*), Cuphea (*Cuphea* spp.), Castor (*Ricinus communis*), Poppy (*Papaver somniferum*), Safflower (*Carthamus tinctorius*), Garden cress (*Lepidium sativum*), Mustards (*Sinapis* spp., *Brassica* spp.), Caper spurge (*Euphorbia lagascae*)
- Agronomic and cultivation techniques to improve yields
- Processing technologies
- Biodiesel – cost, cost-effectiveness, production technologies
- Biolubricants e.g. R&D in Hungary is looking into using sunflower seed oil for biolubricants, and also at using by-products from ethanol production and biodiesel production (glycerine).

Markets

Of the approximately 100 million tonnes of oils and fats produced worldwide, by far the largest share is used by human foodstuffs (approximately 80%); around 14% is available for oleochemistry[23]. The use of the oils within industry is determined by the composition of the fatty acids contained in the oil. Coconut oil and palm kernel oil, for example, are suitable for further processing to surfactants and cosmetics because of their high proportion of short or medium chain fatty acids (mainly C12 and C14). Palm, soyabean, rapeseed and sunflower are used in polymer applications and lubricants because they contain mainly long-chain fatty acids (e.g. C18).

In the last IENICA report it was noted that most European countries have oilseed crushing and refining facilities. Crushing/refining technology is generally well developed, but new investigations were, and still are, in progress to identify more environmentally-friendly and cost-effective extraction technology. Figures 7 and 8 show the oilseeds crushed in 2003 in the European Union and Eastern Europe[24].

[22] **http://www.biomatnet.org**
[23] Hill, K (2000) *Fats and Oils as Oleochemical Raw Materials* Pure Appl. Chem., Vol 72, No 7 pp 1255-1264
[24] Fediol data, 2003

Figure 7
Crushing of Main Oilseeds
– EU-15, 2003

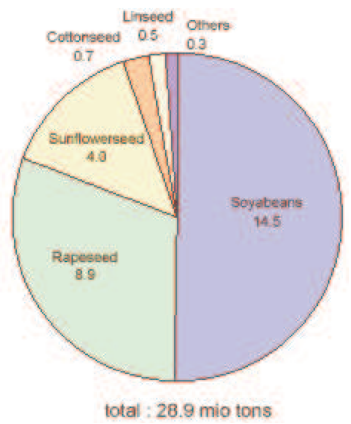
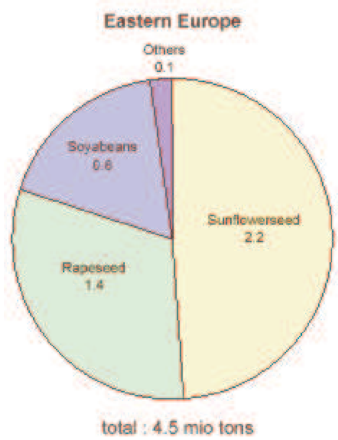


Figure 8
Crushing of Main Oilseeds
– Eastern Europe[25], 2003



Annex D shows, for 2003, where the main oilseeds were crushed worldwide[26]. It shows that:

- 25% of worldwide **rapeseed** production is crushed in EU-15 and 4% in Eastern Europe
- 17% of worldwide **sunflower seed** production is crushed in EU-15 and 9.5% in Eastern Europe
- 8.5% of worldwide **soyabean** production is crushed in EU-15
- 28% of worldwide **linseed** production is crushed in EU-15

Annex D also shows that, within EU-15, by far the majority of oilseeds are crushed in Germany (29%), followed by the Netherlands (14.5%), Spain (13%) and France (11%).

Whilst movements have occurred in the industry in recent years, one key element still remains true: *"oil purchases are made on the basis of availability, raw material price, manufacturing costs and utilisation potential and quality parameters"*. The problem with vegetable oil as an industrial feedstock is that it is usually more expensive than mineral oil and rarely offers specific quality advantages. This is not always true, however. *Crambe abyssinica* offers a fatty acid profile which is almost tailor-made for use by industry (it contains fewer polyunsaturated fatty acids than HEAR; these PUFAs cause problems when the erucic acid undergoes further chemical modification 'downstream'[27]). Nevertheless, new crops and new oils will always be slow in their initial development due to small volumes and the conservative nature of the industry. This is likely to be one of the main reasons for the, surprisingly, slow development of the industry in recent years.

The previous report gives a description of the processes of conversion of oils into oleochemical products and so will not be repeated here. The key markets in which vegetable oils are used are outlined below (more detail is given in the original report). Whilst these markets represent existing use and significant opportunities for vegetable oils, the last report noted, and this is still the case, that the oils industry will have no interest in non-competitive materials.

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[25] Bosnia-Herzegovina, Bulgaria, Croatia, Czech Republic, Hungary, Macedonia, Poland, Romania, Serbia-Montenegro, Slovakia, Slovenia
[26] Fediol data, 2003
[27] Springdale Crop Synergies Ltd.

Surfactants/detergents/soap[28]

The word surfactant is short for ***surf***ace ***act***ive ***a***ge***nt***. One part of the surfactant molecule is hydrophilic and one part is hydrophobic and it interposes itself between water and water-insoluble substances. Surfactants are generally classified as being anionic, cationic, non-ionic and amphoteric, depending on the type and charge of the hydrophilic groups. The most important functions for surfactants are i) to emulsify and solubilise hydrophobic substances in water or vice versa ii) to disperse solid particles is solution and prevent them to flocculate iii) to produce foams and iv) to enable water solutions to wet a hydrophobic surface. These functions make surfactants abundant in detergents and cleaners (54%); as auxiliaries for textiles, leather and paper (13%); in chemical processes (10%); in cosmetics and pharmaceuticals (10%); in the food industry (3%); in agriculture (2%) and in other areas (8%).

The surfactant with the highest volume, apart from soap, is the petrochemical-based alkyl benzene sulfonate. However, in recent years there has been a continuous trend towards surfactants based on renewable resources. The term natural surfactant is often more broadly used for surfactants where either the hydrophilic or hydrophobic parts are obtained from a natural source.

The total worldwide market for surfactants amounted to approximately 17 million tonnes in 2000 (including soap); the European market in surfactants represents a volume of approximately 2.4 million tonnes, of which around 30% come from plants. The stakes are thus high for a veritable renewable alternative in this sector, and could represent several thousand hectares of crops, as it takes approximately 60,000 hectares of land to produce 100,000 tonnes of vegetable surfactant. The hydrophilic part can come from co-products of the starch or sugar industries (e.g. sugar beet, derivatives of maize or other grain crops).

The hydrophobic part is more commonly obtained from triglycerides from vegetables or animals; about 50% of total production is based on renewable raw materials. Short C_{12}-C_{14} hydrophobic alkyl chains are suited for detergent and wetting applications, whereas longer chains are more suitable as emulsifiers, softeners and lubricants. Typically, the hydrophobic part can for example come from oleo-chemical raw materials derived from rapeseed, sunflower, palm, or other plants. A problem with EU-grown oil crops is that they cannot compete as a raw material for short chain surfactants (C_{12-14}) with those derived from tropical oilseeds, e.g. coconut and palm kernel. Consequently, there is a need to find alternative niche markets for these products, such as pesticide adjuvants. The development of new crops such as high lauric rape varieties might increase the competitiveness of EU-grown oil crops.

The last IENICA report described new processes which associate a hydrophobic component made up of fatty alcohols with a hydrophilic component derived from by-products of starch and sugar processes. Recent research work has allowed the commercial-scale production of these alkyl polyglycosides (APG's), which are based exclusively on renewable resources. These 'doubly natural' compounds have a good compatibility with the eyes, skin and mucous membranes and are also completely biodegradable, both aerobically and anaerobically. There are therefore suitable for cosmetic and personal care applications. However, they use mainly coconut oil and/or animal fats rather than native vegetable oils.

[28] Much of the information here is taken from IENICA Newsletter 21 (December 2003), from an article prepared by the IENICA partner for Sweden, from the Institute for Surface Chemistry in Stockholm; from Hill, K (2000) *Fats and Oils as Oleochemical Raw Materials* Pure Appl. Chem., Vol 72, No 7 pp 1255-1264, and from Patel, M (2004) *Surfactants Based on Renewable Raw Materials: Carbon Dioxide Reduction Potential and Policies and Measures for the European Union* Journal of Industrial Ecology, Vol 7, No3-4

There is currently considerable interest and research (i.e. in France and Sweden) in developing surfactant synthesis processes which are environmentally friendly i.e. enzyme catalysis. In addition, there is interest in developing fermentation processes with yeast or bacteria to increase the yield and thus decrease the cost for truly natural surfactants. A new manufacturing process has been developed for cocomonoglyceride sulfate (CMGS) which, although has been known for a long time and has already been used in a few products, has been manufactured using methods with various disadvantages i.e. the use of solvents. This new process obtains CMGS directly from coconut oil in a solvent-free two-stage process; it is used in cosmetic products such as shower gels and shampoos.

Polymeric surfactants are likely are be more extensively used in the future. In many cases these have improved surfactant properties. Natural based amphiphilic polymers can be based on chemical modification of polysaccharides like dextran, cellulose and starch.

Germany accounts for 25-30% of total EU production. Based on figures from the IENICA update report from France, and total European production of 2.4 million tonnes, France produces around 17%. The largest amounts are consumed by the household detergent industry. Erucic oil derivatives, due to their specific properties, are marketed as antifoaming agents; 10,000-15,000 tonnes of oil are dedicated to this production each year.

In Estonia a new, patented surfactant, ANROL has been derived from rape oil. It will be used for washing away graphite from walls, for the cleaning of crude oil cisterns and oil bores et cetera. A production plant will be built in the near future in Põlvamaa, Estonia. Its annual turnover is estimated to be 33 million EUR.

Lubricants[29]

The primary functions of lubricants are decreased friction and wear, plus many other effects including heat transfer; contaminant suspension; liquid sealing and corrosion protection. Between 5,000 and 10,000 different lubricant formulations are necessary to satisfy more than 90% of all lubricant applications.

To meet these requirements, most modern lubricants are complex formulated products consisting of 70-90% base oils with the right physical characteristics, mixed with functional additives to optimise the physical properties i.e. viscosity index improvers, antioxidants, antiwear agents. The base oil can be mineral, vegetable, synthetic or re-refined. Mineral oil bases are the most common.

The global lubricant market in the past 10 years has undergone dramatic changes due to industry consolidation. It has seen overall demand for lubricants remain flat at around 35 million tonnes a year since 1991. The same holds true for EU-15, at around 5.3 million tonnes/year since 1982 and the broader European geographical region at around 10.2 million tonnes/year. The industry has seen sharp shifts in consumption, increased competition and greater pressure on profits. The static (or even decreasing) demand for lubricants, despite the growth in activities involving machinery that needs to be lubricated, is due to the efforts in almost all application areas to increase the useful life of lubricants, due to the desire to decrease the costs of purchase, service and maintenance, and disposal and recycling.

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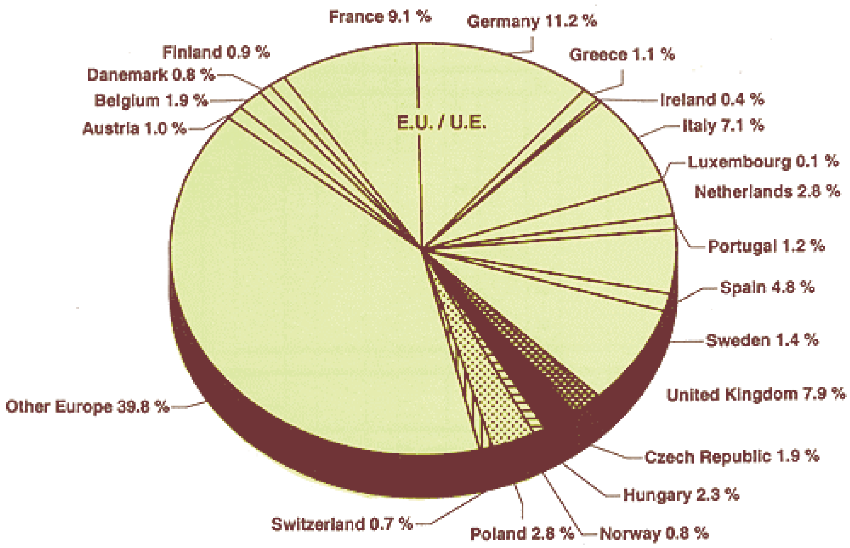
[29] Much of the information here is taken from *Background Document: Development of Criteria for the Award of the European Eco-Label to Lubricants*, IVAM, April 2004; Lubrizol (**www.lubrizol.com**); Hill, K (2000) *Fats and Oils as Oleochemical Raw Materials* Pure Appl. Chem., Vol 72, No 7 pp 1255-1264 and from Boyde, S (2002) *High Performance Lubricants from Renewable Raw Materials* Lubricating the Market: The Future for Bio-Based Lubricants, an ACTIN conference, Warwick, May 2002

Worldwide there are around 1700 manufacturers of end-product lubricants, 300 of these are in Europe. Less than 2% of lubricant manufacturers produce more than 60% of global lubricant volumes.

Figure 9 shows the breakdown of the European lubricants market (a total of 10.2 million tonnes) in 1999. Germany is the largest national market in Europe (11.2%) and ranks fifth in the worldwide market. France also has a large market; the French update report estimates it to be 850,000 tonnes a year, and though today is still limited to a few thousand tonnes of oil-based lubricants, this sector is very promising.

Figure 9 European lubricants market, 1999

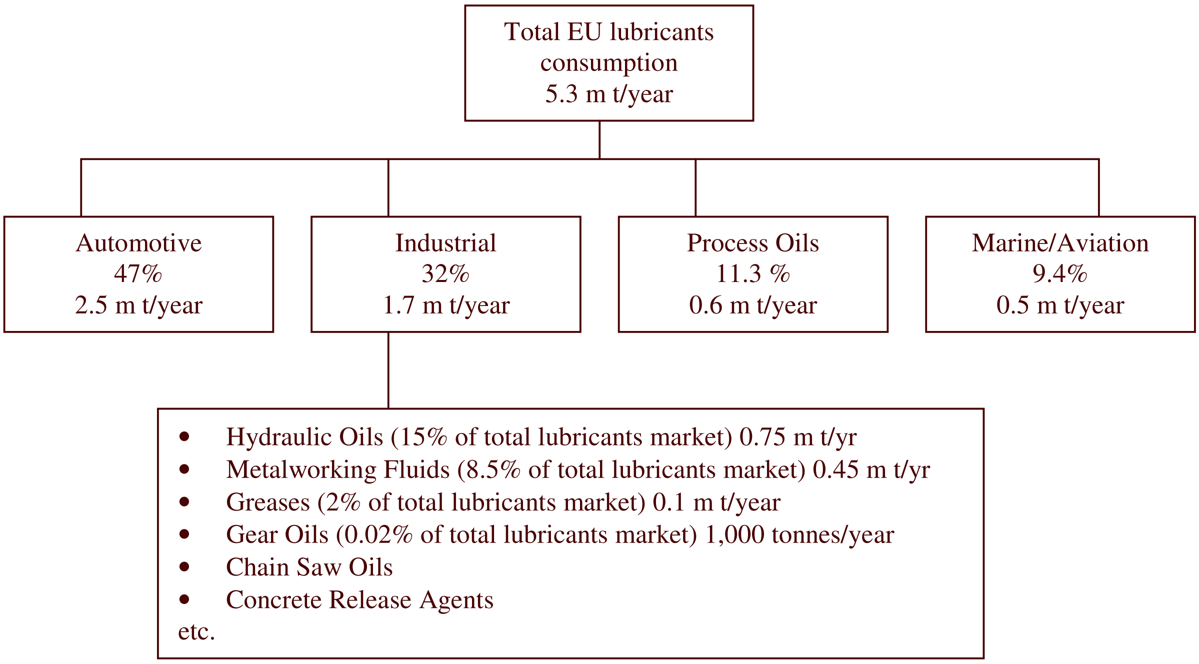


Source: Europalub

Figure 10 shows the end-use applications for lubricants within EU-15 (a total of 5.3 million tonnes/year), and shows that the automotive industry consumes by far the majority: 47%, 2.5 million tonnes/year. Industrial lubricants consume 32%, process oils 11.3% and marine and aviation 9.4%. Hydraulic oils make up the biggest part of industrial oils and are the second most important group of lubricants after automotive, accounting for approximately 15% of total lubricant consumption[30].

[30] Background Document, IVAM, 2004

Figure 10 EU-15 lubricants consumption



Source: Background Document IVAM 2004

There is an increasing demand for environmentally-compatible lubricants, particularly in areas where they can come into contact with water, food or people. These 'biolubricants' are often, but not necessarily, based on vegetable oils (some mineral oils can be biodegradable). They can also be synthetic esters which may be partly derived from renewable resources i.e. the hydrolysis of fats and oils to produce the constituent fatty acids. These can be made from a wider variety of natural sources including solid fats and low grade or waste materials such as tallows. Vegetable base oils are produced mainly from rapeseed, sunflower, palm and coconut. Rapeseed oil is the most widely used vegetable base oil because of its relatively good oxidative stability (compared with other regular vegetable oils), its reasonable cost (compared with alternative fluids) and its wide availability in both Europe and North America. Genetically-modified vegetable oils, such as high-oleic sunflower and rapeseed, are also beginning to find use in applications where higher oxidative stability is needed.

Table 1 Recent European Market Volumes and Growth Rates

Product Type	1999 European volume (000 tonnes)	Annual Growth %
Lubricants	5000	-1.4
Biolubricants	102	10
Synthetics	305	6
Synthetic Esters	80	5
Additives	600	0

Source: Boyde, S[31]

Vegetable base oils have the advantage over mineral oils of being biodegradable and non-toxic, as well as having superior lubricity and a high flash point. Also, they have a higher viscosity index compared with mineral oils, indicated that their viscosity does not vary with temperature as

[31] Boyde, S (2002) *High Performance Lubricants from Renewable Raw Materials* Lubricating the Market: The Future for Bio-Based Lubricants, an ACTIN conference, Warwick, May 2002

much as mineral oil. This can be an advantage when designing lubricants for use over a wide temperature range. However, vegetable oil-based lubricants have low temperature limitations. The addition of co-solvents such as synthetic fluids or mineral oils can improve the low-temperature properties of vegetable oils.

Although all major petrochemical companies are able to provide biolubricants the market is dominated by independent suppliers: there are around 70-80 independent manufacturers supporting 80% of the biolubricants market. Key players besides the major oil companies include AGIP, Addinol, Binol, Blaser, Cargill, Carl Bechem, Fuchs Petrolub, Kajo Chemie, Klüber Lubrication, Karlshamn, Novance, Panolin, Raisio, Zeller and Gmelin and many others[32].

In 1999, only 2% of the lubricants market was 'environmentally-friendly' lubricants (see Table 1). Table 2 gives, for 1999, the areas and volumes in which biolubricants were used. It shows that the most significant markets are hydraulic oils, chainsaw oils and concrete release agents.

Table 2 Markets for Biolubricants, 1999

Lubricants marketed as 'biolubricants'	Market volumes in 1999 (tonnes)
Hydraulic oils	51,000
Chainsaw oils	29,000
Concrete release agents	10,650
Metalworking fluids	4,000
Two-stroke engine oils	2,000
Greases	1,700
Gear oils	1,000

Source: Background Document, IVAM 2004

The market for biolubricants will be driven by environmental concerns, as well as by economics and performance issues and, as such, the two most significant opportunities for biolubricants are:

- In applications where there is a high probability of accidental exposure of the lubricants to sensitive environments: 'high-risk lubricants' for example hydraulic equipment in forests and by water.
- 'Total loss lubricants' – where, by the design of the equipment or application the lubricant ends up almost entirely in the environment. Loss lubricants account for 8% of all lubricants, and the market is divided as follows: two-stroke engine oils, 30%; mould release agents, 25%; various greases, 17%; protective oils, 10%; chainsaw oils, 8%.

These environmental drivers for biolubricants have led to a more rapid increase in use in certain areas. The Nordic countries, for example, have seen the most significant growth, due to national policies to protect their sensitive environmental areas. The update report for Austria suggests a future potential requirement for lubrication material in a range between 90,000 to 100,000 tonnes per year, particularly for the water protection alpine areas with special environmental regulations. It comments that this could easily be covered by plant oils.

It is the opinion of the industry[33] that the high price of biolubricants (both on the basis of vegetable oils and especially based on synthetic esters) is the main restriction for the development of biolubricants at the current time. They are generally between 1.5 and 5 times more expensive than conventional lubricants. The German update report for IENICA supports this, and suggests

[32] IVAM
[33] As discussed in Background Document, IVAM, 2004

that this price difference is the reason why the market share of the products of plant origin is only about 40,000 tonnes, which is 3.4% of the total use of lubricants and hydraulic fluids in Germany. The lack of pan-European regulatory incentives is also cited to be a major restriction. In Germany, a market introduction programme for users in environmentally sensitive areas was introduced in 2001. Today, nearly 2000 entrepreneurs have been supported to convert their machines to bio-based lubricants.

Whilst low levels of overall growth in the total lubricants market are predicted over the next few years (as has proved to be the case in recent years, as described above, with trends including extending the useful life of lubricants and increased emphasis on lubricant recycling), it is anticipated that the use of biolubricants will increase. Industry claims suggest that over 90% of all lubricants could be replaced by biolubricants. If this were the case, the potential European market could be up to 9 million tonnes of biolubricants per year (based on a total European lubricants market of 10.2 million tonnes/year). However, this will not be achieved until biolubricants for four-stroke engines (mainly for passenger cars) are available commercially.

National and European policy and regulations will be major drivers of the further development of the biolubricants market. Several national 'eco-labels'/schemes and one international standard have been developed in recent years throughout Europe, setting requirements for the ecological and technical characteristics of lubricants:

Nordic Countries (Nordic Swan): Lubricating oils (including chain oil, mould oil, hydraulic oil, 2-stroke oil, lubricating grease, metal cutting fluid and transmission-/gear oil). There are currently no products carrying the Nordic Swan.

Sweden: Standard for hydraulic fluids (SS 155434) and greases (SS 55470). There are currently 61 products qualifying for the SS 155434 (hydraulic fluids) and about 20 products qualifying for SS 155470 (greases). The success of the Swedish Standard is often ascribed to the fact that the criteria were developed in close co-operation between manufacturers and end-users during the project

Germany (Blue Angel): Criteria have been developed for the following lubricant subgroups:
RAL UZ-79 Hydraulic fluids
RAL UZ-48 Rapidly Biodegradable Chain Lubricants for Motor Saws
RALUZ-64 Lubricating oils and greases (also applicable to concrete release agents)
There are 235 different products qualified within these. Public procurement gave a strong impetus to the increasing success of the Blue Angel in the case of lubricants.

France (NF-Environment Mark): Developed an eco-label for chain saw oils in 2003. There are no products carrying the NF-Environment mark at present because it is a very recent scheme but the French update report comments that this is a first step in a very promising area. Representative companies are Novance, Mobil and Fuchs.

Austria: Established an eco-label for chain saw oils (UZ 14 Chain Saw oils) in 1991. Until three years ago there were four licence holders but there is at present only one left. This is mainly due to concentration processes of international companies and to change in companies strategies.

The Netherlands (VAMIL regulation): Environmental criteria have been established for hydraulic fluids and greases within the framework of the VAMIL regulation (accelerated depreciation on environmental investments). More than 60 products (mainly hydraulic fluids) meet the VAMIL requirements.

ISO 15380: This International Standard specifies the environmental requirements for environmentally acceptable hydraulic fluids. The ISO 15380 criteria apply to the formulated end-product.

Reported activities in the newly accessed states within the field of biolubricants are somewhat limited. A few countries (primarily the Czech Republic and Lithuania) report the use of rapeseed for biolubricants and hydraulic fluids, and there are also activities in Hungary looking at the use of sunflower seed oil for lubricants, and also at using by-products from ethanol production and biodiesel production (glycerine). The report for Lithuania comments that the biolubricants industry is an emerging market and has good prospects for development. The report for Bulgaria outlines that rapeseed could be used for this in the future. The Czech Republic reports the production of lubricants from rape oil in a mixture with methyl esters, which are used in ecologically threatened areas and as hydraulic liquids. The report suggests that more extensive use depends on better ecological legislation and an economical subsidy, as biolubricants are so much more expensive.

The INFO*RRM* project carried out a case study on oilseed rape as a lubricant/coolant in metal-forming and on oilseed rape for transmission/hydraulic fluid in tractors[34].

See also the IENICA Market Data Sheet on Biolubricants (**www.ienica.net**).

Paints and surface coatings

As reported in the previous IENICA report, vegetable oils are currently used in the manufacture of:

- Gloss (oil-based) paints
- Resins – oil modified alkyl resins which form reticulated films with variable drying times and have many paints and varnish applications.
- Varnishes – oleoresinous varnishes.
- Printing inks – as 'vehicles' in lithographic, letterpress and thermally polymerised inks.
- Slip agents – the production of erucamide from high erucic rapeseed oil is well established. Since the last report was published, *Crambe abyssinica* has been commercialised in the UK. Crambe is high in erucic acid and the main established market is in the plastics industry. This industry relies heavily on erucic acid feedstocks to produce erucamide. Erucamide has two functions when added to plastics: as a lubricant to ease the production of plastic parts, and to provide a thin layer of lubrication on the extruded plastic film surface, reducing the coefficient of friction, acting as a 'slip-agent'[35].

The majority of oil modified resins are based on soya oil, although recently sunflower, which has similar properties has become popular as a direct replacement. Linseed, tung and soya oils are those most commonly used in paints and inks as they contain high levels of polyunsaturated fatty acids, which aid drying. Developments with Calendula oil offer a European replacement for tung oil, which is imported from locations such as China, South America and elsewhere.

The EU-15 states have reported a general increase in use and demand for vegetable oil-based printing inks, paints, varnishes, coatings and wood impregnation products during the period since the last report was published. Linseed is the main oilseed used for these applications (it is classified as a 'drying oil' as it has a high drying index - it's high linolenic acid content offers

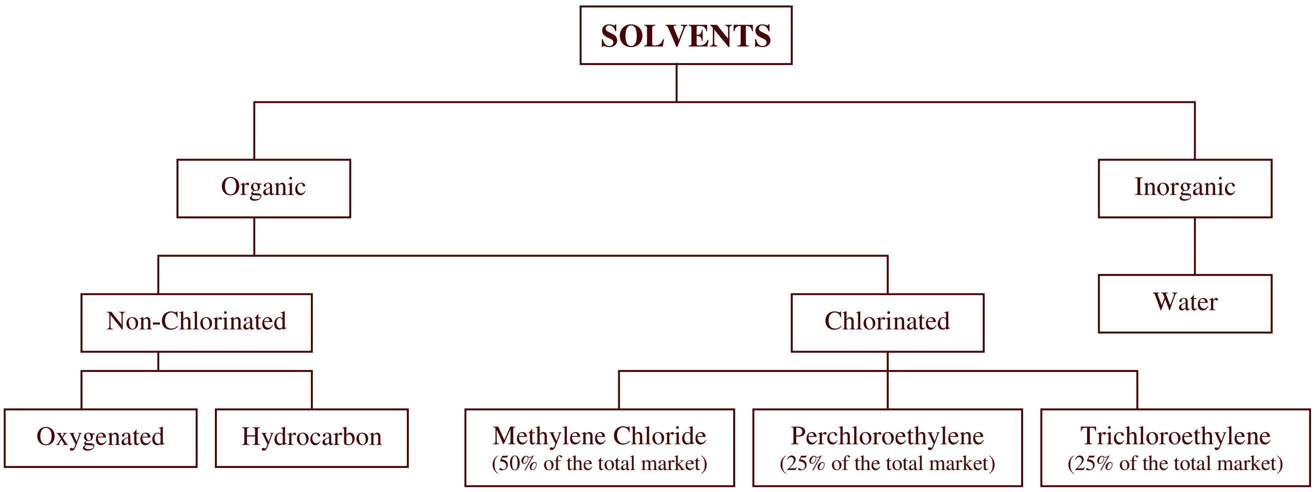
[34] **http://inforrm.csl.gov.uk/CS1.asp**
[35] Springdale Crop Synergies Ltd.

good drying properties), as well as castor bean, sunflower and soy bean oils. Reports show that much of the market for these products could be substituted by vegetable oils. In Austria, for example, 22,000 tonnes/year of printing inks are used, but only 12,000 tonnes are produced from the domestic supply. In France, the market for inks is 18,000 tonnes and the update report suggests that this could be largely substituted.

The reports from the newly accessed states also show that linseed dominates in this sector, with reported uses in the Czech Republic (as a drying oil for varnishes, paints and in linoleum), Estonia (surface coatings from linseed are imported), Lithuania (80ha for wood impregnation products) and Romania (for wood impregnation products). 2,000 tonnes/year of sunflower seed is used in Bulgaria for, among other things, paints and varnishes, and a small amount of jojoba is used in Israel for printing ink. Soyabean, sunflower and castor are used in Romania for resins for paints.

Solvents[36]
A solvent is a liquid which has the ability to dissolve, suspend or extract other materials, without chemical change to the material or solvent. There are two main groups of solvents: organic and inorganic (i.e. water or salt solutions). Figure 11 shows how these groups are further divided:

Figure 11 Solvent Classification



Source: HGCA Solvents Research Review

Non-chlorinated solvents (i.e. oxygenated and hydrocarbon) are mainly used in the paint and surface coating industries. Hydrocarbon solvents are made from refining crude oil or coal tar. Water is the main substance used as an inorganic solvent but other acidic or caustic liquids are also used in industry.

A major concern regarding the conventional use of organic solvents is their contribution towards emissions of volatile organic compounds (VOC's) and impacts on ozone layer depletion and their contribution to photochemical smog. Solvents currently account for 10% of the EU VOC contribution to ground level ozone. In 1999 the EC introduced a Solvent Directive (*European Directive 1999/13/EC: Directive on the Limitation of Emissions of VOCs due to the use of Organic Solvents in Certain Activities and Installations*), with the aim of reducing VOC

[36] Much of the information here is taken from HGCA Research Review 52: *The Opportunities for Use of Esters of Rapeseed Oil as Bio-Renewable Solvents*, March 2004 and Defra Demonstration Project: *Evaluation of Vegetable Based Biosolvents for use as Cleaning Agents in the Printing Industry*, March 2004 (Not Yet Published)

emissions from industrial processes by 66% by 2007 (against a 1990 baseline). This Directive requires preventive actions to protect public health and the environment against the consequences of harmful emissions from the use of organic solvents.

Modified vegetable oils have very good solvating properties and the use of such materials would be compatible with many areas of current solvent use. There is increasing interest in the development of these solvents for environmental and health reasons. Vegetable oils are composed of triglycerides, large branched molecules comprised of glycerine and three associated fatty acid chains. Simple esterification reactions with alcohols can separate the fatty acids from the glycerine to form fatty acid esters. This reduces viscosity and improves technical performance for the solvent market. Rape methyl ester is one of the most well known vegetable derived esters and has attracted significant commercial interest as biodiesel. Rapeseed oils and coconut esters currently dominate the European market for technical applications, while soya based esters dominate in the US.

The cleaning performance and environmental impact of a solvent is determined by its physical and chemical parameters, including: boiling point, vapour pressure, flash point, density, viscosity, surface tension and solubility. Oilseed-based solvents have the same cleaning properties as petrochemical-based solvents, but they offer additional advantages in some of these areas, including, for example:

- Low viscosity.
- High boiling point and so low vapour pressure (resulting in a less volatile substance and so lower VOC emissions – offering environmental and user benefits).
- Can be used manually through wiping, without specialist equipment.
- Reduced volumes (studies have shown that the same level of cleaning performance can be achieved with lower volumes of product[37]).
- Odour reduction, improving the working environment.

Solvents are used in a large number of different areas, as shown in Table 3.

Table 3 Percentage of solvent shipments (i.e. usage) in the EU by end user sector, 1997

	% of shipments by end-user sector
Coatings	43
Inks	12
Pharmaceuticals	8
Adhesives	7
Extraction Agent in Food	3
Rubber/Polymer Manufacturing	3
Cosmetics	2
Metal Cleaning	2
Dry Cleaning	1
Agrochemical	1
Others	18

Source: Frost and Sullivan Market Report, 1998

As shown, the surface coating sector (i.e. paints) and the printing industry are the two most important end users of solvents in the EU. There is also a heavy reliance on organic solvents in

[37] Defra Demonstration Project: *Evaluation of Vegetable Based Biosolvents for use as Cleaning Agents in the Printing Industry*, March 2004 (Not Yet Published)

the metal cleaning sector, which accounts for around 280,000 tonnes of organic solvent use in the EU, and there are opportunities for vegetable derived esters in all of these market sectors.

Surface coatings: More than 60% of solvents in the EU surface coatings sector are hydrocarbon based. 15% are ester based; 10% ether based; less than 8% alcohol based and 7% others. 40% are used in building and home applications, 20% in the automotive industry and 20% in wood and timber treatments. The paint industry has moved away from organic solvent formulations in recent years, to water-based or non-solvent formulations. This, and the requirement for solvents with low boiling points, limits the potential for vegetable oil based products. Vegetable oils are still used in gloss paints (mainly linseed and tung oils). Alkyl resins, derived from vegetable oils, can also be used in paints and surface coatings because of their film-forming properties. These are mainly produced from soya, but also more recently from sunflower oil.

Printing inks and cleaning solvents: Vegetable-based solvents can be used in both as a raw material in ink formulation and in formulated cleaning products. In inks, solvents are used to solubilise the ink resins to allow the ink to be applied and to facilitate the flow of liquid inks. Soya oils, esters and alcohols have increased their presence in the market, while ethers and chlorinated solvents have decreased. The use of hydrocarbons, the largest product type used in printing inks, remains flat. A number of vegetable oil based ink formulations have been developed. The EU market for vegetable based printing inks is more than 120,000 tonnes per year. This industry is dominated by Belgium, the Netherlands, Germany and Scandinavia. In Belgium, 80% of the printing ink market is vegetable based and continued growth in this area is expected (although the contribution of European agricultural production in that growth is not yet certain[38]). The ink manufacture sector in France gains growing interest; the French market is 18,000 tonnes and could largely be substituted but today it is still limited[39]. Vegetable based inks have therefore already achieved significant levels of market penetration. Considering that printing inks constitute 6% of the Western Europe solvents market (excluding chlorinated solvents), which would correspond to around 270,000 tonnes in absolute figures, an overall EU market penetration of around 40-45% would already have been achieved in this market segment.

The INFO*RRM* project carried out a case study on oilseed rape and soya oil as printing ink and linseed oil as a cleaning product[40].

Further substitution could occur in cleaning materials. Currently, the cleaning process for offset printing machines using conventional solvents accounts for 1% of total EU VOC emissions. 100,000 tonnes of solvents are used each year in the EU to clean printing machines. Conventional solvents used in the printing industry can be classified as low boiling point hydrocarbon solvents. These volatilise very quickly, leaving little need for further treatment, and so have been used for many years. Much of the printing industry is currently converting to the use of high boiling aliphatic hydrocarbons, developed to replace traditional high VOC solvents. However, although these products reduce inhalation exposure and risks to workers, they are not considered to be as safe for workers as vegetable based solvents; this is therefore a potential area for substitution. Evidence from the Agricultural and Rural Strategy Group at the Central Science Laboratory in the UK suggests this is tenable.

Metal cleaning: Organic solvents and aqueous cleaners are currently used. The industry is slowly phasing out organic solvents but looking for 'green' replacements that are more cost effective than aqueous cleaning processes. Vegetable oil fatty acid esters should be capable of removing

[38] IENICA Update report for Belgium, December 2003
[39] IENICA Update report for France, December 2003
[40] **http://inforrm.csl.gov.uk/CS1.asp**

lubricants, greases, oils, dust et cetera. However, much of this industry relies on recycling and re-use of solvent material, which results in a preference for coconut based products with greater oxidative stability.

Other niche areas of interest for the substitution with vegetable oil based solvents are in treatments for oil spill clean up and graffiti removal. Further work is required in these areas. The French IENICA update report notes that bitumen solvents from rapeseed oil have found recent outlets: 3,000 tonnes were produced in 2001 and a potential of 20,000 tonnes could be reached within the next few years.

The total EU market for solvents is diminishing as users, under pressure to reduce their VOC emissions, progressively improve the efficiency of their processes and switch to non-solvent methods. One estimate suggests that the market is diminishing at a rate of 1-2% per year[41]. Total solvent use could fall to 1.9 million tonnes by 2010. However, the use of vegetable oil based solvents is expected to increase in volume and as a proportion of the market.

The latest available market information shows a total annual EU consumption of hydrocarbon and oxygenated solvents of 4–4.5 million tonnes (in 1998). Of this total consumption, 45% is hydrocarbon and 55% oxygenated. Sales of chlorinated solvents by EU producers have steadily declined over the last ten years as users have switched to alternative processes using smaller volumes or other substances altogether. The chlorinated solvent market amounted to roughly 300,000 tonnes in 1998. Of total solvent use, only 1.5% (60,000 tonnes) comes from renewable sources. Estimates[42] have suggested that this figure could potentially increase to 235,000 tonnes by 2010 (a potential share of 12.5%) and the previous IENICA report identified a potential substitution market in excess of 500,000 tonnes.

The key barriers to the further use of vegetable oil based solvents are the cost of materials; the costs of capital investment required to introduce new technology and the lack of recognition of potential damage to workers' health from conventional volatile solvent use. Driving forces behind this industry are important to move it further forward, including the banning of hazardous products; Government and EU policies; health and safety legislation and public opinion.

The INFO*RRM* project carried out a case study on sunflower oil as a bitumen solvent in road construction[43].

Polymers

Polymers are long chain molecules of high molecular weight; they are formed from many small monomers. Polymers are most familiar as plastics e.g. packaging materials. The vast majority (>99%) of current plastics are derived from fossil fuels, and the majority are non-biodegradable so persist in the environment. Many different parts of a plant can be used in the manufacture of polymers, including fibres, starch, protein, lignin and oil. Vegetable oil derivatives can be used in the manufacture of polymers in a number of ways (see also Figure 12):

- Functional additives, where they can alter physical properties. Vegetable oil derivatives are used in slip, anti-block, anti-static and plasticising agents (i.e. epoxidised soyabean oil), as

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[41] Johansson, D (2000) *Renewable Raw Materials: A way to reduced greenhouse gas emissions for the EU industry?* European Commission, DG Enterprise **http://europa.eu.int/comm/enterprise/environment/reports_studies/reports/rrm-finalreport-dj-july2000.pdf**

[42] Ehrenberg, J (2002) *Current situation and future prospects of EU industry using renewable raw materials* European Commission, DG Enterprise **http://europa.eu.int/comm/enterprise/environment/reports_studies/reports/rrm_awarenessreport_2002.pdf**

[43] **http://inforrm.csl.gov.uk/CS1.asp**

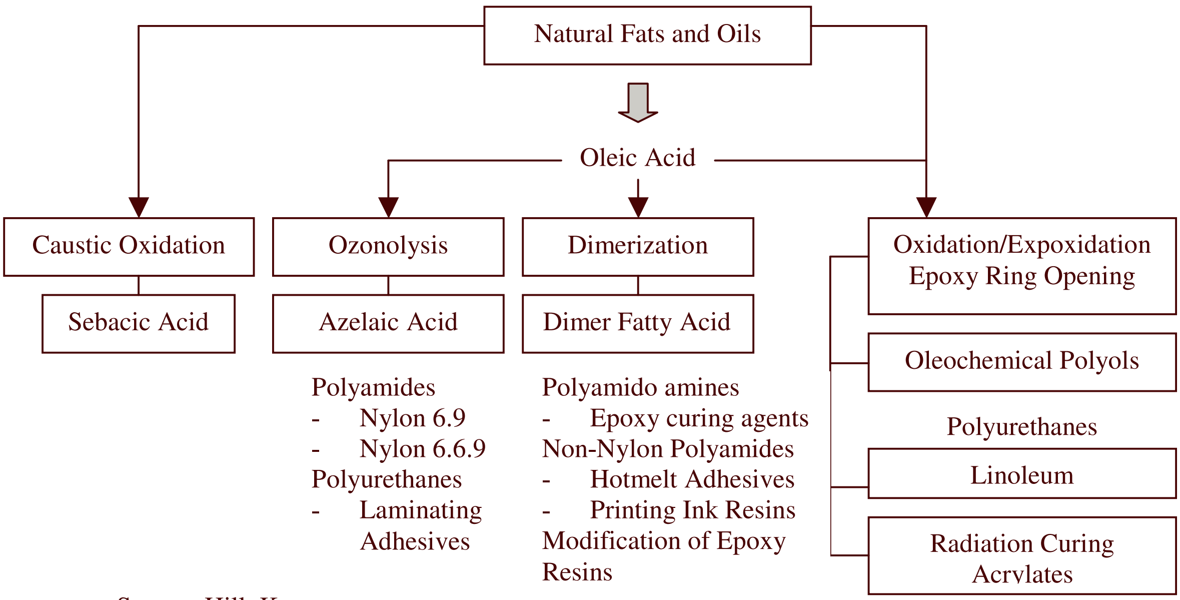
stabilisers and processing aids and as flame retardants in the manufacture of plastics. The principle chemical currently produced and used in this way is erucamide, which is derived from HEAR and more recently Crambe and is used as a slip agent. Erucic acid is used as the starting material for both nylon-13 and nylon 13,13 (a tough form of nylon used for moulded plastic).

- Reactive ingredients (where they form part of the polymer chain). Used in the manufacture of polyamides, polyesters and polyurethanes. The potential to produce oils from modified plants and for using biotechnological processes to convert vegetable oils into polymer substrates in substantial.

- Direct production of polymers. Genetic engineering is opening up the possibility of producing oilseeds that synthesis polymers in the plant itself. Polymers can already be derived from plants via the bacterial fermentation of carbohydrate feedstocks.

Plant oils used in these areas include predominantly soyabean oil, rapeseed oil and castor oil, as well as linseed and sunflower.

Figure 12 Building Blocks for Polymers Based on Natural Oils



Source: Hill, K

Considering the total market for polymers of approximately 150 million tonnes in 1997[44] and is expanding, the share of renewable-based products is very small. This share is likely to increase with environmental and other drivers, as already mentioned.

The Vegetable Oils Polymer Network in the UK (2004-2007) has recently been given a grant (£61,000) by the Engineering and Physical Sciences Research Council (EPSRC) to demonstrate the ability and to develop the generic science and technology to produce resins and polymer composites having low environmental impact.

Linoleum

Linoleum was patented in England in 1863 and since that time, and particularly in recent years, technology and design have combined to expand the selection and use of the product. Linoleum is

[44] Hill, K, 2000

manufactured from natural products: linseed oil (which gives it its name), wood flour, cork dust, tree (i.e. pine) resins, ground limestone and pigments, normally with a jute backing. One kilogram of linseed oil is required for each 1m^2 of linoleum. The market for smooth floor coverings is increasing in Europe (at the expense of textile floor coverings), boosted by new, dynamic niche areas. Linoleum is becoming increasingly fashionable, with new developments in design for example. Also, because linoleum is a natural product, its use is likely to be furthered by environmental concerns and regulations. Germany is one of the strongest linoleum markets globally, because German Government specifications have been called for green products since the early 1990's[45].

As outlined in the original IENICA report, linoleum has particular benefits in 'high tech' situations because it doesn't generate static electricity. In addition, it is more durable and has a longer life span than synthetic products such as vinyl flooring. It is also naturally anti-bacterial, so no chemical anti-bacterial agents are needed in its manufacture or maintenance, and when it is used with a low-VOC adhesive it emits far lower levels of contaminants than does vinyl flooring[46]. For these reasons, the use of linoleum in health care and similar buildings is a strong market area (as confirmed by the report for Lithuania).

There is no market information available to assess whether the estimate made in the last report was correct. It was estimated that the European market for linoleum would increase from 36 million m^2 in 1995 to 56 million m^2 in 2003. It is widely agreed, however, that in both the EU-15 states and the newly accessed states the use and market for this product is increasing, for the reasons given above. Estimates suggest that the demand for linseed oil for the production of linoleum has increased from 10,000 tonnes in 1975 to 50,000 tonnes in 1998[47].

Barriers to Progress

Barriers as identified in the original report are outlined in boxes A-S below; whilst some improvements have been made these issues still exist and still hamper the development of the industry. These have been confirmed by the newly accessed states and the associated states, as reported below, plus additional constraints and issues raised.

Crop Production

A

Further development of 'designer' oil profiles is likely to be the fastest way to meet industry's needs. The domestication of new species with useful fatty acid profiles to diversify crop species is occurring, but progress is slow and needs both industry demand and biological improvement to focus on a small selection for successful commercialisation.

Specific 'designer' oils are coming on stream from classical selection and/or breeding programmes. These include sunflower and rapeseed varieties with very high oleic acid (C18:1) content.

Crambe has been introduced in several countries. This provides an oil with high erucic acid (C22:1) content and has the advantage of not cross pollinating with

45 **www.floordaily.net**
46 **www.advancedbuildings.org**
47 Hill, K, 2000

rapeseed and having different seed characteristics which make it more easily distinguishable from rapeseed.

B
Oilseed rape is prone to shattering which gives rise to a significant volunteer problem in subsequent crops. Crop development to minimise this problem would increase yield and reduce costs and problems of volunteers in subsequent crops.

Initial programmes focussed upon reduction of pod shatter began using GM technologies although commercialisation may prove difficult in the current climate of public opinion.

C
The oil extraction industry is based on old technology; the development of improved extraction technology needs to offer cost savings, improved environmental practice and the ability to handle an ever increasing range of crop types.

Some rethinking of extrusion followed by hexane extraction could offer added-value potential for metabolites in meal.

The barrier described in Box A is supported by the reports from the **newly accessed states**:

- Plant breeding is required to improve crops. However, significant changes can hardly be expected in the mid-term perspective. Special efforts must be made to improve the oil crops concerning the compatibility between the crop quality and industrial needs, as well as the creation of productive varieties which assure high and reproducible yields.

- Variety improvement for disease resistance is required, as a major problem for all oil crop species is the diseases which appear during the whole period of growth. This will also provide environmental benefits, reducing the need for chemical treatment. Such an approach would support Pillar II objectives of the revised CAP.

- In Switzerland, further agricultural research is needed if new oil crops are to be developed. In addition, research should also provide cultivation guidelines for new and potential oil crops (recommended varieties, best dates for sowing and harvesting, plant protection, harvesting methods and if necessary, further processing of the seeds). The development of guidelines takes at least three years. Also, for some oil crops, no varieties with promising agronomic characteristics are available. In this case, breeding has to take place. For progress to occur species in need of breeding improvement are often disappointing in terms of evenness of maturation, yield and oil or fatty acid content. For linseed and all other potential oil crops, no plant protection products are registered currently in Switzerland.

Additional constraints in the **newly accessed states**, identified since the previous IENICA report:

- Poor climatic conditions have led to low production levels (i.e. sunflower in Bulgaria and Romania; poppy in the Czech Republic). In 2001 in Bulgaria, 2% of the crop was lost due to unfavourable agro-climatic conditions. In Romania, even though sunflower can potentially be grown well, the area irrigated was low which led to reduced yields, as the crop was subject to drought. In the Czech Republic in 2000, the acreage of poppy cultivated was 32% lower than in 1999, due to poor climatic conditions.

- Fluctuating linseed yields due to frequent difficulties related to early sowing, late ripening, difficult seed desiccation after rain as well as to the risk of sprouting before harvest. The late maturity of linseed complicates the harvesting of this crop in rainy weather, which is quite common in Lithuania at the end of September and October.

- Lack of grower knowledge in agronomy results in low yields (e.g. oilseed rape in Estonia: in the best farms of Estonia the yield of rapeseed is 2-3 t/ha, which shows that the yield can significantly be increased over the current mean yield).

- As identified in the Romanian report, farmers own relatively low production areas and consequently have little financial possibilities for research in the field. Limited finance limits ability to purchase highly productive varieties and cultivation equipment.

- In Lithuania, the success of developing high erucic or other possible types of technical rape varieties is doubtful. Such varieties tested in Lithuania have a high seed shatter level, so considerable yield losses can be expected. The seed remains viable in soil for more than 10 years and can reduce the quality of oilseed rape seed for human consumption. Very strict seed production and growing systems must be applied in order to implement safe growing of high erucic rape varieties. Low cold resistance of winter rape is still an important constraint in growing this crop.

- High costs of irrigation and expensive labour in Israel result in high production costs. In large parts of the Middle East, semi-arid and arid conditions prevail in many agricultural areas and fresh water resources are limited. Hence, supplementary irrigation during the winter is commonly needed due to uneven rain-spread or lack of efficient rains. In the spring and the summer seasons full irrigation is needed to ensure yield and quality.

- In Poland, the two main barriers in the cultivation of oilseed rape are low winter resistance to frosts and shedding of seeds during harvest.

Industrial Use

D
While considerable substitution of European vegetable oils for imported tropical oils, animal fats and mineral oils is theoretically possible, it is unlikely to occur because European vegetable oils are generally more expensive. Substitution is more likely to occur for environmental and customer preference reasons. Legislation is a key driver in EU-25.

This is still relevant.

E
Major technical performance barriers remain to be overcome to enable vegetable oils to be more widely competitive with mineral oils.
Lubricants: Development of new biodegradable environmentally friendly products. Development of new products based on high oleic oils where high oxidative stability is required.
Solvents: Development of new vegetable oil based solvents to meet EU VOC directive by 2007
Surfactants: Replacement of tallow by vegetable oils in personal surfactant products. Development of soap formulations using C18 fatty acids to replace tropical C12/14

> Additionally, firm specifications for primary feedstocks need to be defined by end users.

Additional constraints identified by the **original members** since the previous IENICA report:

- Industry wishes to keep a maximum of flexibility and prefers to rely on the international markets for finding the raw materials at the best commercial or technical conditions. In some countries (i.e. Austria, Belgium) industry appears to be reluctant to address domestic agriculture in order to contract production volumes of a specified quality at an agreed price. In some cases this is also due to the administrative complexity linked to this utilisation.

- The capacity of agriculture to invest in industry seems too weak.

- In many countries a lack of domestic tax exemption on biofuel means that biodiesel cannot compete economically with fossil diesel.

- Western European (EU-15) farmers often cannot compete with the prices of crops grown in Eastern Europe and major parts of the material crushed, and the oil, are often imported.

Constraints as identified by the **newly accessed states**:

- Technologies and industrial equipment are often old-fashioned and require modernising in order to obtain products by non-polluting methods. Modern technologies and equipment have recently been imported into most of the newly accessed states from Western countries (particularly Europe and the USA). Clearly cost considerations are an issue, though investment by former EU-15 states may be an option, bearing in mind the lower production costs structure applying in newly accessed states.

- In some countries (e.g. Hungary) a few multinational companies control the food-purpose plant oil production and also the processing, and only a few independent producers are in the situation to apply new cultivation technologies. This can limit non-food production.

- In Hungary, there is currently no processing capacity in operation which can produce high purity glycerine from the by-product low grade glycerine arising from plant oil processing, although the cosmetics industry has significant demands for purified glycerine.

Economic

> **F**
> *Price is a major barrier to development. European oilseed prices are not competitive in comparison with the world market prices for many vegetable and mineral oils.*
>
> This still remains true and is perhaps the most significant constraint in the development of this industry. The updated German report suggested that biolubricants, for example, are three to five times more expensive than mineral oils, despite their many advantages. This explains why the market share of vegetable-based biolubricants is only about 40,000 tonnes, which is 3.4% of the total use of lubricants and hydraulic fluids.

Should true price/value as opposed to economic cost be the deciding factor for choice?

G

The impact of Agenda 2000 on the production of non-food oilseed production is likely to be negative. The projected prices for the main oilseed crops are reduced, particularly linseed.

Certainly the EU-25 linseed area is declining in the face of reduced economic support, though Canada will probably expand its linseed/flax production. USDA suggests rapeseed prices will rise only in line with inflation. Poorer growers may not be able to compete.

H

The overall value of oilseed crops depends on developing a viable market for crop co-products. Traditionally these have been used as animal feed but increasingly by-products are less able to meet the requirements of animal feed manufacturers. New products, particularly in the non-food area, are required to improve the total income from oilseed crops.

Traditional approaches need to be revisited. Revisiting rapeseed processing procedures could open up new possibilities for co-products from meal.

In Greece, for example, olive oil is still prohibitively expensive as an industrial non-food feedstock, but recent investigations into the use of its by-products show where value could be added i.e. soap from the olive kernel oil extracted from the pressed olive cakes; olive residues and wastes utilisation e.g. for the production of biofertilisers and biofuels, as well as notably the fractionation of high value-added polyphenols from olive mill effluents.

Additional constraints identified by the **original members** since the previous report:

- Economically the production of sunflower depends primarily upon end prices and subsidies (Bulgaria).

- Since the last report, the low retail price level of the oil market for various plant oils in Austria, such as from safflower, linseed, milk thistle and sesame, forced the oil manufacturing industry to buy on world markets. Thus the demand for the domestic market dropped sharply, which was reflected in significant decreases in cultivated areas of oilseeds.

- In Israel, jojoba is dependent on demand and price in the international markets. There is no home market at present.

- In Lithuania, production chains and systems of contractual links between growers, primary processors and retailers must be created. Great fluctuations in production and exports must be softened by introducing future contracts. Merchants and processors are reluctant to sign long term contracts with growers because of market price fluctuations.

- Low levels of state support reduce the interest to initiate local production.

Environmental

I
Oilseed crops produced by gene transfer offer a potential to meet industry oil profile demands, but are currently unacceptable to the general public in EU. It will be necessary to devise acceptable environmentally friendly production practices to minimise pollen transfer and public anxiety to enable commercialisation of these types or develop alternative non GM technologies.

This is still relevant.

J
Much of the benefits of vegetable oils are built on biodegradability and good ecotoxological performance. These benefits must be seen to be maintained in all new products i.e. true cost versus economic cost.

This remains the case and is actually much more significant now. The last few years have seen an ever-increasing focus on the environment and sustainability at a world-wide, international and national level and industrial materials based on renewable raw materials are likely to have a much larger role in meeting objectives and targets.

K
The environmental benefits of vegetable oils are poorly communicated both to the general public and industry at large. Education coupled with EU-wide schemes to label environmentally friendly products based on vegetable oils (as already exists in some countries) would enhance consumer demand.

Regulation (EC) 1980/2000 of 17 July 2000 on a revised Community Eco-label award scheme established a Community Eco-label award scheme which is intended to promote the design, production, marketing and use of products and services which have reduced environmental impact during their entire life cycle. The criteria are established by product group, using life cycle considerations (LCC). The European Union Eco-labelling Board (EUEB) has begun work on establishing ecological criteria for the award of the European Eco-label to lubricants. For more information see the IENICA Market Data Booklet on Biolubricants (**www.ienica.net**)

Additional constraints identified since the previous report:

- Further efforts must be made to increase resistance of crops to pests and diseases and to reduce the level of pesticide application in terms of times and rate of application.

- In some newly accessed EU countries it is necessary to modernise technologies and industrial equipment in order to obtain products by non-polluting methods.

Legislative

L
To enhance the development of vegetable oil based products and to meet International Agreements on Climate Change and Biodiversity an overarching and integrated EU legislative framework should be established. This would be

particularly focused upon extending efforts with regard to protection of the environment from pollution by mineral oil based products.

This is still relevant.

M
European List of Notifiable Chemical Substances Regulations (ELINCS) and the European Inventory of Existing Commercial Chemical Substances Regulations (EINECS), are a major burden and constraint on industrial development and exploitation of new feed stocks from plants. Consideration should be given to ameliorating its impact for large and small-scale industries, otherwise R&D investment in new products will be seriously impaired.

In October 2003, the European Commission adopted a proposal for a new EU regulatory framework for chemicals: REACH (**R**egistration, **E**valuation and **A**uthorisation of **CH**emicals). Registration is the main element of REACH. Chemicals that are manufactured or imported in quantities of more than one tonne per year and per manufacturer/importer are registered in a central database.

Additional constraints identified since the previous report:

- The removal of subsidies in Sweden has caused the dramatic decrease in linseed production.

- In the majority of the newly accessed states there is no specific activity/legislation (except in some cases for hemp and poppy cultivation) stimulating the development of the vegetable oil industry. Some developments have taken place, such as the founding of the Biofuels Association of Romania in July 2003, with the aim of elaborating provisions with legislation.

- In addition, in many countries the lack of a national specific subsidy systems is blocking the development of the industry. Economically and logistically, it is advantageous for multinational companies, who often own a large share of the local processing capacity, to place their non-food production in countries where subsidy is available.

- A prohibition by law for the use of mineral oil based products in environmentally sensitive areas could enforce the use of vegetable oil based lubricants and hydraulic oils. A first step has been taken in France through the adoption in 2003 of the French environmental quality label for lubricants for chainsaws ‘NF Environnement 375’.

EU Actions

N
The position of non-food oilseeds in Agenda 2000 and following CAP reform particularly in relation to set aside and acceptable crops needs urgent review to minimise barriers created to increased non-food oilseed production.

This is still relevant.

O
The WTO Blair House accord poses limitations on oilseed production (oilseed rape, sunflower and soya). The position of EC/US Oilseeds Agreement post 2003 needs clarification and any barrier to increased non-food oilseed production removed.

This is still relevant.

P
It would be helpful to long-term research and investment by industry if the EU could produce a definitive long-term statement governing industrial crops and products and ensure integration of policy making in all DG's of the EC.

This is still relevant.

Q
There is continuing need for EC support of research and development, particularly to help overcome scientific/technical barriers. More of this support should be directed towards pilot projects to bridge the gap between scientific small-scale developments and full commercialisation.

Framework Programme 6 of EU Research has not been helpful in this respect.

Additional constraints identified since the previous report:

- Changes in EU policy (CAP reform; reductions in support) have resulted in the decrease in cultivation of a number of oil crops, particularly of oilseed rape. The Italian report states that 'in reality, the subsidies do not compensate for the inferior price given for non-food destinations. Therefore, the farmer does not have any economic benefit to produce in the non-food sector and thus does not take this possibility into consideration.' The Greek report suggests that a main obstacle for successful development of the sector lies in the present use of the CAP by Greek farmers, their Unions and the National State and that as long as the present EU subsidies regime persists no major changes will take place, with minor developments in the areas of by-products and wastes. It states that if, however, the Brussels subsidy scheme shifts to more 'green' targets and/or tends to lower its contributions, then the whole oil crop balance could move towards more industrial uses incorporating non-food applications.

- It is possible that the newly accessed states can expect more rapid development of non-food oilseed rape and linseed when EU rules on non-food crops on set-aside fields are implemented.

Communication

R
Communications between the main participants in the non-food oil industry, farmers, seed vendors, storage operators, research bodies, crusher, refiners and industrial users need significant improvement and integration. Only by multi-path

communication will confidence and requirements of all parties be defined and understood.

This still remains a significant problem. For example, the Italian report states that the agricultural and industrial sectors remain separate and do not have knowledge of what one offers and the other requests.

S
Communication of the new vegetable oil products and their environmental benefits, to industrial and domestic users will overcome the lack of knowledge and enhance product demand.

This is still relevant: the key to sustainability is awareness amongst consumers as well as producers. Except in Germany approaches have been minimal.

IENICA

~ FIBRE CROPS ~

Introduction[48]

[48] Key references for this chapter are:

- nova Institute for FNR (2000) *Study on Markets and Prices for Natural Fibres (Germany and EU)* **www.nova-institut.de**
- Karus, M (2002) European Hemp Industry 2002: Cultivation, Processing and Product Lines nova-Institute, Germany

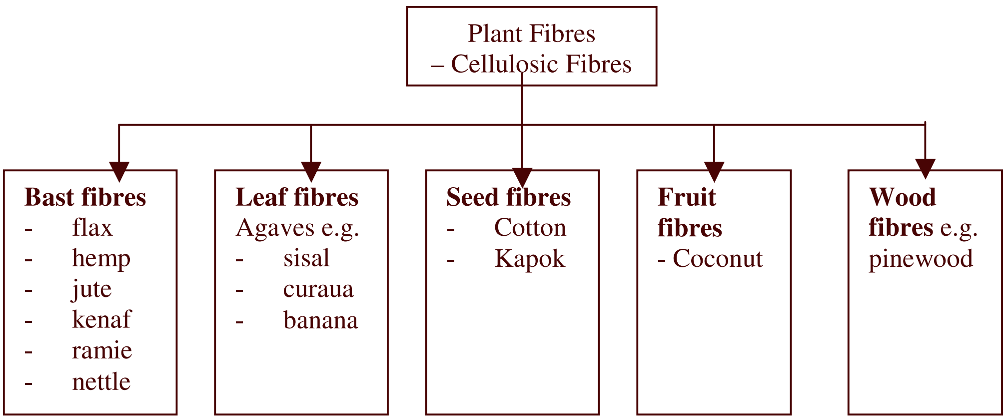
Plants have a history of use for fibre production from long before formal records began. *Linum usitatissimum* is the oldest cultivated fibre plant, with evidence of its growth and use dating back to the fifth millennium BC. In England, by the 16th Century, laws were enacted requiring that a ¼ of an acre of flax be planted for every 60 acres under cultivation[49]. Most particularly used in textiles where they were the single source of raw material, but also in applications such as construction, ropes and paper, natural fibres have had a multitude of applications for a very long time. The introduction of man-made fibres in the late 1800's caused a dramatic shift from natural fibres, as they could be produced more cheaply and to a more uniform standard.

Interest in natural fibres is increasing again for a number of reasons, most particularly due to new environmental legislation and concerns, resulting in a growing market for biodegradable and recyclable materials.

Total worldwide demand for fibre (cellulosic, cotton, wool, man-made, others) is predicted to increase from approximately 50 million tonnes/year (1999 figure) to 130 million tonnes/year by 2050 (in line with the predicted growth of the world's population). Cotton production will not be able to be doubled to meet this demand (for example due to climatic limitations, water limitations and high pesticide consumption on non-GM varieties), so the market for natural fibres will increase[50].

Plant fibres can be classified into 1 of 5 categories based on their anatomical source (see Figure 1). For further information on bast fibres (hemp and flax specifically) see the IENICA's 'Fibre Facts' booklet (www.ienica.net) – A Framework for Buyers and Sellers of Flax and Hemp Fibres Within the EU.

Figure 1 Classification of Plant Fibres



European production of natural fibres focuses largely upon flax and hemp, as described below. Both long and short fibres are produced from these crops, as well as a number of other products. Long fibres are the main, and most valuable, product of traditional flax and hemp processing, and are primarily used in the apparel and home textile markets (see later). Short fibres (tow), shives (flax woody core) and hurds (hemp woody core) are also produced as co-products and are used for a number of the industrial applications reported in this chapter.

49 **www.nps.gov**
50 Ditchfield, C (1999) *Hemp and Other Natural Fibres: Today and Tomorrow* A report for the Rural Industries Research and Development Corporation, Australia

France, Belgium and the Netherlands are the 'traditional' flax countries; in these countries, flax short fibre production is a by-product of flax long fibre processing. In contrast the 'new' flax and hemp countries (Germany, the UK, Scandinavia) process short fibres almost entirely by 'total fibre' lines, which do not separate long and short fibres. Production of long fibre hemp is now limited to Eastern Europe and China. In the EU-15 countries, hemp fibres are exclusively processed with total fibre lines. The total fibre lines, developed in Europe since the 1980's, yield the total fibre contained in straw as short fibre. Production costs are lower compared with long fibre lines. The short fibres produced are predominantly used as technical fibres for the uses described here. Specific fibre length varies considerably depending on the end-use.

Science and Technology

As was indicated in the last report, the number of species produced commercially is relatively small and amazingly consistent throughout Europe. This remains the case even with the accession of 10 more countries.

The range of research into different fibres for Europe was outlined in the last report, and these most recent investigations have shown that some of that research has now given rise to more commercial developments than there were at that time. Species of interest for Southern Europe were shown to be Giant Reed (*Arundo donax*), Kenaf (*Hibiscus cannabinus*) and Fibre Sorghum (*Sorghum bicolor*); Miscanthus (*Miscanthus sinensis*) throughout Europe and Stinging Nettle (*Urtica dioica*) and Reed Canary Grass (*Phalaris arundinacea*) in Northern and Western Europe. At that time (2000), flax (*Linum usitatissimum)* and hemp (*Cannabis sativa*) were the only commercialised sources of European plant fibres. Whilst flax and hemp still dominate this sector there have been developments in Miscanthus most particularly. Fibre sorghum and RCG are increasing in interest. In addition, stinging nettle for long fibre production is of interest in a number of countries for use in textiles, interior fabrics and speciality products. It is important to note that flax and hemp in particular face competition in some of the technical markets discussed in this chapter from the cheaper production of wood-based/derived materials.

Short fibres from European flax and hemp for the industrial applications described in this chapter face competition from various places[51]:

- **Within EU-25**: It is estimated that, on average, EU-15 companies import about 13,000 tonnes of flax short fibres annually (and around 6,000 tonnes of flax long fibres), particularly from Egypt and Lithuania. Hemp fibres are currently only imported in marginal quantities (following the decline of the Eastern European hemp industry after the dissolution of the former USSR).

- **Jute, sisal and kenaf fibres from Asia**: These fibres are used in composites in the same ways as fibres from flax and hemp. Primary fibres from these plants are increasingly used (rather than recycled fibres from sacks, for example); their price is equal to or even higher than flax and hemp fibres. Jute fibre in particular is produced in much larger quantities than flax and hemp fibres. The most important countries of origin are Bangladesh and India. FAOSTAT data 2004 gives figures for the jute and sisal areas harvested in 2003 at 1.3 million ha and 352,000 ha respectively. However, supply and quality can be variable.

- **Synthetic fibres**: Plastics, glass, mineral and carbon fibres compete with natural fibres in technical applications. In addition, man-made fibres (and cotton) have dramatically reduced the use of (long) natural fibres in the textile industry. The prices of synthetic fibres are

[51] Study on Markets and Prices for Natural Fibres (Germany and EU), March 2000, nova Institute for FNR

generally higher than those of natural fibres and are also directly dependent on (rising) crude oil prices. However, standardised synthetic fibres offer advantages in many applications. The nova Institute report: Study on Markets and Prices for Natural Fibres, 2000, suggests that natural fibres have good prospects against synthetic fibres if they can be further standardised; new production technologies specifically adapted to natural fibres can be realised; comparable (or better) product properties can be achieved; environmental aspects are considered and manufacturing costs are comparable (or lower). In some applications e.g. press-moulded parts in the automotive industry, this has already been achieved,

- **Competition with each other**: Organisation, production costs and market prices for fibres from total fibre lines and tow from long fibre processing are different. The technical fibres from total fibre processing have to yield the entire fibre profit; their market prices are closely associated with their production costs and vary only little. Tow from long fibre production is only a low value by-product, whose price is mostly determined by the market; prices vary accordingly.

Competition among natural fibres is mostly determined by:

- Their technical properties (and therefore their potential applications)
- Their market volume and market structure (and therefore their supply security)
- Their market prices

There is much research taking place in Europe into both natural fibres and their industrial applications[52]. EU funding has been available for natural fibre projects and it is estimated that, between 1982 and 2002, a total funding of 52 million Euros was provided, from DG's VI, XII and IV[53]. The projects have been mostly geared towards the development of new technical applications for flax and hemp fibres and the associated framework (e.g. suitable varieties). This European funding has been in addition to national funding, research programmes and projects. German industry over the last 10 years or so has invested about 90 million Euros in R&D related to natural fibre applications. Around 50% of this total funding has come from state sources.

Whilst much of this research is now taking place into the industrial uses of fibre crops, and into the improvement of processing and manufacturing techniques, much of the scientific development in the recently accessed states is occurring with regards to production – breeding, agronomy and cultivation practices to provide varieties with improved characteristics (e.g. disease and insect resistance); ensure more stable production, higher yields and improved quality of the raw material.

Research and Development is recognised as being central to the future of the natural fibres industry in Europe. Defra's Strategy for Non-Food Crops and Uses in the UK (2004, draft under consultation) suggests that '*Technological development will play a key part in the introduction of new and enhanced farming techniques, complementing development work with industrial processes*'.

In Denmark, two fibre technology centres have been established to revive the fibre industry. In 1996, the 'Centre for Plant Fibre Technology' was established, with 2 Universities, 2 research centres and one commercial company making up the Centre. Whilst it does still exist officially, the joint research activities are currently rather modest. A few years ago the 'Fibre Tech Centre'

[52] See BioMatNet (**www.biomatnet.org**)
[53] nova Institute, 2000

was established, focusing on the establishment of new fibre-based productions and is composed of a research centre (Green Centre) and an innovation centre (Syd Tech).

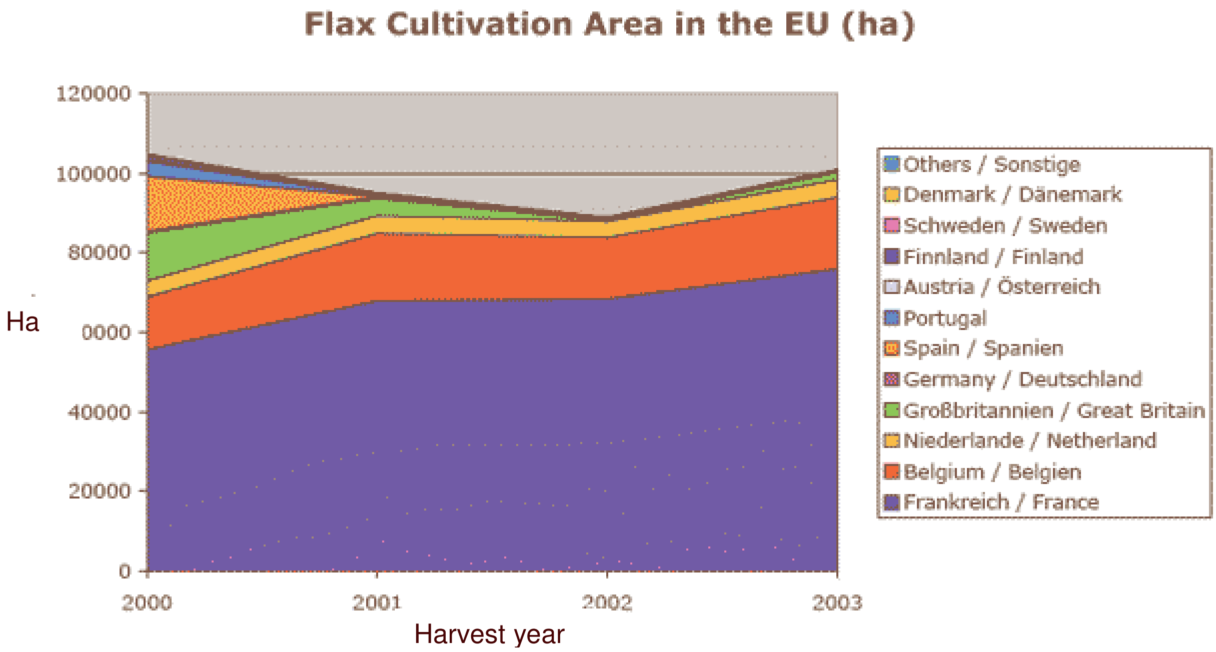
One key element in the expansion of fibre crops area in EU-15 has been market support. Decline or removal of that support (e.g. for short fibre flax) or future changes in aid for any fibre crops could have major detrimental impact and a negative environmental impact by delaying replacement of high energy demand and low degradability materials like fibreglass with plant-derived materials of equal or better technical performance. This area needs to be considered as a part of a new and integrated approach to fibres across the European Commission.

LONG FIBRE PLANTS

Note: As already mentioned, some crops are used for the production of both long and short fibres.

Flax (*Linum usitatissimum*):
Changes have occurred during recent years in the amount of flax cultivated in Europe, but not consistently between countries. Figure 2 shows the recent changes in the European flax area.

Figure 2



Source: Karus, M (2002) *European Hemp Industry 2002: Cultivation, Processing and Product Lines*

Of note are the significant increases in production seen in France and Belgium, largely following developments in the textile market and subsequent increased demand. Almost all long flax fibres are used in the apparel and home textiles industries. In Belgium, nearly all is grown under contract to the flax industry. Whilst France is the second largest producer in the world (producing 80% of the European area[54]) it is not anticipated that the area will increase much more, until new products for the crop are developed. In 2003, the flax area was 68,000 ha. If this is 80%, the European area (EU-15) can be estimated at approximately 85,000 ha in 2003. Other estimates suggest an EU (15) area of flax in 2003 of 100,000 ha[55].

[54] Date from the IENICA national report for France
[55] **www.chanvre-info.ch**

Germany, Austria, Denmark and the UK have seen a decline in the amount of flax cultivated. In Germany, a poorly developed processing industry is to blame for the decrease in area to only 225 hectares – only 6% of the area in 1997. In Austria, insufficient harvesting and processing technologies have resulted in a drop from 800 ha in 1997 to only 175 ha in 2002 (although it is suggested that this industry is of interest and the area could be enlarged again) and in Denmark production has almost ceased completely due to poor economics. In the UK, flax production continues to decline (from 15,500 ha in 1999 to 2,000 ha in 2003) as a result of decreasing processing capacity and the low value associated with the crop compared with other potential crop options[56]. Reductions in aid have had a major impact.

Even with the increase in Belgian and French areas, these decreases in production resulted in an overall decrease across EU-15 since 1999/2000; the area has increased once again, since 2002, as shown in Figure 2.

Whilst flax is grown in a number of the newly accessed states (most notably the Czech Republic – 6,000 ha in 2003; Lithuania – 9,000 ha in 2003 and Poland - 5,100 in 2002[57]), cultivation areas are still relatively small (particularly in comparison with those in some of the EU-15 countries e.g. France and Belgium: 68,000 and 20,000 ha respectively in 2003). Flax does have a long history of significant production and use in Eastern Europe, for traditional applications (linen and coarser textiles e.g. canvas, bags, rope) and the climate in many countries is ideal for its cultivation. In 1989, 70,000 ha of flax was grown in Romania alone. However, significant decreases in area have been seen since that time (the Romanian flax area is now around 400 ha; 0.5% of that in 1989; the Polish flax area was over 100,000 ha at the beginning of the 1970's) for a number of reasons, including[58]:

- Competition with cheaper and more industrially friendly cotton and synthetic fibres
- Transformation of the Polish economy resulting in a considerable decrease of the production capacity of factories and raw material availability. Key factors involved in this were: financial reforms of the state including changes in credit policies for factories; changes in industrial activity as a result of ownership restructuring; opening of the market to high quality raw material among others from the EU countries; changes in the structure of production and connected increase of demand for high quality fibre
- Retrocession of the land from the state to the former owners
- Farmers' own relatively low production areas and consequently limits on finance to buy high quality seed and to invest in growing technology
- Decrease in the number of processing units (this is the main reason given for flax no longer being grown in Estonia)
- Decline of the domestic textile industry
- Increase of cheap imported ready-made clothes

In addition, cultivation ended in Hungary in 1980 due to flax's sensitivity to drought; the climate is not wet enough for its production. Before that time it was an important industrial plant in the country.

Hitherto, Government grants and subsidies in the Czech Republic and Lithuania have resulted in an increasing flax area in those countries.

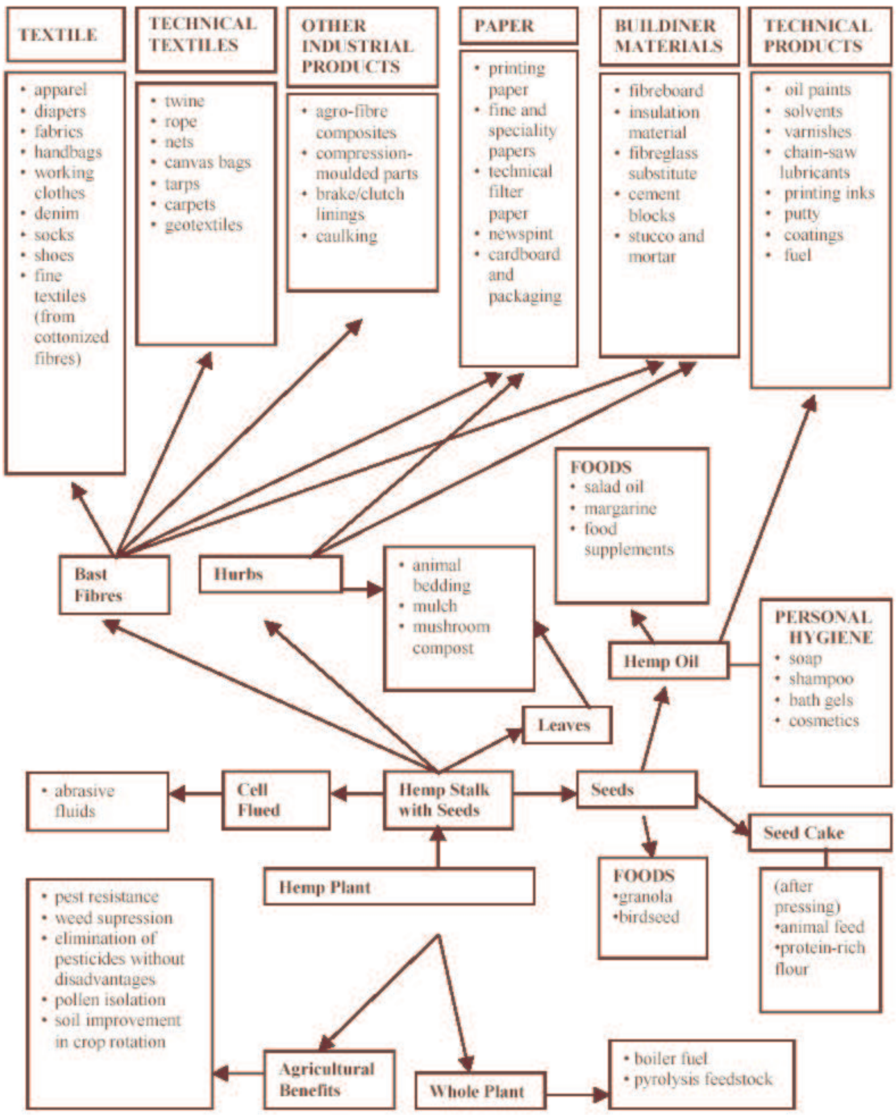
Hemp (*Cannabis sativa*):

[56] Date from the IENICA national report for the UK
[57] Data from the IENICA national reports
[58] Date from the IENICA reports for Romania and Poland

Currently in the European Union about 10 companies are engaged in the primary processing of hemp, plus another 5-10 such companies in Eastern Europe[59]. The leading primary hemp processors in Europe are AGRO-Dienst (Germany); BaFa (Germany); Hemcore (UK); HempFlax (the Netherlands); Hempron (the Netherlands); LCDA (France) and Vernaro (Germany). In 2002 these companies represented a market share of 80-90% in terms of hemp fibres produced in the EU. As already mentioned, traditional long fibre processing of hemp prevails in Eastern Europe and in the EU-15 countries whole fibre processing ('total fibre lines') is practised.

The previous IENCIA report recognised that hemp has a wide range of potential uses (see Figure 3) for its many components and that cultivation and use of this plant would be likely to see significant future development. The presence of Delta(9) tetrahydrocannabinol (THC), albeit at low levels, has, as predicted, held the industry back someway, but Europe is now beginning to see the potential. This is largely due to the suitability of the hemp plant to a range of 'novel' uses (such as in the automotive industry) and the removal of the bans on the plants where it was previously been proscribed.

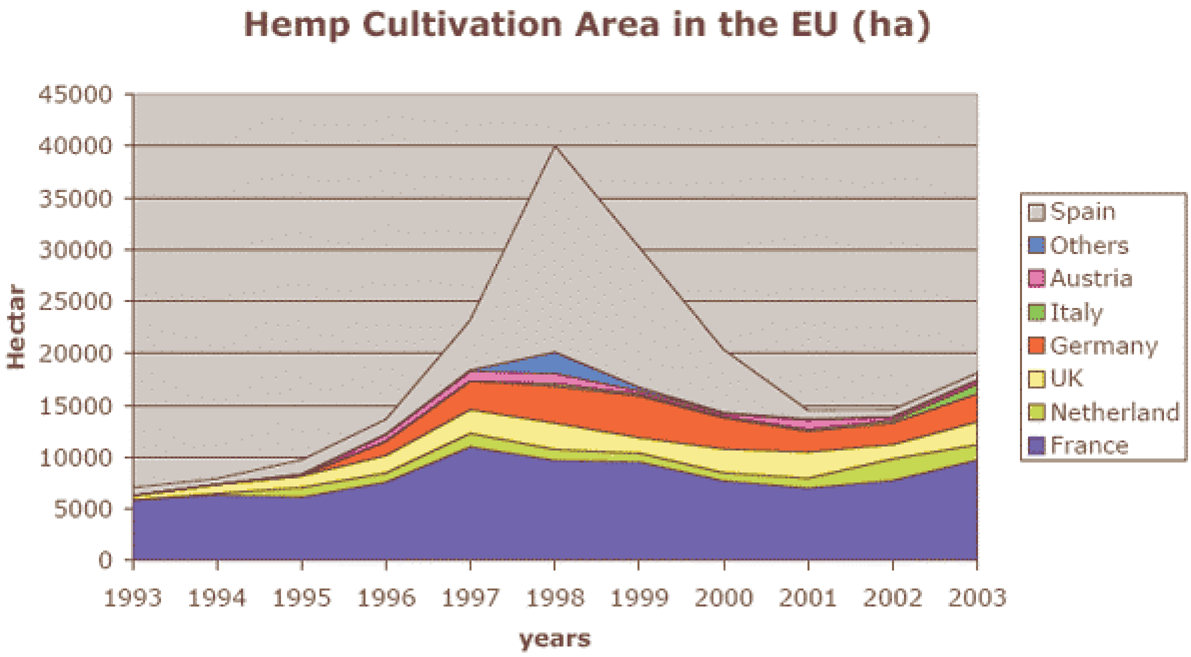
Figure 3 Potential Uses for Hemp[60]



[59] Karus, M (2002)
[60] IENICA Final Report (2000)

In 2002, the 7 companies listed earlier had a total contract area of about 10,380 ha under hemp cultivation. This was approximately 71% of the total area under hemp cultivation in the EU which gives a total area in EU-15 of 14,600 ha in 2002. In 2003 the area has considerably increased to approximately 18,000 ha, showing the further increasing demand for industrial hemp fibres[61]. Figure 4 shows the evolution of hemp cultivation in the EU since 1993. In line with the increase in hemp cultivation, the amount of EU-produced hemp fibres has also continuously increased in recent years and was estimated to amount to more than 25,000 tonnes per year in 2002 and 30,000 tonnes in 2003 (world production is estimated at about 70,000 tonnes). Combined, the companies listed above produced more than 21,000 tonnes in 2002. About 31,000 tonnes of hurds and more than 5,300 tonnes of hemp seeds were also produced by these companies as value-added co-products[62].

Figure 4



Source: Karus, M (2002)

Austria is the exception to the overall increase in cultivation across the EU-15 area, where it has seen a decline in the area grown, for the same reasons as its decrease in flax cultivation (insufficient harvest and processing technologies).

As can be seen in Figure 4, France grows around 50% of the European area of hemp and although this area did decrease after the reduction of EU subsidies in 1997, an equilibrium has been reached.

The Italian hemp industry has seen recent rapid developments for textile applications, following the organisation of the production chain into a consortium involving primary producers, primary processors and others up to a large industry that produces high fashion apparel. In 2003 a primary processing factory was inaugurated.

This suggests a way forward for producers in other EU states.

[61] Karus, M (2002)
[62] Karus, M (2002)

Hemp is also of considerable interest in the newly accessed states, although actual commercial cultivation is more limited than in EU-15. Hungary and Romania grow hemp in the largest amounts (although both only around 1,200 ha) and their climates are suited to its production. Hemp is stated to be the most promising non-food crop in Hungary (due to the ideal climate and soils) and is in fact one of the biggest and oldest European producers, although hemp was typically only for home utilisation. Now, large-scale industrial growing and manufacturing has developed, as a result of R&D and mechanisation.

Production in the other newly accessed states in limited, although most countries (with a suitable climate) recognise that hemp has great potential for industrial purposes and suggest that production is likely to increase in the short term.

Romania, as for its flax area, had significant hemp production until 1989 when the area was 46,000 ha. However, cultivation has declined to around 3% of that, for the reasons given as for flax, above. The story is similar in Poland, where 30,000 ha of hemp was grown at its peak in the 1960's. Competition from man-made fibres is given as the reason in this case. Investments seem to be a recurring problem; hemp can be grown legally in Estonia but costs (primarily the supervision required during the entire vegetation period) nullify the economic profit gained. In Lithuania, the growing technologies (e.g. varieties, fertiliser) do not exist.

Stinging Nettle:
Since the last report was written interest has been shown in the stinging nettle (*Urtica dioica*) for long fibre production. Experimental areas in Austria, Italy, Germany and the UK have been established. Around 10 ha is grown in Finland, producing 20-40 tonnes of straw which is used in textiles, interior fabrics and speciality products. Consideration is also being given to use of stinging nettle as a biomass crop in Austria.

SHORT FIBRE PLANTS

Cereal Straws: These were outlined in the previous report as a potential source of fibre for the board and paper/pulp industries: this is a by-product which could potentially add value to the production of food grains (if processing does not occur at too great a distance from where it is harvested). It is still the case that few commercial developments have occurred, with the notable exceptions of Belgium, where around 3-5% of total cereal straw production (approx. 50,000 tonnes) is destined for use as paper, cardboard, insulation panels et cetera. and Hungary, where around 50,000 tonnes of wheat straw is processed into approx. 30,000 tonnes of cellulose, used for food purposes (30%) and paper production (70%)[63]. In the UK, the BioRegional MiniMill project was established in 1997 to develop and apply small-scale clean technology to pulp straw and recover energy and pulping chemicals from the effluent. It can process hemp, flax, wheat or rice straw and other crop fibres, and is adaptable for wood and recovered fibre. The MiniMill has been developed to the point where the technical and economic feasibility is proven and construction of a full industrial scale pilot and demonstration plant is the next step[64].

It is important to note potential conflicts between cereal straw for application as a fibre raw material and for ethanol production.

Miscanthus (*Miscanthus sinensis*): Whilst its primary market is as a biofuel, a number of alternative markets utilising its short fibre components have been identified. Little change has occurred since the last report was written. Scientific interest is shown in Miscanthus in a number

[63] Date from the IENICA national reports for Belgium and Hungary
[64] **www.bioregional.com**

of the EU-15 countries but there is little interest from the newly accessed states. Several attempts to introduce miscanthus to Belgium have failed, and although productivity trials have been taking place in Ireland for more than 10 years there are few commercial outlets at present. 40-50 ha are grown in Denmark, for energy and fibre, and commercial thatching with miscanthus is now taking place. Investigations have occurred in Lithuania but there is no commercial production at present, although potential as an insulation material has been suggested. In Switzerland, miscanthus is the most significant fibre crop, grown by 170 farmers on a total of 200-250 ha, primarily for granules for alternatives to plastics – mainly plant pots at present. In the UK, miscanthus production is on approximately 2-3 thousand ha, although much is used for rhizome production for multiplication. Many end-uses have been developed, including animal bedding, in composites and biodegradable plastics and as an energy crop. Yields can vary year to year depending on the weather; Miscanthus has low cold resistance and so performance can be unstable. This has been reported several times in EU-15 in the last 15 years.

Reed Canary Grass (*Phalaris arundinacea*): European activity in RCG is limited to Scandinavia – Sweden and Finland[65] - where there is interest in the plant as a source of short fibre for pulp and fine paper production. RCG is ideally suited to low temperatures and poor soil conditions. In Finland, around 2,000 ha are cultivated (2003), providing 10-16 thousand tonnes of dry straw, used for bioenergy. In Sweden, around 500 ha are grown and this can be used as a fuel raw material. It is noted in the Swedish report that this is a rapidly expanding sector. In addition, there are most likely more possibilities for RCG as a raw material in products ranging from fibreboards to dissolving pulp, but more research is needed.

Short Rotation Coppice: SRC is willow (*Salix* spp.) or poplar (*Populus* spp.) coppiced in a 3 yearly cycle; developed primarily as a source of biofuel although the short fibres have been shown to have a limited range of alternative uses. No significant developments have occurred in this area during the period. Around 15-20 ha of natural willow areas in Lithuania are used for industrial uses such as wickerwork, the extraction of tannins and for cellulose and fuel. Disappointing developments have been seen in the UK with the failure of the ARBRE project – a gasification facility for processing short rotation coppice, which recently finished operations.

Fibre Sorghum (*Sorghum bicolor*): There is some sorghum cultivation in Hungary and Romania, for the production of brooms. Fibre sorghum was grown in France at an experimental scale (20 ha in 1998), but this has now stopped as it is not competitive compared with wood material. The area of sorghum in Greece has declined by almost 90% since pre-EU levels (from 9,000 ha in 1970 to around 1,000 ha today); being replaced by heavily subsidised competitors. New industrial/energy sorghum plantations described in the original report for Greece may, however, increase the fibre potential once again. The Romanian Biofuels Society has set up an agreement with a German-American consortium with the aim to cultivate sorghum on 500,000 ha for technical ethanol and pulp production.

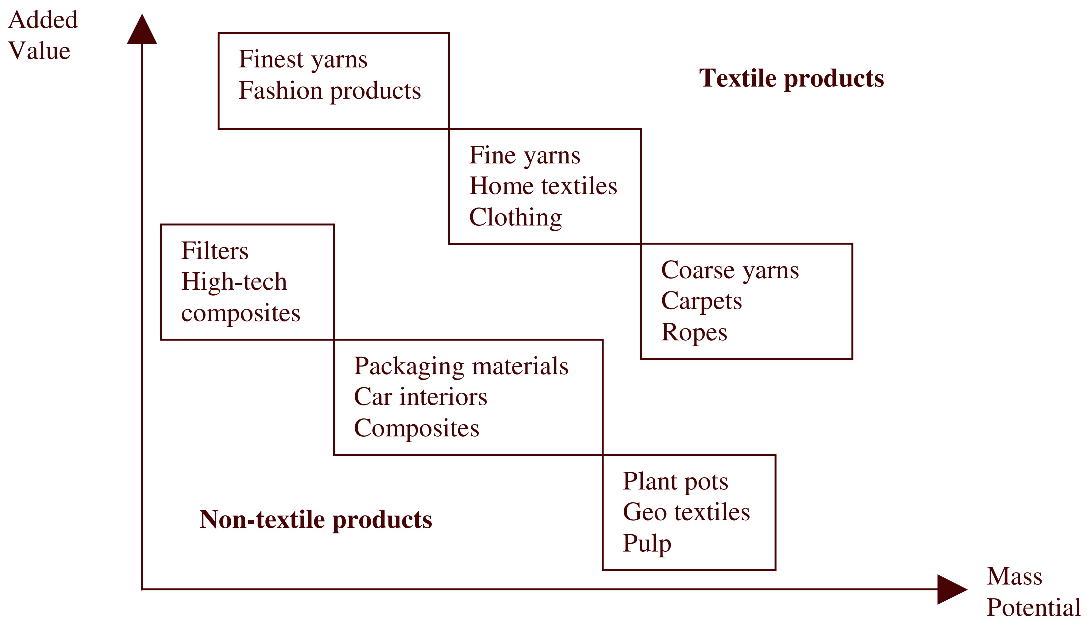
Linseed Straw: Short-fibres, produced as a by-product of linseed production, are utilised in Finland for thermal insulation, packaging materials, reinforced composites and growth substances (mainly imported material is used; around 1,900 tonnes of straw from approx. 2,000 ha).

Markets

The very wide-range of applications for natural fibres was illustrated in a previous IENICA report. These applications vary from lower volume, higher value markets to higher volume, lower value - as illustrated in Figure 5:

[65] Data from the IENICA national reports for Sweden and Finland

Figure 5 Added value versus volume potential of bast fibre products



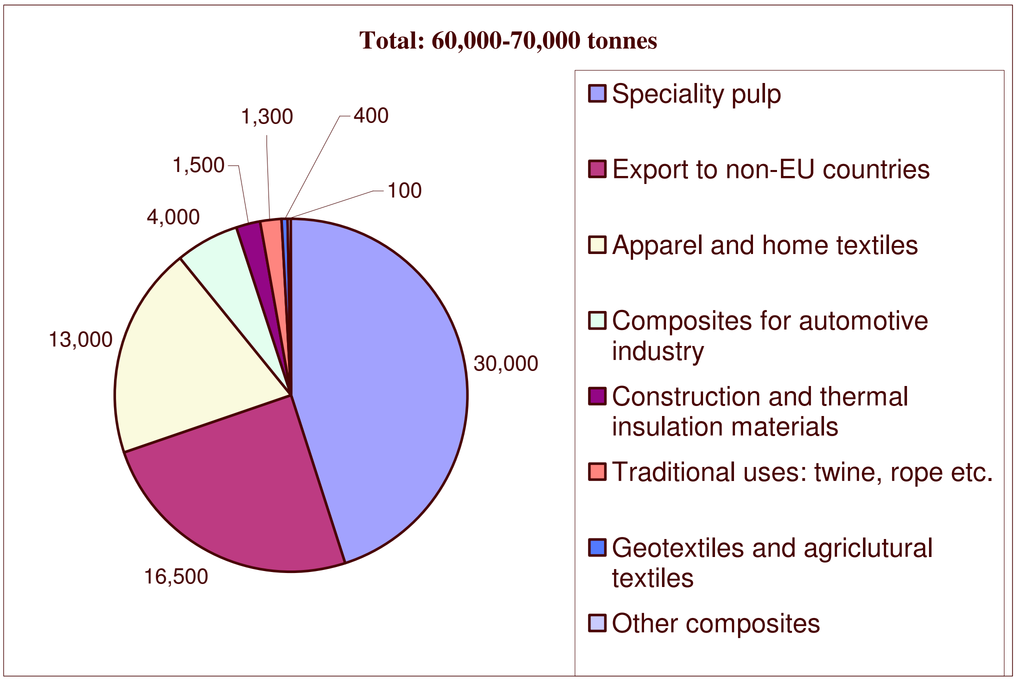
The markets for European-produced fibres are varied and many are developing rapidly. Textiles has traditionally been an important market for natural fibres, but with the domination of cotton and synthetic fabrics, especially as cotton/polyester mixtures, the importance of this area has significantly declined. This is particularly so in EU-15, where more 'novel' industrial markets are becoming increasingly important. However, in stark contrast, it is clear that textile markets are still by far the primary end-user of fibres produced in the newly accessed states and their interest and development into the 'new' markets is currently limited. It is important to note that France, as the largest flax producer in Europe, has seen an increase in the flax area from 49,000 ha in 1999 to 68,000 ha in 2003. This growth is mainly due to a strong demand from the textile market and could reach an estimated 72,000 ha[66]. 61% of the French flax crop is used for apparel, although this only accounts for 1.5% of the whole textile industry.

As the European natural fibre sector is dominated by flax and hemp, the markets described here will be discussed primarily in relation to these crops. Where relevant, other fibres are discussed.

[66] Date from the IENICA report for France

Other than the apparel and home textiles industries, which utilise almost all the long fibres produced in Europe, the industrial applications described here make use of the short-fibres produced either as a by-product from long-fibre processing or from total fibre lines (described earlier). These markets are relatively new, as discussed earlier, and their importance as well as the fraction of their fibre supply grown in the EU has been increasing in the past years and is expected to increase further. This is due to 'new' flax and hemp countries employing only total fibre lines and targeting technical markets. Estimated data for flax in 1999 and hemp in 2002 are shown in Figures 6 and 7.

Figure 6 Flax short fibre applications, tonnes (EU, 1999)[67]



As shown in Figures 6 and 7, the most important markets for flax and hemp short fibres are pulp (commodity and speciality pulps) and the apparel and home textile sector (see below). However, in recent years a number of new developments and markets for short fibres (also relevant to the different fibres discussed under Science and Technology, earlier, have opened up, motivated by comprehensively sponsored research and development projects and innovative entrepreneurs. The two most important of these new products lines are composites in the automotive industry and thermal insulation materials in the building sector. In 2000 it was reported[68] that *'market shares for all new technical product lines are somewhat below 10% for flax and slightly above 10% for hemp. European fibre processors forecast a market share for these products lines of about 30-40% of the still growing market as soon as 2005'*.

The building/construction industry is fast-developing as a major area for the application of natural fibres, which can make a significant contribution to a more sustainable construction

[67] Source: nova Institute, 2000
[68] nova Institute, 2000

industry. Products include insulation materials, building materials, panel products; the major areas are described below.

The previous IENICA report also demonstrated that each market has very different, specific, requirements for the raw material, and an identified problem is that these specifications are not always known. For this reason, the IENICA project has published a Market Specification Sheet on bast fibres, identifying the areas which must be considered by buyers and sellers before entering the supply chain i.e. a list of criteria against which each party can establish whether they have completed their task correctly[69].

An important issue is that, to be able to utilise all grades of fibre produced, it is important to separate and direct each component to the appropriate market. It was noted in the previous report that fibre cleanliness (e.g. low shive content) is an important characteristic which many flax and hemp processors find difficult to achieve.

As discussed earlier, current research and development in this sector focuses upon improving production, extraction and processing technologies so as to improve fibre yield and quality, and so meet market requirements more closely, thereby potentially improving the price gained for the raw material.

Textiles:
Traditionally an important market for natural fibres, the sector is now dominated by cotton and synthetics and the use of crop fibres other than cotton has declined significantly. In the EU-15 countries, almost all long flax fibres are used in the apparel and home textiles industries. Hemp fibres and short flax fibres are used for the industrial applications described below. The vast majority of fibres produced in central and Eastern Europe go into this market – higher quality, finer, yarns into apparel and home textiles and coarser, lower-quality fibres into more ‘industrial’ textiles such as canvas, bags, rope. Many of these products are of low value (e.g. bags, rope) and it is therefore difficult to justify investment in their production and processing. Also, if a change in feedstock involves a change in processing equipment, additional investment is likely to be a limiting factor. These ‘industrial’-purpose fibres can find slightly higher value applications in furniture, floor coverings and horticultural matting, for example.

In the EU, more than 80% of long flax fibres are further processed by wet spinning; more than 10% by dry spinning and the remaining ~10% are processed to twine. 50% of the long fibre yarns – spun in the EU and other countries – are used for apparel, 13% for furniture covers, 20% for other home textiles and 17% for sacks, tarps and other uses. More than 50% of the long fibres are actually exported for spinning, not spun in the EU, especially to China and Brazil (50% and 5% respectively, in 1998). The fibres return to the European market as yarns or fabric. Small amounts of flax long fibres are also imported, in particular from Egypt and Lithuania (60% and 13% respectively, in 1998)[70].

In addition to flax long fibres the short fibres are also used in this industry, depending on when flax is in fashion in the apparel industry. Around 25% are generally used in this sector[71], although when flax is en vogue in the apparel industry this figure can rise to around 50%, with less used for pulp and paper. Obviously, the flax industry is interested in selling the largest possible quantities of short fibres into this high-priced sector.

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[69] **www.ienica.net**
[70] Study on Markets and Prices for Natural Fibres (Germany and EU), March 2000, nova Institute for FNR
[71] As for footnote 13

A key factor in the production of natural fibres is dependency upon the processing facilities. In many countries the number of these facilities has decreased and so the cultivation of the crops has also decreased at least proportionately.

European fibres are often in competition from tropical fibres in this area, though transport costs and reliability of supply are key factors favouring home production. In addition, and in some markets only, the use of bast fibres in Europe can be limited not only by competition from tropical fibres, but also by the cheaper production of cellulose products from wood or wood wastes.

Pulp and Paper:
Within Europe, the paper and pulp industry is represented by CEPI, the Confederation of European Paper Industries. CEPI has 19 members[72] which, in 2003, together produced 95 million tonnes of paper and board. CEPI figures[73] show that the industry is made up of more than 1,280 pulp and paper mills and uses 42% recycled fibres and 43% virgin pulp, the rest being other pulp (1%) and non-fibrous materials (14%). Their data suggests that Germany is the largest paper producer, followed closely by Finland, Sweden and France. The main pulp-producing countries are Finland and Sweden. CEPI member countries account for more than 29% of world paper and board production, slightly behind North America (31%) and Asia (30%).

This market is divided into speciality pulps and paper and commodity pulp and paper. This is an important sector for flax (45% of flax short fibres in 1999; see Figure 6) and most particularly hemp (80% of hemp fibre in 2002; see Figure 7) where it represents by far the most important product line, as well as other fibres such as RCG and cereal straws.

- **Speciality**: Pulps produced from annual plants such as cotton, abaca, flax or hemp possess very different properties from those of wood pulps. They are used for speciality papers such as cigarette paper, filter paper, bank notes, hygiene products and various technical papers. There are niches for hemp, flax and others (e.g. reed canary grass) to replace some imported abaca, sisal, jute and cotton waste and for enhancing pulps based upon recycled paper. With a share of 70-80% of the hemp fibre market, this traditional application still represents by far the most important product line (Figure 7). 95% of the flax and hemp pulp processed annually in the EU is used for cigarette paper. Although demand has been largely constant in this area, its relative share has decreased. Without any significant technical progress and/or the development of new fields of application, little economic growth of this sector is expected. The paper industry increasingly seeks to substitute expensive speciality pulps by less expensive wood pulps with suitable additives. France continues to be the most important country for the use of hemp fibres in the speciality pulp sector.

- **Commodity**: Flax and hemp fibres can also be used in this area and are mostly used in mixtures with recycled paper and/or wood pulp. This market represents primarily an 'emergency market' for inferior or overstock fibres. The market is dominated by wood fibre. It features generally large-scale operations which require an assured supply of constant quality raw material and are likely to remain almost exclusively customers of the timber industry. Predictions have suggested[74] that the total global consumption of paper-making fibre will increase from about 300 million tonnes in 1998 to approximately 425 million tonnes by 2010 and that most of the increase will come from recovered paper, and the rest from fast-

[72] Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Hungary, Ireland, Italy Norway, Poland, Portugal, Spain, Sweden, Switzerland, the Netherlands, UK and the Slovak Republic (an Associate member)
[73] **http://cepi.org**
[74] Paavilainen, 1997

growing hardwoods, with only a moderate increase in the use of non-wood plant fibres. Only a tiny faction of mills have the facilities to turn non-wood fibres such as flax and hemp into pulp; mills the world over are almost exclusively geared to convert wood into pulp and then paper. Though the pulping processes are similar, flax or hemp (with their longer fibres) cannot be fed into a pulp mill that is set up to use virgin wood fibre[75]. The previous IENICA report indicated that there are currently 31 mills throughout the world using flax/hemp; only 3 of these are in Western Europe.

Estimates suggest that, in 2000, the production of flax and hemp pulp in the EU was 25,000-30,000 tonnes (with a production capacity of 30,000-35,000 tonnes). To produce these quantities, about 37,000-45,000 tonnes of fibres are necessary[76].

The individual national reports from the IENICA partner countries show large tonnages and relative importance in this area. As mentioned, cereal straws can have applications here. 50,000 tonnes of wheat straw are used in Hungary to produce about 30,000 tonnes of cellulose, two thirds of which is used in paper production, and a proportion of the 50,000 tonnes of cereal straw in Belgium for industrial uses goes into paper production. The paper industry is the primary end-user for French hemp (95% of production) whilst the pulp industry will remain the most important user of flax and hemp in Germany. German figures show that, in 2000, 45% of EU flax short fibres, and 87% of hemp short fibres, went into pulp. A limited amount of reed canary grass grown in Sweden (less than 500ha) is used to produce paper.

The recently accessed states show little or no development in natural fibres for pulp and paper. Lithuania considers its flax is unlikely to be used for paper, but a project looking at a large cellulose production factory using wood is being discussed. The Institute for Natural Fibres in Poland conducts research in this area, and indicates that pulp and paper production are of the most promising potential applications for hemp, most specifically as a speciality paper. Some imported flax in the Czech Republic is used for paper manufacture.

Wood-based panels:
The wood-based panel industry is based on small roundwood and wood residues and produces particleboard, medium density fibreboard (MDF) and oriented strand board. The separated, non-fibre component of crops like flax and hemp can be used as a substitute in particle boards and several fibre plants offer opportunities for use in MDF. Cereal straws can also be used in this area. It was suggested in the last report that the wood-based panels industry probably offers the best opportunity for bulk usage of agricultural raw materials. Whilst this may be the case, there is little reported activity in this market from either the EU-15 countries or the newly accessed states. In Ireland, both miscanthus and hemp are used for processed board use and this is considered to be the main non-food crop option. It is estimated that, to replace even 10% of the approximate 2 million tonnes of wood used at present, 6,000 ha of hemp would be needed. However, it is stated that neither crop can compete with forest waste as a cheaper raw material source. In Italy, 20-50 ha of hemp are used to produce panels (in a mix with kenaf). No interest in this area, or developments, have been reported in the newly accessed states.

Fibre reinforced composites[77]:
Composite materials consist of a tough fibrous material such as glass fibre bound together with a resin. Although they offer many benefits in performance – they are light weight and strong – they

[75] **http://www.livingtreepaper.com**
[76] nova Institute, 2000
[77] Much of the information in this section has been sourced from the Annual Reports for the UK Government-Industry Forum on Non-Food Uses of Crops (**www.defra.gov.uk/gifnfc**)

only account for 0.2% of a market which remains dominated by metal, plastics and wood[78]. However, their use is growing rapidly. In 2002 alone, growth in North America and Western Europe was estimated at 20%[79].

About 90% of composites are based on glass fibre, combined with polyester or vinyl ester resins. However, the use of natural fibres such as hemp and flax[80] has been growing rapidly.

Short fibre flax has dominated the market since 1996, with an approximate 70% market share. It has been shown (see the last IENICA report) that natural fibres can in fact provide equal or better performance; can reduce product weight by about 15% and have very reactive surface chemistry.

The major market identified in the last report for the application of plant-derived fibres is to replace fibreglass in the automotive industry. This is still very much the case and the *"development and increasing interest in the field of renewable materials is accelerating the development work of natural fibre reinforced composites in the automotive supply industry"*[81]. Sisal and jute fibres have been used for years in the German automotive industry but their share among natural fibres is decreasing. Kenaf fibre from the US and Asia is relatively new in this industry, but its market share has increased considerably in recent years. The use of flax and hemp fibres are relatively new in this industry; the market share of hemp fibres used in this sector amounted to 15% in 2002 (a demand of 3,300 tonnes), compared with less than 1% in 1996.

In 2002 the UK's Government Industry Forum on Non-Food Uses of Crops reported that the use of natural fibres in the European automotive sector has grown from virtually zero in 1994 to in excess of 28,000 tonnes in 2000. The nova Institute[82] suggests a figure of 25,000 tonnes of natural fibres used in the European automotive industry in 2002. Of this total, 60% (17,000 tonnes) is accounted for by the German automotive industry, which has a 2/3 share of the total natural fibre use. The report suggested that the potential demand for natural fibres in the EU automotive sector is estimated to reach 100,000 tonnes by 2010, equating to a potential EU market in excess of 100 million Euros, excluding any export fibres[83]. The introduction of every new car model increases demand, depending on the model, by 500-3,000 tonnes/year[84]. If injection moulded components are included (see below) the market could be as large as 160,000 tonnes/year. However, the most recent German figures (from the IENICA update report for Germany) suggest that 80% of natural fibres are used in the automotive industry - approximately 50,000 tonnes in 2003, and potential figures vary, especially in the automotive industry, from 4 to 18 million tonnes/year. Other German figures[85] have shown that, in 1999, of the total use of natural fibres in the automotive industry in Europe, 75% were flax, 10% jute, 8% hemp, 5% kenaf and 2.5% sisal. In addition, the German automotive industry uses about 50,000-60,000 tonnes/year of recovered cotton and 50,000-70,000 tonnes/year of wood fibres, in addition to the

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[78] **www.researchandmarkets.com**
[79] Growth rate confirmed by Dr. J. Winandy, USDA Madison, at the 5th Global Wood and Natural Fibres Composites Symposium, Kassel, Germany, April 2004
[80] Other materials which can be used include jute, straw, wood fibre, kenaf, wheat, barley and cane (**www.researchandmarkets.com)**
[81] Philipp, K (2003) *State of the art, novel developments and trends in the fields of natural fibre reinforced composites in automotive interiors* Proceedings of the (IENICA sponsored) 4th International Symposium 'Materials from Renewable Resources', Erfurt, Germany, 11-12 September 2003
[82] **http://www.nova-institut.de**
[83] These figures are confirmed by Ceccarini, L; Angelini, L. G (2003) *Spartium junceum* L.: A New Crop for Natural Fibre for the Automotive Industry *International South Europe Symposium: Non-Food Crops: From Agriculture to Industry* An IENICA seminar, Bologna, Italy, May 2003
[84] nova Institute, 2000
[85] **http://www.nova-institut.de/**

natural fibres[86]. However, these materials are experiencing a downward trend, due to their inferior mechanical properties and their odour, which will benefit hemp and flax fibres.

Investigations in Italy are looking at the use of Spanish Broom (*Spartium junceum* L), grown in Mediterranean areas, as a possible source of fibre for the automotive industry.

Benefits provided by natural fibres in this sector include:

- Reduced weight – a reduction of 10-30%. This is a major environmental benefit as around 85% of the energy usage of a vehicle is in its use phase and weight is key.
- Favourable mechanical and acoustic properties.
- Less abrasive on injection moulding and compression moulding tools.
- Potential for one-step manufacturing, even of complex construction elements.
- Favourable accident performance (high stability, no splintering).
- They require less energy. A life cycle assessment (LCA) of natural fibre mats compared with glass fibre mats indicates that the former uses around 80% less energy.
- Natural fibres avoid certain health problems. Many physicians believe that glass dust generated when processing glass fibres causes allergies and irritations.
- Natural fibres are seen as 'green' or environmentally friendly as they are broadly CO_2 neutral and therefore consistent with a sustainable development strategy.

Processing technology in this sector is moving toward injection moulding. The majority of natural fibres are currently employed in compression moulded thermoset plastic materials used for vehicle interior parts such as door liners, parcel shelves and sound deadening materials. The increasing awareness of the potential for injection-moulded thermoplastic materials is considered key to the continuing development of natural fibres in the automotive industry; industry estimates suggest that in the future 80% of all plastics in cars will be this type. Although in the relatively early stages of development, this area represents a key market opportunity. It is likely to require increased focus on fibre quality and will probably require the creation of uniform fibre standards to ensure high and consistent quality. However, experience to date has not confirmed any definitive specifications for fibre feedstocks from industry (excluding textiles).

Applications for plant fibres in vehicles (as reported previously) include (see also Table 1):
- Door trim panels
- Rear parcel shelf
- Boot liners
- Various damping and insulation parts
- Centre console trim
- Seat cushion parts

Mercedes Benz have reported excellent properties through the replacement of wood fibre materials with a flax/sisal fibre mat embedded in an epoxy resin matrix in the door panels of the Mercedes Benz E-class. A 20% weight reduction was achieved; mechanical properties, important for passenger protection in the event of an accident, were improved, and the new material can be moulded into complex 3-dimensional shapes, making it more suitable for door trim panels than the previously used materials.

These improved properties have resulted in the rapid development of this sector, as mentioned, and now many major vehicle manufacturers use natural fibres in some of their lines (see Table 1).

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[86] nova Institute, 2000

The automobile manufacturers who are leading the development are all German (BMW, Audi and Daimler Chrysler) and represent the premium end of the sector.

Table 1 Use of natural fibres in automotive parts, 1999

Manufacturer	Model Application (dependent on model)
Audi	**A3, A4, A4 Avant, A6, A8, Roadster, Coupe**
	Seat back, side and back door panel, boot lining, hat rack, spare tire lining
BMW	**3, 5 and 7 Series and others**
	Door panels, headliner panel, boot lining, seat back
Daimler/Chrysler	**A-Series, C-Series, E-Series, S-Series**
	Door panels, windshield/dashboard, business table, pillar cover panel
Fiat	**Punto, Brava, Marea, Alfa Romeo 146, 156**
Ford	**Mondeo CD 162, Focus**
	Door panels, B-pillar, boot liner
Opel	**Astra, Vectra, Zafira**
	Headliner panel, door panels, pillar cover panel, instrument panel
Peugeot	**New model 406**
Renault	**Clio**
Rover	**Rover 2000 and others**
	Insulation, rear storage shelf/panel
Saab	Door panels
SEAT	Door panels, seat back
Volkswagen	**Golf A4, Passat Variant, Bora**
	Door panel, seat back, boot lid finish panel, boot liner
Volvo	**C70, V70**

Source: nova Institute, 2000

As reported previously by IENICA, the use of plant fibres per automobile (excluding lorries and buses) is:

- Front door liners: 1.2 - 1.8kg
- Rear door liners: 0.8 – 1.5kg
- Boot liners: 1.5 – 2.5kg
- Parcel shelves: <2kg

A further 5kg could be used in other parts of a vehicle interior.

It is expected that Western Europe will see a growth in automobile production of 1.5% per year, but much more significant growth is expected to be seen in Central-Eastern Europe, with an anticipated annual increase of 6.1%. With a current world automobile production of approximately 59 million motor vehicles per annum[87], of which 33% is Europe, then potential

[87] Verband der Automobilindustrie (**http://www.vda.de**)

markets for natural fibres are approximately 19.4 million vehicles and up to 250,000 tonnes of plant fibres per year.

The opportunities which natural fibres in the automotive industry offer for recycling were suggested in the previous report. However, the current EU drive towards recycling is often believed to be in conflict with the use of renewable materials, as the use of renewable materials does not contribute to recycling targets and this carries a financial cost. It is generally uneconomic to recycle renewable materials. The End of Life Vehicle Directive is central to this issue. It will require all vehicles to be recoverable (recycling plus burning with energy recovery) to a level of at least 85% by weight by 2006. A level of 95% recoverable by weight must be achieved by 2015. All or a significant part of the costs of this exercise has to be met by the automotive manufacturers. The automotive industry will therefore both reduce materials that are expensive to recycle and avoid materials that affect achievement of the 85% recycling target. However, it is considered by some[88] that *'Contrary to initial concerns, the ELV Directive will presumably have no negative effect on the use of natural fibres in automobiles. For example, the German implementation of this Directive appears to be neutral relative to the use of natural fibres, regardless of whether the parts are subsequently incinerated or recycled.'*

The Directive does not mention renewable materials although Article 7.2 suggests that the EU is concerned with not obstructing the development of more environmentally sustainable materials.

Similarly, the ELV Directive is also potentially in conflict with the promotion of compostable bioplastics.

Reports from the newly accessed states show that this is not yet an industrial market for their natural fibres, which are almost solely utilised in textile applications.

The environmental benefits of natural fibre composites would also be enhanced considerably if biodegradable resins were to be used. Bioresins such as tannin and lignin derived from plants as well as glues and adhesives derived from animals have been known and used for many years, though only recently have resins derived from plant oils been formulated for industrial use.

In the UK, naturally hydrophobic (water-resistant) plant oils have been used as starting materials for a range of resin products currently under study at The BioComposites Centre[89]. Vegetable oils such as Rape (Canola) Soya, Sunflower, and Cashew Nut Shell Liquid (CNSL) can be transformed to resin precursors that will polymerise when heated in the presence of acidic or basic catalysts. Typically, these resins can be used as formaldehyde-free alternatives to replace urea/phenol/ melamine formaldehydes in various applications.

In the UK, a company working with The BioComposites Centre has won an award to develop an eco-friendly resin derived from oilseed rape, which could be an alternative to the formaldehyde-based resins used in huge amounts in the building and furniture industries[90]. It is reported that the bioresin is *'as strong as high-performance chemical resins but with several ecological advantages: it creates no toxic emissions; the raw material is sustainable and renewable; it is cost effective and the raw materials are widely-grown; its products are recyclable and it is naturally water-resistant'*. This company suggests that *'we are already seeing a movement away from resins made with harmful chemicals, particularly in North America'*. Currently 145,000

[88] Karus, M (2002) *European Hemp Industry 2002: Cultivation, Processing and Product Lines*
[89] **www.bc.bangor.ac.uk**
[90] **www.cambridge-biopolymers.com**

tonnes of formaldehyde-based phenolic resins are used per year in Western Europe, with a similar amount used in the USA.

Fibre/Cement composites:
Wood fibre-reinforced cement products are widely available and combine high tensile strength, impact resistance and workability of wood with the fire resistance, durability and dimensional stability of cement-based materials. The result is a range of products offering a unique balance of performance characteristics and aesthetic qualities at competitive cost.

Research is continuing worldwide on the incorporation of alternative fibres and the use of new processes (e.g. extrusion) to manufacture such cement-based composites.

In France, Isochanvre® has been developed as a thermal and acoustic insulation material. Manufactured from hemp shiv, this product can either be used loose – poured or blown into place, or used with natural and pure limes to form a conglomerate.

Packaging materials:
As reported in the original IENICA summary, the introduction of new regulations regarding the disposal of packaging waste materials, as well as consumer pressures, are beginning to create new opportunities for the introduction of natural fibres. Low-grade moulded (short fibre) pulp products have the potential to displace expanded polystyrene for example in some applications (over 100,000 tonnes/year of expanded polystyrene is currently used for packaging in EU-15).

The opportunities for natural fibre tying material to replace polypropylene in the market of agricultural and industrial twines may be stimulated by the increasing need for biodegradable materials, although the price advantage of polypropylene is a major factor in its increasing use in this area.

Filters and absorbents:
Their surface chemistry and large surface area should make fibres ideal as filters. Unmodified plant fibres absorb heavy metal ions and chemical modification techniques and can potentially be used to enhance both heavy metal and oil absorption properties. Applications could include the clean up of polluted drinking water, industrial run-off water and various other waste waters. Opportunities also exist for use of plant fibre filters in capturing volatile emissions from industrial processes. A demonstration project in the UK is looking at hemp and flax spool wound cartridge filters. Research in the US has looked at juniper fibre and sphagnum moss for the removal of suspended solids and for biological filtration.

In addition to synthetic fibres, cellulose, cotton and wool are primarily used in this sector.

Hemp and flax shiv have good moisture absorbent qualities and commercial markets have been developed for animal bedding, mainly horses, and pet litter (see later).

The use of all parts of the plant is crucial to achieving economic success. Using the hurds and shive for absorbent materials, as a by-product from short and long fibre production, can help achieve this.

Insulation products:
An area of some growth since the last report, natural fibres for the production of insulation materials,is of interest in most EU-15 countries and commercial developments have occurred in a number, including Belgium and Germany for example. In many countries, this market is growing

faster than the total market for insulation materials[91]. In 2002, just under 5% of EU hemp fibres were used in this application[92]. By 2005, sales of flax and hemp fibres to the European insulation market are estimated to increase from 1,400 tonnes in 2000 to almost 25,000 tonnes[93]. This development assumes that processing costs can be lowered and comprehensive marketing schemes will be implemented. Plant fibre offers potential to replace glass fibre and rock wool as an insulation material and most major developments have been with flax fibre (CHECK??). The requirement is to develop efficient, integrated growing and processing operations to produce products competitive with jute produced in India or Bangladesh. Flax fibre processors in particular have high hopes in the thermal insulation market.

This market depends on the general situation of the construction industry, which now shows inconsistent trends among EU countries.

Little interest or activity has been recorded in the newly accessed states, although the only flax factory in Estonia produces around 95,000 m^3 of linen felt from 140,000 tonnes of imported short fibre, which is exported as an insulation material to Finland and Norway. In Lithuania, some of the by-products of flax production for textiles are processed into an insulation mat, and interest has been shown in miscanthus for this use in the future. Work has been carried out in Switzerland into grass 'blow-in' insulation.

German figures show that insulation from renewable materials is currently around 4% of the total size of the industry (29 million m^3/year) (the previous report stated a medium term projection for 10% of market share), and since the last summary report a market introduction programme has been introduced (in 2003), causing noticeable sales increases. Alternative insulation materials currently used in Germany account for an approximate 3% market share (1998): Cellulose (53%); wood fibre board (27%); Flax and Hemp (7%); Sheep's wood (5%); Cotton (3%); Cork (3%); Wood shavings (1%) and others (1%)[94]. A 10% market share is considered to be realistic, for both Germany and the EU.

The INFO*RRM* project carried out a case study on flax as an insulation in building materials[95].

Polymers and plastics:
It was reported in the previous IENICA summary that, in France, steam cracking systems to extract lignin from fibre sorghum have been developed as part of a plant fractionalisation system. After solubilisation (NMMO solvent) and regeneration, films, fibres or foams can be obtained from polymer cellulose.

Others:
Other end-uses for natural fibres include agro- and geotextiles (10% and 2% respectively[96]). It is expected that domestic flax and hemp fibres can only occupy small niche markets and some speciality applications in these areas, largely due to rapid biodegradation and relatively high price. Coir fibres are better suited as they have a longer term stability when exposed to water and soil and prices are lower. Other fibres used in this sector are nonwovens from jute, also less expensive than flax and hemp. An area of application for flax and hemp nonwovens was introduced in Germany in 2000: the production of substrates for plant growth e.g. for the

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[91] nova Institute, 2000
[92] Karus, M (2002)
[93] nova Institute, 2000
[94] nova Institute, 2000
[95] **http://inforrm.csl.gov.uk/CS1.asp**
[96] Karus, M (2002)

sprouting of seeds of lettuce and herbs. The main benefit is the full biodegradability of the product.

During fibre separation, significant amounts of the woody core of both flax and hemp are generated. These hurds have uses as animal bedding and in the construction sector. In 2002, the total EU production of hemp hurds was approximately 40,000 tonnes[97]. Approximately 75% of hemp hurds are used as animal bedding, the vast majority which is used as horse bedding, as well as for other animals and for poultry farming. The hurds have favourable properties for animal bedding: good absorbency, low dust/low allergenicity characteristics, easy handling and rapid composting after use.

In the construction sector the hurds are used as pour-in insulation, hurd board or as additive to bricks or loam construction. This market offers much undeveloped potential and in recent years has taken some of the market share of hemp hurds from animal bedding. In contrast, flax is used to a greater extent in the construction industry than for animal bedding (due to the different suitability of the hurds and shives).

Barriers to Progress

Barriers as identified in the original IENICA report are outlined below (boxes A to R); whilst some improvements have been made these issues still exist and continue to hamper the development of the industry. Additional constraints and issues raised by the newly accessed states are also reported.

Crop Production

A

Little plant breeding in the major fibre crops (flax, hemp, miscanthus and reed canary grass) specifically targeted at meeting the changing fibre market requirements and improving crop performance and agronomy, is taking place. Current EU approved hemp varieties are restricted to French sources, limiting the potential for crop improvement. While significant progress has been made, further information is required on the interaction of crop management, weather and harvesting processes to produce fibre of optimised and consistent quality.

An improved understanding of physiology as it relates to harvest date and fibre quality is desirable. European varieties of hemp can be seen at: **http://www.gnis.fr/english/frame3_0.htm**

B

Hemp drug policing is a serious limiting factor. The identification of cultivars with zero THC, and visual or simple field diagnosis tests for these types are urgently required.

Whilst this is still a major factor within the newly accessed states (hemp cultivation is prohibited in Lithuania, for example), hemp has achieved greater acceptance in Western Europe in the last few years.

C

[97] Karus, M (2002)

The pulp market is large-scale operation based on wood. It is well organized and quite conservative. It is difficult to see a method for introducing significant quantities of raw material from new sources, into the pulp production system. Efficient small-scale systems need to be piloted to encourage greater use of non-wood materials.

The environmental impact of some 'pulp' species (e.g. Eucalypts) may be adverse and require more investigation.

D

A number of alternative crops have been identified particularly for southern Europe, while some progress has been made, further production, processing and market development is required for large scale commercialisation.

Often the issue is one of disparate production and lack of vertical coordination and integration.

E

A range of harvesting processes are being developed for each crop but harvesting cost and efficacy is still a limiting factor to economic production of high quality fibre. Primary processing systems still depend largely on old high-energy input technology; new environmentally sensitive and cost effective solutions are a limiting factor. Fibre cleanliness is a major limiting factor for higher value uses.

This is still relevant.

Additional constraints identified since the previous report:

- Some activities into new stinging nettle varieties for fibre production have taken place in Austria, Italy and the UK, for apparel. A promising EU-project in Austria has now ended however, as it failed to find new commercial sponsors.
- Fibre sorghum has been investigated in a number of countries (Belgium, France, Italy and Spain) and produced commercially in Greece. However, the French programme is no longer ongoing due to a lack of competitiveness compared with wood material and the production in Greece has reduced by 90% since the 1970's, replaced by heavily subsidised competitors. The impact of CAP reforms may redress the situation.

Constraints identified by the **newly accessed states**:

- Whilst the interest in the cultivation of non-food crops is increasing, in some of the newly accessed states there is limited experience of non-food industrial applications and significant improvement can be expected with the investment and know-how coming from the most advanced EU countries.
- Growing technology (e.g. varieties, fertilisation) is not always available for farmers in the newly accessed states (Lithuania)
- Cotton yields can fluctuate widely if grown on non-irrigated lands (Bulgaria).
- Breeding of cotton cultivars with higher quality lint is essential (Israel).
- Flax is very sensitive to droughts and in Hungary this has resulted in all production having ceased.
- The resistance of flax to extreme weather conditions and some diseases, resulting in a higher yield and quality stability, must be increased: flax must become more resilient and reliable to succeed commercially.

- Competition from the cheaper production of cellulose from wood can limit the use of bast fibres.
- Initial investments in growing and processing technologies for bast fibres often cannot be made because of cost (Estonia). This can be a particular problem for hemp, in Estonia for example, where the legal basis for growing hemp is in place but the investments for growing it (especially the supervision required for the entire vegetative period) nullify the economic profit gained.
- Low cold resistance of Miscanthus can cause the performance of this crop to be unstable.
- The newly accessed states generally have highly qualified human resources for applied research, but the material base of the research institutes is in many cases (morally and physically) old-fashioned (Romania). In Poland the machinery for production and processing of these materials is outdated (high energy consumption, high level of noise emission, old processing technologies) and there is a lack of funds for its modernisation (high price for modern equipment).
- In many of the newly accessed states farmers own relatively small farms and consequently have low financial resources with which to buy high quality seed and to introduce new approaches and technologies in this field (Romania).
- Significant fractionation and dispersion of fibre plant plantations (Poland).
- High price for certified sowing material (Poland).

Industrial Use

F
Considerable progress has been made in the development of new products and markets, particularly fibre reinforced composites in Germany. Continued development will be necessary to compete with synthetic materials and focus on the biodegradable benefits of these materials. In many cases a greater understanding at the macromolecular level will aid process optimisation. Developments should be whole-chain to ensure the availability of optimum quality fibres and concentrate on added value products.

This is still relevant.

Additional constraints identified since the previous report:

- Insufficient or out-dated/old-fashioned harvesting and processing technologies is a major limiting factor in many countries, including some Western European countries (e.g. Austria). This can be a significant problem in some of the newly accessed states (e.g. Hungary) where the existing processing capacity is unable to fulfil the needs of improved production volumes and new fibre products (e.g. hemp for insulation, which would require special processing machinery). In addition, processing technology must be able to fully utilise the by-products of fibre production. Out-dated technology can result in high production costs and low long fibre output. Large investments are required in many of the newly accessed states to upgrade this sector to the acceptable EU standard. It is necessary to reorganise, modernise and rebuild these production capacities.
- Lack of research (in Austria, only industry-sponsored research of a few enterprises with German institutions).
- Industry wishes to keep a maximum of flexibility and prefers to rely on the international markets for finding the raw materials at the best commercial or technical conditions. Industry is reluctant to address domestic agriculture in order to contract production volumes of a specified quality at a determined price (Belgium).
- The capacity of agriculture to invest in industry seems too weak (Belgium).

Constraints identified by the **newly accessed states**:

- There is often a lack of interest regarding the use of the fibre crops and by-products obtained in the fibre separating process in other fields, besides the textile industry. It is necessary to co-ordinate the research in the agricultural sector (crops breeding, the culture technology) with those in the chemical field (extraction technology and the technology for reutilisation).

Economic

> **G**
> *Price is a major barrier to development. Competition is with fossil fuel derived synthetic materials and tropical fibres.*
>
> The newly accessed states also face competition from subsidised fibres from the EU. Economic cost is often used as the benchmark although true cost would be more appropriate. Correction of approaches requires a coordinated strategy in EU policy making.

> **H**
> *Concern has been expressed as a result of the recent proposals on flax and hemp aid by DG-Agriculture; these seem to conflict strongly with the increasing development of new industrial markets. They could result in a significant reduction in the availability of European produced fibre. Investment by industry in new product facilities will only take place if supply of raw materials is assured.*
>
> Instability caused by such proposal is hampering progress, though post-CAP reform should be lessened.

Additional constraints identified since the previous report:

- The area under cotton is dependent on international costs and the price proportion in relation to other agricultural crops. In Bulgaria, the total area under cotton has decreased in the last 6 years due to low farm-gate prices and highly competitive imports of long-fibre cotton; in Israel, the constant drop of prices in the international markets has lead to a 60% reduction in the area of cotton.
- The main problem of the Hungarian fibre crop production is the lack of market information. No clearinghouse exists with up to date information on cultivation technologies, subsidies, buyer requirements and market prices. In addition, the export of the products is not organised.
- A scarcity of legislative and economic measures directed to the development of non-food crops is a major barrier (Lithuania).
- Out of date technologies in the newly accessed states can result in high production costs, and large investments are needed to upgrade this sector to the EU standard level (Lithuania). In addition, the industry processing natural fibres is highly capital consuming and there is often a lack of funds to purchase machinery for processing wastes resulting from fibre plant processing (Poland).
- Average quality of domestic fibre results in low profitability (Poland).

Environmental

> **I**
> *Much of the benefits of products derived from plant fibres are built on biodegradability. These benefits must be seen to be maintained in all new products.*

This remains the case and is actually much more significant now. The last few years have seen an ever-increasing focus on the environment and sustainability at a world-wide, international and national level and industrial materials based on renewable raw materials are likely to have a much larger role in meeting objectives and targets. True value assessments are needed.

J
The environmental benefits of products derived from plant fibres are poorly communicated to the general public. Education coupled with EU wide schemes to label environmentally friendly products (as already exist in some countries) would enhance consumer demand.

This is still relevant.

K
Most fibre crops (though not cotton) require low inputs of chemicals and fertilisers and are therefore environmentally desirable; low input systems should be encouraged and suitable labelling introduced.

Cotton is not environmentally friendly because of the high level of pesticides utilization and high water demand; suitable varieties need to be introduced to improve this. Further development of biological control of pests and diseases is required. Changes to agro-technology and better cultivation practices (e.g. precision agriculture) are required. This should include underground trickle systems for efficient and conservative fertigation and special devices for application of pesticides to confined areas or locations.

Additional constraints identified since the previous report:

- Traditional biological (anaerobic retting in water) and mechanical methods of fibre extraction from flax and hemp can be air polluting (dust, fibre particles) and water polluting (nitrates, anaerobic microbial flora).

Legislative

L
To enhance the development of crop derived plant fibres and to meet International Agreements on Climate Change and Biodiversity an overarching and integrated EU legislative framework should be established. This would be particularly aimed at extending the legislation with regard to identifying sustainable and biodegradable products and taxation of non-biodegradable packaging and should interlink objectives.

This is still relevant.

Additional constraints identified since the previous report:

- In many countries a special framework or market structure of any description to encourage the production or utilisation of fibre crops is absent. In the Czech Republic the flax area decreased because no funding was provided to growers and production costs were high and market prices for the fibre were low. Government grants have since been introduced and, together with a rapid progress in alternative uses of the fibre, have resulted in an increasing flax area. A market introduction programme has been introduced in Germany to encourage the use of insulation materials from natural fibres.

- There is also a notable lack of suitable financing incentives for the construction of modern processing facilities and so in areas which would otherwise be ideal for fibre production (i.e. South Hungary) the cultivation is small scale or non existent.
- Restrictions in hemp cultivation due to the content of THC can limit production (Lithuania, Romania). The law ought to establish clearly the way in which the hemp cultures are monitored as well as the producers' responsibility for their usage (stems production for fibres and seed production).

EU Actions

M
The proposed changes in CAP policy regarding fibre crops appear to be a significant barrier to progress. The impact of Agenda 2000 and CAP reform should be reviewed, particularly aspects impacting on the support for hemp and flax production and to ensure newer fibre crops remain viable where they are shown to have benefits over petrochemical-fibre derived.

This is still relevant.

N
Maximum hemp fibre yield requires the adoption of a very late flowering variety, currently this does not comply with EC regulations on seed formation, prior to harvest. This restriction is impeding progress and limited quality of fibre. EC policy with regard to approval of new cultivars is a barrier to progress and should be reviewed.

This is still relevant.

O
It is desirable that a long term integrated strategy involving research and investment by industry in EU could be produced, thereby providing a definitive long-term status for industrial crops.

This is still relevant.

P
There is continuing need for EU support of research and development, particularly to help overcome scientific/technical barriers. A greater proportion of this support should be directed towards pilot projects to bridge the gap between scientific small-scale developments and full commercialisation.

This is still relevant.

Additional constraints identified since the previous report:

- The French report notes that, since 1997, the EU has reduced hemp subsidies and the competitiveness of this crop has been threatened for a while, which explains the decrease of the French hemp acreage. In 2003, however, an equilibrium is being reached.

Communication

Q
Communications between the main participants in the fibre industry, farmers, seed vendors, storage operators, research bodies, primary and secondary processors and industrial users need are minimal and generally unsatisfactory. Only by multi-path communication, will the confidence and requirements of all parties be defined and understood.

This is still relevant.

R
Communication of the new fibre products and their environmental benefits to industrial and domestic users will over come the lack of knowledge and enhance awareness and product demand. Policy makers need to be aware of these issues too.

This is still relevant.

IENICA

~ CARBOHYDRATE CROPS ~

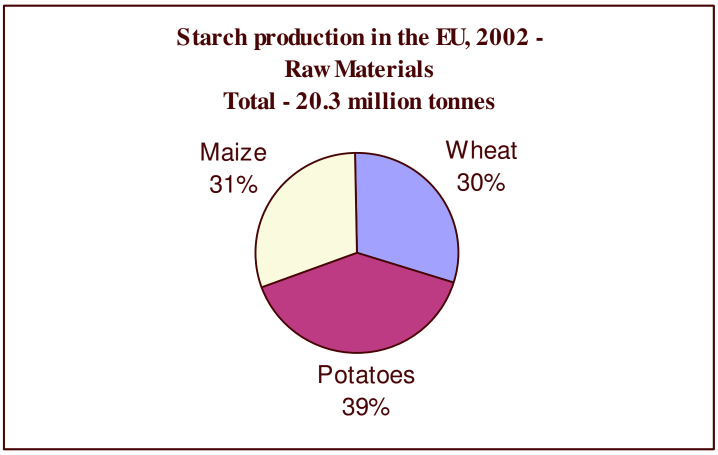
Introduction[98]

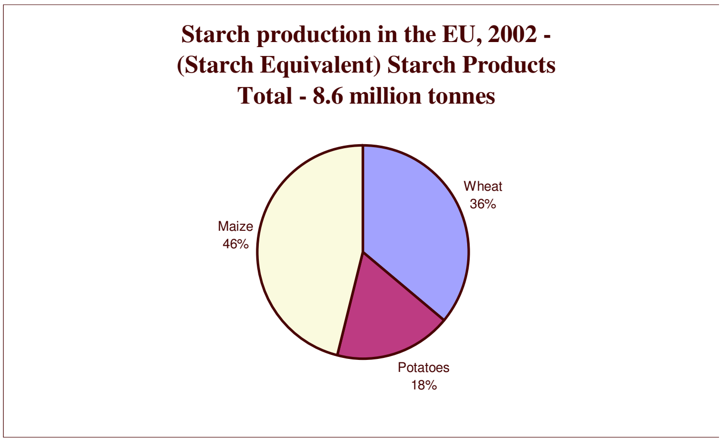
Starch is formed in plants through the process of photosynthesis. The plant initially assimilates the carbon from the atmosphere and transforms it into the basic molecule, glucose. This is then used for the synthesis of the starch polymers. In plants, starch appears as small granules, insoluble in cold water. Their sizes (3-100 microns) and form vary according to their origin. The basic chemical formula of the starch molecule is $(C_6H_{10}O_5)_n$.

Starch is typically biomodal in molecular nature; this refers to the major molecular components: the high molecular weight branched amylopectin and the more linear amylose. The ratio of these two components varies depending upon the source of the starch and everything from 100% amylopectin to 100% amylose has been recorded as occurring in nature or as a result of classical plant breeding (especially with maize where the full range has been reported). Amylose typically occurs at levels between 20-30%, but higher levels have been reported in barley and pea and high amylopectin sources have been reported in barley, wheat, pea and rice, as well as maize.

Virtually all plants contain carbohydrate in one form or another, but it is primarily those which store carbohydrate which can later be extracted that are of interest here. In Europe, as is the case worldwide, starch is derived mainly from cereals, but is also obtained in significant quantities from tubers. Worldwide, the main sources of starch are maize, wheat, potatoes and cassava (from which tapioca starch is derived). Whilst exhaustive research has been carried out on the agronomic and phenotypic properties of tropical starch crops (e.g. cassava, arrowroot, sago, taro, sweet potato and yam) they have not benefited from the kind of value-added research required for competition on an international scale. As a result, maize, wheat and potatoes continue to dominate world markets for starches in food and non-food industries. The primary starch crops in the EU and the newly accessed states are maize, wheat and starch potatoes, plus sugar beet. The EU is unusual in that its starch industry is more widely diversified in its raw material sources than other starch industries elsewhere and the different raw materials each supply a large share of total starch output, as shown in Figure 1. The US starch production is almost entirely dependent on maize, with only 1% production from wheat.

Figure 1





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[98] Key references for this chapter are:

- European Commission: The Evaluation of the Community Policy for Starch and Starch Products. Final Report 2002 **http://europa.eu.int/comm/agriculture/eval/reports/amidon/index_en.htm**
- Association des Amidonneries de Céréales de l'Union Européenne (Association of Cereals Starch Industries of the European Union - AAC) **http://www.aac-eu.org**

Unless otherwise stated, EU is EU-15

Source: AAC

Potatoes contain the lowest recoverable starch content of about 17% of dry matter; maize has the highest, at 62.5% and wheat has approximately 50%.

Starch processing

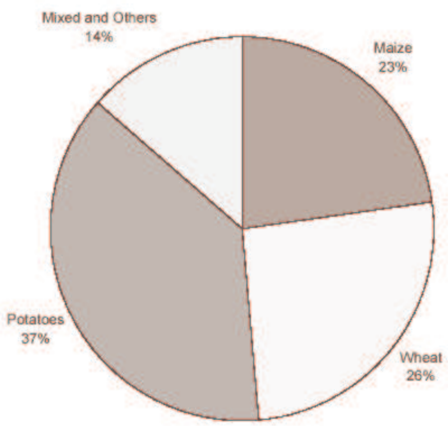
Starch processing initially involves physically separating the components of the plant (starch, protein, cellulose, soluble fractions) through a series of simple stages (crushing, sifting, centrifuging). The methods are specific to each plant and the industrial tools are normally dedicated to one particular raw material; Table 1 shows the number of factories producing native starches in the EC in 2001 and Figure 2 shows the high proportion (86%) which are dedicated to one particular raw material. Germany and France have the largest number of starch factories, with 16 and 9 respectively. In all, in 2001 there were 66 individual starch production factories within 13 of the EU-15 countries; only Ireland and Luxembourg have no industrial starch factories. The total number of factories has declined since 1992, but the average capacity of the surviving factories has increased for all raw materials. It is estimated that an average European starch factory consumes 1,000-2,000 tonnes of cereals/day. Whilst no data is available on the number of starch factories in the newly accessed states, the majority of the individual national reports submitted for IENICA report starch production activities.

Table 1 Number of Factories Producing Native Starches in the EC, 2001

	Maize	Maize and Wheat	Potatoes	Wheat, Oats and Barley	Rice	Total
Austria	1	-	1	-	-	**2**
Belgium	-	-	-	1	1	**2**
Denmark	-	-	4	-	-	**4**
Finland	-	-	3	3	-	**6**
France	2	2	3	2	-	**9**
Germany	2	-	8	6	-	**16**
Greece	1	-	-	-	-	**1**
Italy	2	-	-	2	-	**4**
Netherlands	1	2	2	1	-	**6**
Portugal	1	-	-	-	-	**1**
Spain	3	-	-	-	-	**3**
Sweden	-	-	4	3	-	**7**
UK	2	-	-	3	-	**5**
Total	15	**4**	**25**	**21**	**1**	**66**

Source: European Commission Starch Report

Figure 2 Distribution of Factory Numbers by Raw Material, 2001



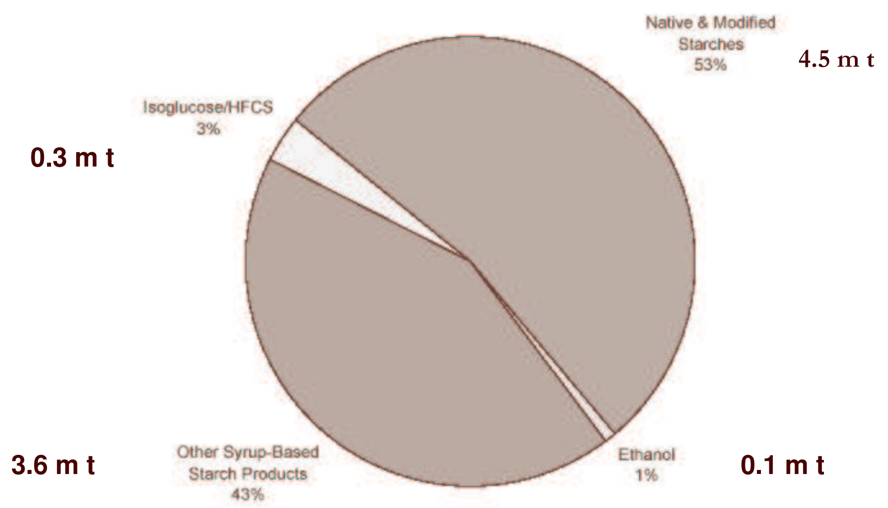
Source: European Commission Starch Report

The starch which has been extracted in its purest form will then either be used as it is after drying ('native starch') or will be further processed, undergoing various transformations aimed either at modifying its performance ('modified starch') or to obtain glucose syrups.

The first modified starch – dextrin – dates from the 19th Century. Other modified starches were then developed, often in partnership with customer industries which sought to have starches compatible with their industrial processes.

These modified starches in turn can then create multiple finished products. Various elements of the starch molecule may be substituted with a range of other chemicals to produce chemically modified starches, generally classified as starch esters and ethers. These are used widely in both food and non-food applications (e.g. cationic starch in the paper industry). Figure 3 shows the composition of EU-15 starch production in 2000 and the relative tonnages of starch produced.

Figure 3 Composition of EU-15 Starch Production, 2000 (Total – 8.4 m tonnes)



Source: European Commission Starch Report (HFCS: High Fructose Corn Syrup)

Starch manufacture has been the subject of extensive research. The creation of new products and applications is a constant challenge, in order to address customers' needs, whilst fully considering the environment. The original IENICA summary report reported many of the scientific and technological developments in this sector.

In this way, starch can be processed into many hundreds of different products, which are used as ingredients and functional supplements in food, non-food and feed applications. It also generates co-products which are sold into animal feed (e.g. wheat proteins, corn gluten feed) and food (e.g. wheat gluten).

EU and World Starch Production and Demand

In total, the world starch market in 2000 was estimated to be 48.5 million tonnes[99], The value of the output of this industry is worth approximately 15 billion euros/year. Estimates[100] suggest an

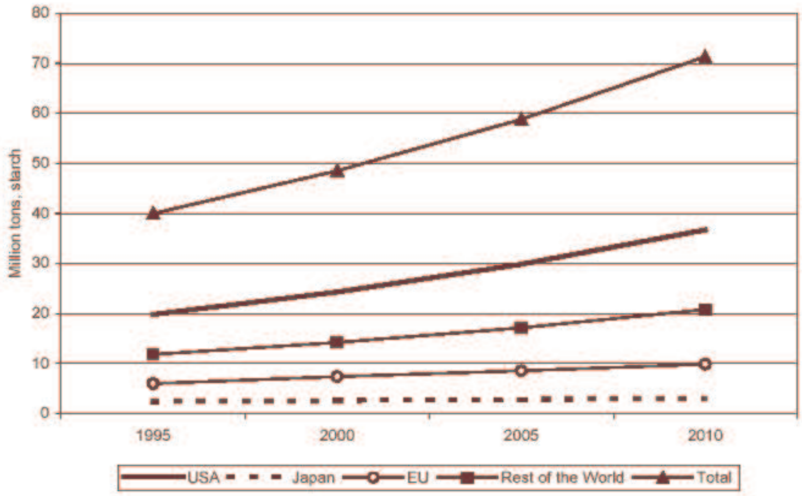
[99] Including native and modified starches, the large volume of starch converted into syrups for direct use as glucose and isoglucose, and as substrates in the form of very high dextrose syrups (starch hydrolysates) for fermentation into organic chemicals, including ethanol.

[100] European Commission Starch Report

annual worldwide growth rate of approximately 4.3% per year between 1995 and 2000 and it is expected that this will continue during the next decade (see Figure 4). If this is the case, the current world starch market (2004) will be approximately 57 million tonnes and could rise to over 71 million tonnes by 2010.

Within the global industry, the US has the largest starch industry, with 51% of world production (around 29 million tonnes); the industry in EU-15 is second in size, with over 17% of world output and an annual value close to 3 billion euros (around 10 million tonnes). Based on the estimated growth rate, the EU-15 market could be around 12 million tonnes by 2010. The EU has 3.6 times the worldwide average per capita demand for dry starch products, 1.8 times the average for syrups and 2.4 times the average for starch products as a whole. There is no data on the size of the starch market in the newly accessed states.

Figure 4 Forecasts of World Starch Demand



Source: European Commission Starch Report

Based upon a current figure of approximately 47% of starch used for non-food uses, and EU-15 market of 10 million tonnes in 2004 and 12 million tonnes in 2010 translates to 4.7 million tonnes and 5.5 million tonnes of starch being produced for non-food uses in 2005 and 2010 respectively.

Throughout the world, including the EU, maize is the main raw material, supplying over 80% of the global starch market. The EU relies on maize for less than half of its starch production whilst the US is almost entirely dependent on maize. Table 2 demonstrates this, showing starch output by raw material in the EU, US and other countries in 2000.

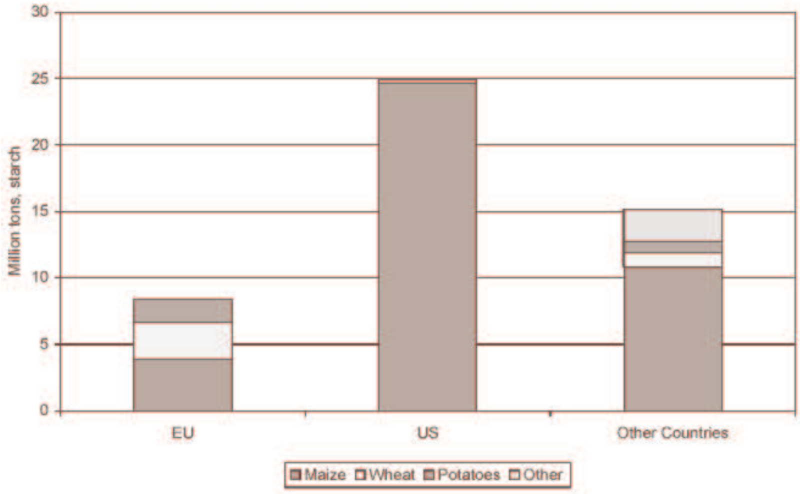
Table 2 Starch Production by Raw Material in EU(15), the US and Other Countries, 2000 (million tonnes, starch content)

	Maize	Potatoes	Wheat	Other	Total
EU	3.9	1.8	2.8	0.0	8.4
US	24.6	0.0	0.3	0.0	24.9
Other Countries	10.9	0.8	1.1	2.5	15.2
World	39.4	2.6	4.1	2.5	48.5

Source: European Commission Starch Report

Over 8% of world starch production is derived from wheat and the EU produces over 2/3 of the total global output of this production. More than 5% of global starch production is obtained from potatoes and the EU produces over 66% of that. Other raw materials (notably cassava) contribute just over 5% of world starch output.

Figure 5 Composition of World Starch Production, 2000



Source: European Commission Starch Report

The starch sector's demand for cereals is modest compared with total European production, which was in excess of 110 million tonnes of wheat and 50 million tonnes of maize in 2003. The sector consumed approximately 5.5 million tonnes of wheat in 2000 and 2001 (5-6% of wheat output) and 6.25 million tonnes of maize in 2000 and 2001 (16-17% of maize production). In addition, the starch industry uses more than 8 million tonnes of starch potatoes.

The consumption of starch and starch derivatives of the EU-15 market was 7.9 million tonnes in 2002. This is from a total quantity of raw materials processed of 20.5 million tonnes, and a total quantity of starch produced of 8.6 million tonnes.

Table 3 EU Starch Production Capacity by Raw Material, 1992-2001 (m tonnes, starch)

	Maize	Wheat	Potatoes	Total
1992	3.6	1.4	1.5	**6.5**
1993	3.6	1.4	1.7	**6.6**
1994	3.6	1.4	1.7	**6.7**
1995	3.8	1.8	1.8	**7.4**
1996	3.8	2.0	1.9	**7.7**
1997	3.9	2.1	1.9	**8.0**
1998	3.9	2.5	1.9	**8.4**
1999	3.8	2.7	1.9	**8.4**
2000	4.0	2.9	1.9	**8.8**
2001	4.0	3.0	1.9	**8.9**

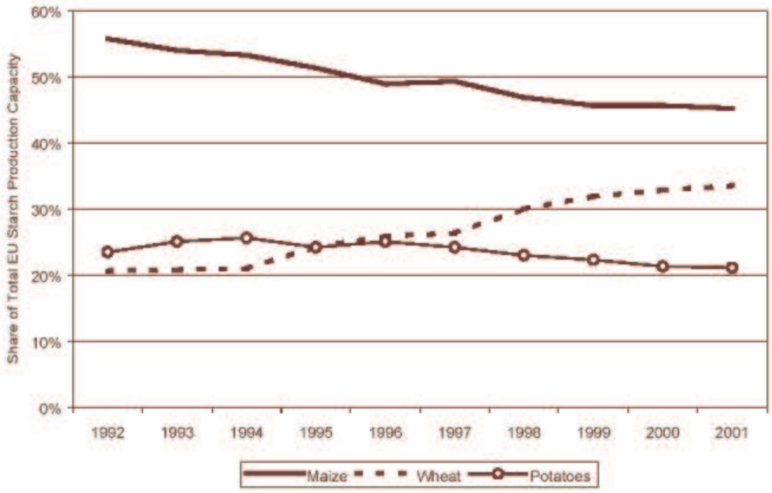
Notes: The wheat figure includes other cereals, such as oats, barley and rice.
The figures refer to the current Community of 15 member states throughout the period.

Source: European Commission Starch Report

Table 3 shows EU starch production capacity until 2001. An estimated 8.3 million tonnes of starch potatoes were processed into approximately 1.9 million tonnes of starch in the EU in 2000; 6.2 million tonnes of maize into 4 million tonnes of starch and 5.5 million tonnes of wheat into 3.0 million tonnes of starch, giving a total starch production of 8.9 million tonnes of starch from 20 million tonnes of crops.

Figure 6 shows the trends in the percentage distribution of starch production capacity by raw material[101]. It shows the decline in maize share which dropped below 50% in 1995; the initial rise in the potato share until the imposition of production quotas, followed by a subsequent decline and the growth in wheat share of the total.

Figure 6 Distribution of EU(15) Starch Production Capacity by Raw Material, 1992-2001



Source: European Commission Starch Report

Import tariffs on native starch, glucose products and modified starches are generally high enough to form an effective barrier to the importation of these products in direct competition with local supplies. The only significant imports of native starches are those made from raw materials, notably cassava, that are not available within Europe and have functional properties that are valued in certain specialist applications. The volume of direct imports of starch products into Europe is therefore relatively small (in comparison with exports); 15,000 tonnes of imports in 2000 of native cassava and other minor starches and nearly 37,000 tonnes of glucose syrups.

Annex E gives information on foreign trade in starch products.

European Starch Regulations

The EU starch sector is administered within the Common Market Organisation (CMO) for cereals. This includes the potato starch sector. The manufacture of starch products currently processes over 5% of the EU's output of common wheat and 16% of its maize production; the CMO for cereals is therefore an important measure to ensure a major outlet for cereals, by allowing the starch industry to purchase its raw materials on terms that are fully consistent with the overall CMO objectives, without jeopardising the ability of EU starch producers and their industrial customers to compete with third country suppliers of starch products. Policy measures towards this are intervention prices, export refunds, production refunds and the import tariffs described above. However, these are likely to change with CAP and WTO reforms and agreements.

In addition to the CMO for cereals, the potato starch sector has been organised by a number of policy measures:

1) Guaranteed minimum prices to the starch potato farmers.

[101] The wheat figure also include minor raw materials – oat, barley and rice.

2) Direct payment to the farmer – a fixed payment per tonne.
3) Special premium to starch processors, in order to compensate potato starch producers for structural disadvantages such as the short processing season for starch potatoes and for the low value of the by-products from potatoes when compared with cereals.
4) Potato starch production quotas for individual Member States – since 1995/1996 – based on assessments of installed capacities and irrevocable commitments made to install new capacities since that time. The Governments of the Member States allocate the quotas to local potato starch factories and these factories control their starch output through annual contracts with individual farmers.

Potato starch production quotas are shown in Table 4. They do *not* apply in other EU-25 states who have no production.

Table 4 EU Potato Starch Quotas (tonnes)

	2004/05	2001/02-2003/04	2000/01	1998/99-1999/00
Denmark	168 215	168 215	173 439	178 460
Germany	656 298	656 298	676 680	696 271
Spain	1 943	1 943	1 972	2 000
France	265 354	265 354	273 595	281 516
Netherlands	507 403	507 403	523 161	538 307
Austria	47 691	47 691	48 409	49 100
Finland	53 178	53 178	53 980	54750
Sweden	62 066	62 066	63 001	63 900
Total EU-15	**1 762 148**	**1 762 148**	**1 814 304**	**1 864 304**
Poland	144 985			
Czech Republic	33 660			
Latvia	5 778			
Lithuania	1 211			
Slovakia	729			
Estonia	250			
Total EU-25	**1 948 732**			

Notes: Quotas for 2004/05 set by Regulation 962/2002 for the EU-15 and the Treaty of Accession for the new Member States.

Source: Agra Europe, CAP Monitor, 2004

The CAP reform measures will impact upon the starch potato sector, in that "40% of the existing aid payable to producers of starch potatoes will be integrated into the single income payment scheme, with the remainder payable as a coupled aid. In addition the existing minimum price arrangements will be maintained, along with the starch production refund"[102].

By-Products

As shown by the previous IENICA report, all starch/sugar extraction processes produce by-products which are currently sold to the animal feed industry. By-products from starch processing of cereals include for wheat: straw, bran leavings, flour, soluble elements and gluten and for maize: soluble elements, draff, oils, filter cake and proteins. It is estimated that approximately 40% of the cereals used for starch are co-products[103]. The EC starch report suggests that just over 1 tonne of by-products is produced for every 2 tonnes of starch extracted from maize.

In order to maximise the value of the whole plant and process, manufacturers are now developing new, added value applications for many of the starch by-products. Some of these were reported in the previous IENICA overview:

[102] Department for Environment, Food and Rural Affairs, UK **www.defra.gov.uk**

[103] AAC

Non-food uses of flours – certain direct applications of grain flours are being developed
1) ROVERCH in France produces POLYNAT, a bioplastic with characteristics close to those of polyethylene or polypropylene made from rye flour by gelling and plasticizing with natural alcohols.
2) ARS is developing packing boats from wheat flour.

Other areas of investigation include, for example, a project in Illinois in the US[104] which focuses on enhancing the utilisation of corn by converting low-value protein feed co-products to higher value industrial products – specifically, biodegradable plastic film and packaging.

In Denmark[105], the starch processors utilise the juice from potato starch extraction for the production of protein (approximately 2,800 tonnes/year) and the potato pulp is used as feed. The starch factories have initiated a development programme to upgrade the by-products for human consumption in an effort to improve the overall economy.

In Sweden[106], the gluten obtained as a by-product from producing ethanol from wheat is being investigated for its use as an oxygen barrier for packaging.

Science and Technology

Areas of interest and R&D reported in the EU-15 and newly accessed states include:
- *Belgium*: Research on the non-food utilisation of inulin and its side-products is promising, particularly in the fields of biopolymers, surfactants, paintings and cosmetics.
- *Denmark*: Research into RRM-based packaging materials (there are two companies now producing films and trays). Also, starch factories have initiated a development programme to upgrade the by-products to products for human consumption, to improve the overall economics.
- *Sweden*: Much research is taking place into the uses of carbohydrates, including as a raw material for surfactant synthesis, as functionalised polymers and for packaging materials. Also, research into the use of gluten as an oxygen barrier for packaging and research on using proteins for surfactant synthesis. Also, research characterising sugar-based surfactants with special properties, and the enzymatic production of these surfactants.
- *UK*: A company in the UK now produces a wheat-based material called 'Eco-bloc', which looks and functions like standard expanded polystyrene packaging. Other areas of R&D include agronomic investigations (such as investigating the effect of growing conditions on the properties of starches isolated from UK wheat); starches for use in film formation and cereal starches as dry lubricants[107].
- *The Czech Republic*: A project was looking at chicory, for inulin and as a raw material for bioethanol production.
- *Hungary*: Research into the production of a starch-derived flocculation agent and the development of an anionic flocculation agent and formulation of a cationic flocculation agent from starch.
- *Lithuania*: Cationic starches have been produced and tested for wastewater treatment and dewatering of sludge. Results showed that they could function in wastewater treatment as coagulants and substitute inorganic salts of aluminium or iron, cause the precipitation of acid and reactive dyestuffs in solution and flocculate suspended solids in suspensions.

[104] **www.ilcorn.org**
[105] Information from the IENICA national report for Denmark
[106] Information from the IENICA national report for Sweden
[107] Information from the IENICA national report for the UK

- *Poland*: The research in the field of potato breeding, cultivation and processing is very well developed. However the significant decrease in the Polish economy will reflect the potato research. The future development of technical, non–food applications of potato derivatives is the main object of intensive work.
- *Romania*: The main research is into the breeding of maize and sorghum to increase the starch content of the grains.
- *Switzerland*: Research into sugar beet, Jerusalem artichoke and sweet sorghum.

As reported earlier, the primary crops grown in the EU for their starch content are maize, wheat and starch potatoes (plus sugar beet) and these raw materials each supply a large share of total starch output.

Potatoes:
The countries which have reported production of potatoes for starch are primarily EU-15 countries. Non-quota production of potato starch is from the recovery of starch from the effluent from potato processing (e.g. for chips). However, it is likely that the volume of starch produced in this way is minor – estimates suggest an output of 10,000-20,000 tonnes[108]. This starch is not entitled to receive the starch premium paid to all processors of potato starch within the quota.

Starch potato production in the EU is regulated by quotas (see Table 4); potatoes account for approximately 21% of starch production capacity in the EU (see Figure 6). The main potato starch countries are Germany and the Netherlands. Of the newly accessed states, Poland the Czech Republic, Latvia, Slovakia and Estonia have quotas, but these are far less than those in the former EU-15 countries. The report for Denmark reports that potato starch is of a better quality than maize starch, but that this quality difference has reduced due to considerable quality improvements of maize starch. Also, potato starch producers have met tough competition from especially cheaper maize starch.

Little commercial production of potatoes for starch is reported in the newly accessed states, with the exceptions of the Czech Republic, which has a big starch industry and Poland. Potatoes are the main source of starch in the Czech Republic, although a slight decrease in industrial potatoes is expected after accession to the EU. It is noted that new cultivars (potentially GM) need to be developed to withstand early frost. The major volume of starch produced in Poland is obtained from potatoes. Poland produces around 55% of the European potato cultivation area[109], and around 0.9 million tonnes of potatoes for starch (180,000 tonnes of starch on average).

In Estonia, the only potato starch factory closed in 2003 as it was uneconomic to produce it in small quantities (cost-effective production begins at 10,000 tonnes per year; the last production of the plant was 89 tonnes in 2002). Lithuania has a production capacity for 8,500 tonnes of potatoes/year (2 starch plants) which could cover domestic demand, but this is currently unused and starch is currently imported in significant amounts, There are a number of reasons for this under utilisation of production capacity: economics; lack of contractual agreements with farmers; a shortage of high quality raw material; lack of seed tubers of special starch varieties.

Maize:
Unregulated by the EU, starch production from maize accounts for the largest proportion (45%) of EU starch production capacity.

[108] European Commission Starch Report
[109] Information from the IENICA national report for Poland

France and Italy are the major maize growers in EU-15 (1.6 million ha and 1.2 million ha in 2003 respectively[110]). France grows 200,000 ha (2002) for starch (this is an increase from 179,000 ha in 1997).

A number of the newly accessed states grow very large areas of maize, in particular Bulgaria (0.5 million ha; 1.2 million tonnes); Hungary (1+ million ha; 6.1 million tonnes) and Romania (3+ million ha; 10+ million tonnes)[111]. Varying amounts of this production are for non-food uses: for example 250,000 tonnes of grain in the Czech Republic is for industrial applications and 22,000 tonnes for industrial purposes in Romania.

Cereals:
Wheat is the primary cereal used for starch in EU-25, and accounts for 34% of the starch production capacity in the EU. In the EU-15 countries, wheat starch is produced in Belgium, Finland, France, Germany, Italy, Sweden and the UK.

Wheat is the only crop for non-food starch in Belgium, but there are no contractual links with the cereal production sector; starch production develops on the basis of wheat availability and price on the free market. The starch industry does, however, mainly use local wheat and uses around one fifth of the national wheat production. Non-food use of wheat starch is a relatively significant sector in Finland, where around 12% of the wheat area is for non-food starch (approximately 23,000 ha, producing 33,000 tonnes of starch. However, Raisio, the most important starch producer in Finland, will end starch production from cereals (wheat and barley) in 2004. Wheat starch production in France has increased since the last IENICA report was published; from 151,000 ha for starch in 1997 (1.02 million tonnes of grain) to 275,000 ha in 2002 (1.96 million tonnes of grain). This reflects the increase in the overall starch sector of 30% during that period.

Wheat production in the newly accessed states is more limited than in the EU-15 countries (the area cultivated is only 40% of that cultivation in EU-15[112]).

Bulgaria, the Czech Republic, Hungary and Poland produce wheat starch, although only in relatively small amounts. 0.6% of total wheat production in the Czech Republic, for example, is for starch (approximately 5,400 ha).

The only other cereal produced in Europe for non-food starch applications is barley, and this is only in Finland, where 11,000 ha and 34,000 tonnes of barley produce 48,000 tonnes of starch for non-food uses (approximately 2% of the total barley area).

Chicory:
Chicory is produced in Europe in Belgium, France and the Netherlands. Belgium is the major producer of chicory in Europe, and has pioneered its development. Production has been stable in Belgium for several years. 80,000-100,000 tonnes of inulin are produced from 580,000 tonnes of roots, from around 16,000 ha. Further crop extension is limited, however, by the capacity of the factories. Two factories process chicory roots for inulin at present, and produce several products, derivatives and co-products, mainly for food. R&D for non-food uses in promising, especially for biopolymers, surfactants, paintings and cosmetics.

[110] FAOSTAT Data
[111] Data from the IENICA national reports for Bulgaria, Hungary and Romania and FAOSTAT data for 2003
[112] FAOSTAT Data

Chicory for inulin is also of interest in the Czech Republic, although not yet commercially produced. No other interest or activities have been reported to IENICA in the newly accessed states.

Other crops:
Some types of peas have applications for the production of starch because of their high amylose content, but little commercialisation has been reported. Starch is extracted from peas (and pulses) in Belgium, but is all used for food applications. Interest has also been shown in the Czech Republic.

Greece has identified sweet sorghum as a new potential source of starch, and 3,000-5,000 ha is cultivated in Romania for starch. One Romanian variety has a starch content of around 75%. There has been some research, particularly on agronomy, in Switzerland into sweet sorghum as a sugar crop.

The previous IENICA report also showed that there has been some interest in oats, quinoa and Jerusalem artichoke as potential starch crops, but no commercial activity was reported then. The new reports do not report any developments in these areas since that time (2000).

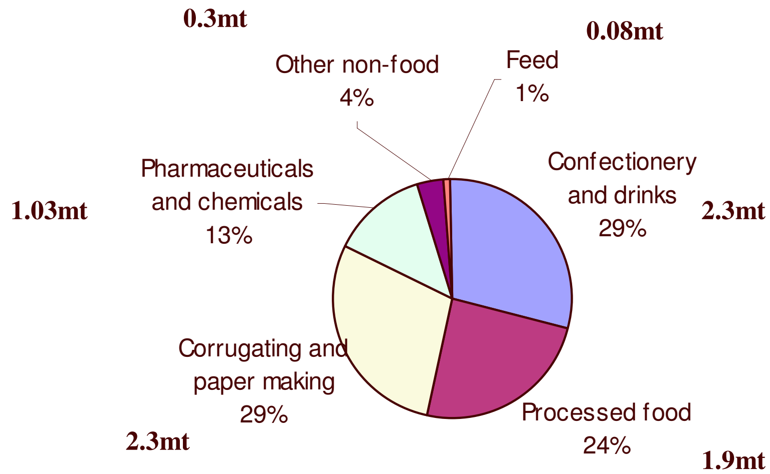
Markets

The European cereal starch industry produces over six hundred products, from native starches to physically or chemically modified starches, through to liquid and solid sweeteners. The versatility of starch products is such that they are used as ingredients and functional supplements in a vast array of food, non-food and feed applications.

There are many applications of starch in the non-food sector, each of which requires very particular functional characteristics. Figure 7 illustrates the different sectors of application of starch products and shows that total non-food applications accounted for 46% of all starch in 2003. Of this:

- 29% was in corrugating and paper-making
- 13% in pharmaceuticals and chemicals
- 4% in ‘other’ non-food

Figure 7 Sectors of Application of Starch Products
Sectors of application in 2002 in terms of consumption in value. Total consumption of starch and starch derivatives in Europe (excluding co-products) in 2002: 7.9 million tonnes.



Total non-food applications: 46% (3.6mt) **Total food applications: 54% (4.3 mt)**

Source: AAC

EU starch markets feature a number of well-established players, mainly multinational companies. These include:

- **Agrana** (www.agrana.com)
- **Amylum** (www.amylumgroup.com)
- **Avebe** (www.avebe.com)
- **Cargill** (www.cargill.com)
- **Cerestar** (www.cerestar.com)
- **Crespel & Deiters** (www.crespel-deiters.de)
- **Emsland-Stärke** (www.emsland-staerke.de)
- **Kröner** (www.kroener-staerke.de)
- **National Starch** (www.nationalstarch.com)
- **Raisio** (www.raisiogroup.com)
- **Roquette Freres** (www.roquette.com)
- **Syral** (www.syral.com)

Use in the chemical industries can be broken down into a number of sectors: biodegradable plastics, adhesive and glues, detergents, agrochemicals, paints, water purification, cosmetics and toiletries, as discussed in the paragraphs below. Starch also has applications in textiles and super-absorbent products.

Paper and Board
By far the largest non-food application for starch in Europe (see Figure 7), both in EU-15 and the newly accessed states, this sector accounts for 29% of total starch production, and approximately 62% of all non-food applications (2.3 million tonnes)[113]. Figures show[114] an estimated 1.4 million

[113] Figure for EU-15 in 2002; AAC
[114] European Commission Starch Report

tonnes of native and modified starch was sold to the domestic paper industry[115] in 2000 (an increase from 0.9 million tonnes in 1992).

Starch products are used in paper bags, tissues and packaging paper, corrugating board and stationery. It would be virtually impossible to make paper in all its current varieties and qualities without starch products, because internal strength and surface 'feel' both depend upon it. Starch also improves the printability and writing properties of paper.

Starch is used at the three principal stages of paper manufacturing:

- 'Wet-end' application – in the paper mass, ensuring internal cohesion of the sheet by forming bonds, cellulose-starch-cellulose. This increases the strength of paper for machining. The increasing use of recycled paper requires more and more starch quantities to avoid deterioration of the quality of fibres during recycling.
- At the size press, to reinforce cohesion of superficial fibres of the sheet and to avoid flaking.
- In coating products. These products are deposited on paper in a coating which makes it possible to mask the irregularities of the surface and to substitute for the natural macroporosity (blotter effect) an artificial microporosity suitable for writing or printing.

This main use of starch is reported in the individual IENICA national reports. The increase of the application of starch in this sector is shown in the report from France, where there has been an increase of 34% since 1997/98, due to the increased consumption of paper. 565,000 tonnes of starch are used in France each year as a viscosity enhancer and binder in paper, and 184,000 tonnes in corrugated paperboard. 130,000 tonnes of cationic starches are used for wet-end application in the paper industry in Sweden. Approximately 60% of starch in Germany for non-food uses is for the paper industry.

This pattern is the same for the newly accessed states. For example, 80% of starch for non-food in the Czech Republic is for paper (potato starch and dextrin); 61% of the 32,000 tonnes/year of starch for non-food uses in Hungary is for paper and around 5,000-6,000 tonnes/year are used in Lithuania.

Biodegradable Plastics[116]

Biodegradable polymers/plastics are different to conventional polymers in that, due to their physical and chemical structure, they can be broken down by microorganisms (i.e. fungi and bacteria). Biodegradable polymers can be produced by a wide variety of technologies, both from renewable resources of animal or plant origin and from fossil resources, and are converted into compostible products. It is the chemical structure of the polymer which determines if it is biodegradable, not the source of raw material.

A major role in their manufacture is played by renewable resources which are already the predominant source of raw materials for them. Biodegradable polymers can now be made completely from renewable resources e.g. polylactic acid (PLA) and polyhydroxyalkanoates (PHA). Blended products, however, are a major element of this sector, combining fossil and renewable resources: synthetic degradable polyesters and pure plant starch. Comparative life-

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[115] Assumed to be EU-15 also, as the figure is for 2000

[116] Much of the information in this section was sourced from: IBAW - International Biodegradable Polymers Association & Working Groups, **www.ibaw.org** and Dr. Ingo Sartorius, Association of Plastics Manufacturers in Germany; presentation on the 'Development of Plastics Manufacturing Industry in Europe, with Respect to Biodegradable Plastics' to the Expert Group Meeting on 'EDP's and Sustainable Development', Trieste, September 2002.

cycle analyses have confirmed that this is an ecologically sound approach[117]. The use of starch in biodegradable polymers is therefore in three areas:

- Adjunct in conventional plastics (6% starch)
- Blended with synthetic polymers (60-75% starch)
- As a thermoplastic starch itself (75-95% starch plus other grain-derived compounds)

This is the most rapidly developing application for starch and the sector has seen major developments and advances since the last report, even though the price is not yet competitive in most countries. Advances are mainly occurring in mass markets, such as the packaging and fibre sectors. The new polymers are considered to be a highly attractive innovation with a wide range of potential applications (see Table 5).

Table 5 Overview of biodegradable plastics applications

Segment	Examples	Argumentation / Driver
Packaging	Loose fill foil, film Hollow bodies, bottles, trays, blisterpacks Nets, sacks, bags	Food packaging biologically contaminated Recycling is therefore difficult Plethora of materials hapers conventional recycling 'Short-lived applications
Fast Food Catering Stand	Crockery Cutlery Straws Beakers	Returnable is not always possible or cheaper Products often biologically contaminated through food contact
Fibres/Textiles	Clothing Technical textiles Fabric	Breathable Haptic properties Gloss
Toys	Craft materials Bricks and blocks Golf tees	Peadagogic advantages Environmental safety/education
Convenience	Organic-waste sacks Personal hygiene products e.g. nappy film, cotton buds Golf T´s	Short-lived articles Recycling difficult (see above) "Natural contact"
Horticulture	Plant pots Underlays Peat sacks Seed/fertilizer tape Binding material	"Natural contact"-Composting advisable Recycling very difficult due to contamination Lower manual costs
Agriculture	Covering film Mulching film Tying film	As for horticulture
Medicine	Implants Operation materials Oral hygiene Gloves	Safe absorption and degradation in the body Short lifetime, disposable
Other	Functional supports Mounting technology Grave lights Writing implements	Specific application advantages Lower manual / waste-management costs Compostability required Advertising effects

Source: IBAW[118]

[117] IBAW - International Biodegradable Polymers Association & Working Groups **www.ibaw.org**
[118] IBAW

Established biodegradable polymers on the market include[119]:

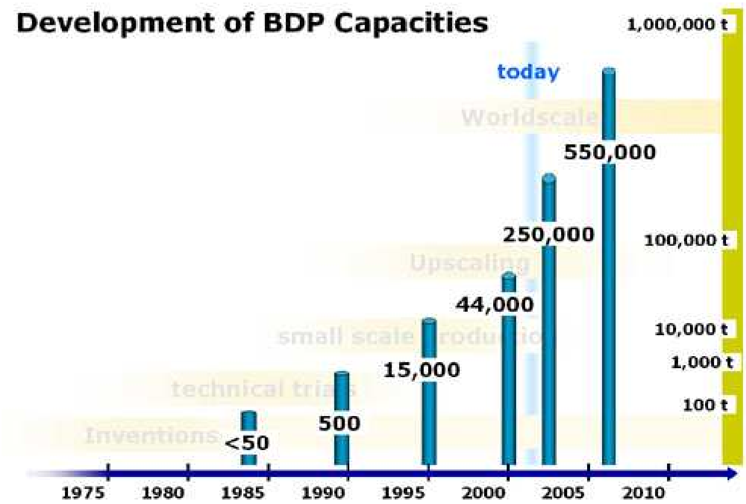
Table 6 Established BDPs on the market

	Manufacturer (trade name)
Mineral oil base	
Polyesters (certain types)	BASF (Ecoflex) DuPont (Biomax) Eastman (Eastar Bio) Showa Denko (Bionolle) Solvay (Capa)
Plant base	
Plant base Starch	Novamont (MaterBi) Rodenburg Biopolymers (Solanyl)
Polyhydroxyalkanoates	Biomer (Biomer) PHB Industries (Biocycle)
Polylactic acid (PLA)	Cargill Dow (NatureWorks) Mitsui (Lacea)
Cellulose (acetates)	Eastman (Tenite) IFA (Fasal) Mazzucchelli (Bioceta) UCB (Natureflex)
Blends	
Starch blends	Novamont (MaterBi types)

Source: IBAW

In addition to the obvious and important waste management characteristics, biodegradable polymers have many functional properties which make them applicable in the areas described. Product properties are now being optimised to meet technical specifications and global production capacity for biodegradable polymers has developed rapidly since the pilot-plant phase of the early 1990's. The following scale-up phase is now making way for industrial-scale production.

Figure 8



Source: IBAW

As Figure 8 shows, current global production capacity is around a quarter of a million tonnes[120]. Some companies such as BASF and Cargill Dow have already announced expansions to their

[119] IBAW
[120] Once the Cargill Dow and Rodenburg Biopolymers production plants have fully come on stream

production capacities – approximately 500,000 tonnes of capacity are expected within 3-5 years. Novamont has shown consistent, strong growth for some years now.

Total plastics consumption in Western Europe in 2000 was c. 40 million tonnes (37% of which is packaging materials, 20% in construction, 9% in electrical, 8% in automobile, 2% in agriculture, 2% in sports and leisure and 22% in others). This is expected to increase to 53 million tonnes by 2010[121]. 27% of total world production of plastics is from Western Europe, and 5% from Eastern Europe. There is, therefore, clearly a huge potential market for biodegradable plastics, particularly with an increasing focus on sustainability.

IBAW data suugests that the consumption of biodegradable polymer products in EU-15 in 2001 was estimated at 20,000 tonnes (0.05% of the 40 million tonnes of total plastic consumption). This had doubled to 35,000-40,000 tonnes in 2003 (0.09-0.1%). Compostable waste bags and starch based loose fill had the biggest share of overall consumption in Europe: In 2003, total consumption of bioplastic loose fill in EU-15 was 10,000-15,000 tonnes; bioplastic films was 20,000-25,000 tonnes and bioplastic packaging (waste bags/loose fill excluded) was 5,000-10,000 tonnes (compared with less than 1,000 tonnes in 2001). It is expected that the biodegradable polymers market will have grown to 0.5-1 million tonnes by 2010, depending on the framework conditions (this is 0.9-1.9% of the 53 million tonnes). The overall application potential for biodegradable polymers is likely to be around 10% of the market[122]. When non-degradable renewable polymers are also included, a considerably higher market share is possible in the long term. Given this market share of 10% and given predominantly carbohydrate products, this would translate to consumption of approximately 5 million tonnes of agricultural products, such as sugar and starch, in Europe. Already biodegradable polymers consist primarily of renewable raw materials (40-95%). Their market share will increase further in the medium and long terms – not only because of the expected price rises in fossil fuels but also because of expectations of consumers and industrial users. The market leader in Europe is Novamont SpA, based in Italy, whilst Cargill Dow has become the world's largest manufacturer, with its new PLA production facility in Nebraska, USA.

See the IBAW Publication 'Highlights in Bioplastics':
(http://www.ibaw.org/eng/downloads/050203_Highlights_in_Bioplastics_en.pdf) for details of bioplastic products currently on the market.

Despite the fact that production costs are still higher, the profitability of biodegradable plastics has steadily improved relative to conventional polymers in recent years. The economics must consider not only the cost of the materials, but also all associated costs e.g. handling and disposal. *"It is likely that biodegradable polymers will no longer be seen as a speciality and will conquer mass markets"*[123].

This sector has considerable future potential, if regulations governing the use of fossil carbon or non-biodegradable packaging are adopted. The environmental impact of the increasing amounts of waste was recognised by the EU in 1994 when the EC introduced the Packaging and Packaging Waste Directive (94/62/EC). *"Market development will depend to a large extent on the framework conditions. A positive framework catalyses market growth and accelerates further investments into material improvement and upscaling. There are many arguments for providing support for biopolymers during the market-entry phase. The biodegradable polymers market is*

[121] Figures from Sartorius (2002) and confirmed by IBAW
[122] IBAW
[123] IBAW

already growing without the kind of support that was given to renewable energies and manufacturers are responding to this growth by increasing production capacities"[124].

Whilst there is interest and some early developments in the newly accessed states, there is no commercial development in polymer production at present in those accessing countries reporting to IENICA. European development is primarily in the EU-15 countries. In France, 16,000 tonnes of starch-based plastics are produced each year. A potential market is in agricultural plastics – 185,000 tonnes/year are used; c. 33% could be replaced with naturally sourced feedstocks. Increasing interest in biodegradable polymers for food packaging in Denmark; 2 food packaging factories now use PLA and starch derivatives in their products (although the biopolymers are imported). In Italy, Novamont is a business leader in this area (and a leader in the European industry, as mentioned) and continues to increase working capacity and lead in the market. Novamont produces Materbi™, a bioplastic from renewable sources, used in industry, agriculture, catering, retail and waste management. In the Netherlands, Rodenburg Biopolymers produce Solanyl® - a biopolymer from potato starch which has been engineered for injection moulding purposes and is used in a wide variety of biodegradable and compostable products such as plant pots and cutlery. Rodenburg's core business centres on potato production and processing for the fast-food and frozen-food markets. The biopolymers company was set-up in 1997 in order to more-profitably utilise potato by-products by converting them into biopolymers.

In the newly accessed states, developments reported by the IENICA countries are:

- Wheat gluten, as a by-product of wheat starch production, has been identified in the Czech Republic as a potential source for biodegradable plastics. There is no commercial exploitation in this sector in the Czech Republic at present.
- The main area of interest and research in Estonia is in biodegradable polymers, and particularly research into PLA. Three areas of development are: adding cereal starch and its modifiers to conventional plastics to increase degradability; producing plastics and films from grain protein; fermenting sugar from starch into lactic acid and producing polylactate. A bioplastic production factory *was* in construction, but the company went bankrupt.
- High scientific potential has been shown by research in Romania, but this is limited at the academic level and to cellulose.
- In Poland, starch is used as 'an additive in the production of polymers and bioplastics'.

In addition to potato, cereal and maize-sourced starch, tapioca starch (cassava) can be used in this sector. A major supermarket in the UK – Sainsbury's – launched, in 2003, a bag partially made from tapioca starch, and number of countries throughout the world produce items such as bags, films and cutlery using this raw material.

The INFO*RRM* project carried out case studies on potato starch for injection moulded bioplastics and sugar beet for polylactic acid for bioplastics[125].

Adhesives and Glues

Whilst this is a much smaller application for starch than paper and board, there are many areas of use. Starch-based adhesives are primarily used for paper bonds, the most important sector being in corrugated board. They are also used for products for wallpaper, posters, labels, adhesive tapes, bags, envelopes and glue in construction, for example. Starch's relatively high viscosity gives an appreciable binding capacity – it can improve storage stability as well as promoting rapid bond strength.

[124] IBAW
[125] **http://inforrm.csl.gov.uk/CS1.asp**

Traditional, starch-based adhesives have faced competition from high performance synthetic products. To maintain their current share of the adhesive market, they must be cost and performance competitive.

Starch from cassava (tapioca starch) stays sticky for a very long period of time when mixed with water or certain chemicals and so is applicable for industrial glues.

The IENICA national reports show the application of starch in this sector in Hungary, Lithuania and Poland, plus France, Germany and Sweden, although it is likely that activities are more extensive than this, but at a relatively low level.

Agrochemicals:
Starches are used as encapsulation agents for pesticides and for the production of aqueous based pesticide formulations. They act as binders in fertilisers and for coating seeds and plant health products. In 2000, Uniqema and National Starch initiated a joint business development effort aimed at providing new technology in this area for agrochemcial producers.

Detergents:
An area of increasing interest and development, largely led by consumer concerns over environmental issues (particularly related to phosphates/eutrophication), the detergent and cleaning industry uses starch products for the production of biodegradable, non-toxic and skin friendly detergents. There are many natural and biodegradable washing and cleaning products now on the market. Starch-derived products are also used as bleaching agents.

Surfactants are the primary cleaning components in formulated detergents and plant-derived carbohydrates may be used to provide the water soluble (hydrophilic) portion of surfactants and to form alkylpolyglucosides (APG's). These latter are non-ionic surfactants made by combining an oleochemical-based oil soluble group and a water soluble group based on glucose derived from starch, thereby producing an entirely 'natural' product APG's have attracted considerable interest in recent years and show interesting properties such as mildness to the skin and eye and temperature insensitive crystalline phases[126]. The IENICA national report for France suggests that the European market of starch in surfactants for cleaning agents is approximately 60,000 tonnes per year.

Builders and co-builders or sequestering agents buffer a wash medium, soften the water and disperse dirt particles, which are removed during washing. As outlined in the previous IENICA report, starch-derived products have shown satisfactory technical qualities but currently there is a lack of a suitable economic process for their production.

The previous IENICA report noted that studies have shown that 60-65% of washing powders could be replaced by biodegradable products.

Paints:
As discussed in the previous IENICA report, based upon either acrylic or vinyl monomer lattices, it has been possible to replace up to 25% of the petroleum-based monomer by native starch from potato, maize, waxy maize or wheat. It is likely that starch-based paints are as economic as synthetic coatings and could have novel properties. Also, they are more environmentally friendly – as the feedstocks are sustainable.

[126] IENICA Newsletter 21 (December 2003) – **www.ienica.net**

Potato, wheat and maize starch-based paints are just as durable, glossy and liquid as synthetic paints. They are potentially biodegradable after disposal, but durable in use. However, current formulations are less water-resistant and take longer to dry than synthetic paints.

Starch has been used in emulsions and alkyds, the two most common types of decorative paint. In emulsions, starch replaces up to 35% of the normal acrylic or vinyl monomers which polymerise to form the finished product. In alkyd paints, oil-derived polyols are replaced by modified starch. The starch is converted into polyols in a novel process which appears economically viable.

National Starch and Chemical[127] (a member of ICI) manufacture a range of industrial starches and dextrins which, in the paints and coatings sector, can function as binders, rheology modifiers, dispersants, flocculants, film formers, strength aids and as gloss agents.

Cosmetics and Toiletries
Starch is used quite extensively in the personal care sector, in cosmetic, make up and toiletry applications e.g. in toothpaste, emulsions, lotions and creams. Sorbitol is a well established use of starch and starch derivatives in this sector; used in toothpaste and cosmetic products.

Starch is used in this sector for many different functions[128]. They are used as film formers (e.g. in hair fixatives, mascara, nail enamels and transfer resistant colour cosmetics); as thickeners and rheology modifiers (in emulsions, gels, hair colourants and hair relaxers); as emulsifiers (in lotions, sunscreens) and as conditioners, moisturisers, emollients, dispersants and water proofers.

Pharmaceuticals
Starch plays an important role in the formulation of antibiotics, vitamins, penicillin, dialysis solution, enteral nutrition, drip-feed systems and even blood plasma substitutes. Starch phosphates have also been used in medicinal films for the treatment of skin wounds and burns – starch esters promote rapid healing and reduce the incidence of infection[129].

The pharmaceutical industry uses glucose hydrolysates or their derivatives as fermentation substrate in order to produce several active compounds (vitamins, antibiotics, hormones). Cyclodextrins stabilise aromas as chelating agent or move bitterness from citrus fruits. They also trap cholesterol and enter the preparation of lightened butter. Inulin from chicory is used as a substrate for pharmaceuticals preparation as it displays beneficial effects on kidney functions, due notably to its rapid excretion.

Starch can also be used in the pharmaceutical industry for coating and dusting tablets, as a filler and base for tablets or to bind the components of the tablets. It can also offer improved disintegration/dissolution properties and enhanced flow and lubricity. These are high value, low volume markets with good growth potential.

Textiles:
One of the earliest known industrial uses of starch, it can be used as a sizing agent, adhesive for fabric lengths and a textile printing thickener, as well as during finishing (to improve hand or surface appearance, aid in warp sizing and slashing and help as a dye fixative). It can be added to individual yarns to increase mechanical strength and resistance to friction wear, and helps resist

[127] **www.nationalstarch.com**
[128] National Starch Personal Care (**www.personalcarepolymers.com**) and Lochhead, R & Jones, J (2004) *Polymers in Cosmetics: Recent Advances* **www.happi.com**
[129] **www.tidco.com**

moisture penetration. It can serve as a stabiliser and filler for coloured inks when fabrics are overprinted.

This is a very small market and declining, since the synthetic alternatives i.e. poly (vinyl alcohol) currently have superior performance, even though are more expensive.

Recent developments have seen the production of textiles directly from renewable sources. DuPont™ Sorona® is a family of polymers made from 1,3 propanediol currently made in a petroleum-based process but from 206 will be made using a fermentation process based on maize sugar. Cargill Dow manufacture Ingeo™ fibres from its NatureWorks™ PLA polymers from maize starch.

Water purification:
A traditional use for starch-based products, they can be used as a coagulant or flocculent. Potato starch is preferred because of its high potassium content. The metal ions in solution can be mixed on acid starches; effluents can thus be purified.

However, starch-based products have been replaced to a large extent by synthetic polyelectrolytes because of their superior performance and lower dosage rates.

The biodegradability of starch may also be undesirable because it increases biological oxygen demand in water.

Construction[130]:
Starch ethers can be used in all mineral cements, in mixed products, and in gypsum board (to bond plaster and paper together) to give specific functional properties (e.g. consistency) and flexibility and are often less expensive than other raw materials, so have the role of acting as a filler.

They support and enhance the effects of conventional water retention agents, improve the adhesiveness of building material mixes on different surfaces and allow the optimised use of air-entrainers[131].

Super-absorbent products[132]:
Superabsorbent polymers (SAP's) are a unique group of materials that can absorb over a hundred times their weight in liquids and do not easily release the absorbed fluids under pressure. There are two primary types of SAP's: starch-graft polymers and those based on cross-linked polyacrylates. Presently, disposable nappies are the main SAP application and account for 80-85% of global SAP consumption. Other areas include as a talc substitute and a root coating in semi-arid zones.

The applications for early products were originally focussed in the agriculture/horticulture markets where they were used as hydrogels to retain moisture in the surrounding soil during growing and transportation.

[130] Source – Agrana & Avebe
[131] An air-entraining agent introduces air in the form of minute bubbles distributed uniformly throughout the cement paste. The main types include salts of wood resins, animal or vegetable fats and oils and sulphonated hydrocarbons.
[132] Source - Nexant's ChemSystems Process Evaluation/Research Planning program, report on Super Absorbent Polymers (03/04S3), April 2004

The popularity of disposable nappies based on SAP's has grown dramatically, leading to explosive growth in SAP demand. In 1990, worldwide demand reached 230,000 metric tonnes per year, primarily in the United States, Japan, and Europe. The disposable nappy market was nearing maturity in the early 1990's when wood pulp prices surged and disposable nappy producers reformulated nappies to reduce wood fluff pulp and give improved properties. The reformulated nappies were thinner due to the reduction in the amount of wood fluff pulp, which was compensated for by an increase in the average amount of SAP per nappy. The average amount of SAP is now in the range of 10-15 grams per disposable nappy.

Global demand for SAP totalled an estimated 1.05 million tonnes in 2003 and demand growth for 2003-2008 is forecast to average 3.6% per year, as a result of rising demand for disposable nappies, primarily in countries with rising disposable incomes and low current penetration rates of SAP's. Although smaller markets in comparison with nappies, strong growth is forecast to continue in feminine hygiene products and in incontinence products in developed regions, as a result of efforts to produce slimmer, more efficient products.

Other applications:
Other applications for starch and starch derivatives include as drilling fluid chemicals (to increase viscosity for hole-cleaning properties and to reduce fluid loss); in the leather industry (as a finishing agent); in the mining industry (i.e. as a floating agent to facilitate drilling) and in the dye industry.

Sugar market:
Currently the EU Sugar Regime is under review. Whilst details are not yet finalised it seems likely that production will be reduced (through cuts in quota) and price per tonne of sucrose decline.

Clearly this will impact upon agriculture and release some land formerly in sugar beet production for alternative uses. Additionally, depending upon any final agreement, a *low* price for sucrose may allow new non-food uses to develop. These latter could be quite diverse including biodegradable plastics and bioethanol as a substitute for gasoline as a transport fuel.

In July 2004, the European Commission tabled a radical overhaul of the EU sugar regime: *"The Commission proposes to substantially cut back sugar exports and export refunds, abolish intervention, reduce EU production and the internal sugar price and grant a de-coupled payment to sugar beet farmers. The reform process shall start in July 2005. To give all parties time to adjust, the changes should be implemented over four years. In view of the uncertainties in the international field, a review is foreseen in 2008."*[133]

Barriers to Progress

Barriers identified in the original IENICA report are outlined below in boxes A-Q; whilst some improvements have been made these issues remain and continue to limit the development of the industry. Additional constraints and issues raised by the newly accessed states are listed.

[133] **http://europa.eu.int**

Crop Production

A
It has been postulated (section 7.3) that European demand for carbohydrates is increasing and that there is potential to replace imported products. There appear to be few scientific limitations to the increased production of existing carbohydrate crops in Europe but significant EU imposed constraints. General increase in productivity has consistently occurred as the result of plant breeding and improved agronomy. It is important that sufficient input continues to improve productivity and reduce inputs through an improved understanding of individual crop physiology. New plant breeding techniques need to be adopted to speed up the production of crop types containing a high content of specific carbohydrate products to ensure changing market requirements can be met. A specifically target should be to elucidate the precise roles and relative importance of the enzymes responsible for controlling starch synthesis in order for the variability in starch types (primarily the ratio of amylose and amylopectin) to be exploited commercially. In potatoes the creation of a type which produces pure amylose starch is a high priority. An increased crop area is likely to be the most positive method of increasing production, providing this is sustainable.

This is still relevant.

B
Chicory is much less developed crop than sugar beet and needs a greater improvement to enable it to become equally productive. The number of carbohydrate crops are limited and the expansion of existing knowledge on barley, oats and peas and the development of new crops such as quinoa and sweet sorghum would improve biodiversity on the farm, with rotational benefits in terms of maintaining soil fertility and pest and disease control.

This is still relevant.

C
To improve attractiveness to processors, attention should be given to meeting crop quality criteria, uniformity and volume of supply.

A review of all market opportunities and their specific needs is recommended.

D
The carbohydrate extraction industry is largely based on old technology, with high-energy requirements; the development of improved extraction technology needs to offer cost savings, improved environmental practice and the ability to handle an increasing range of product types.

Exploitation of co-products needs some enhanced emphasis (see also E).

E
The overall value of carbohydrate crops depends on the market for crop by-products. Traditionally these have been used as animal feed but increasingly higher value by-products need to be produced to ensure the economic efficiency of the whole crop.

This is still relevant.

New constraints identified by the **newly accessed states**:

- Unfavourable climatic conditions can have a significant limiting effect on crop production (i.e. wheat and maize in Bulgaria; wheat in Hungary). Irrigation is very important and droughts can have a dramatic effect on production. In Bulgaria farmers often do not have the finances to pay for irrigation water. In recent years the maize cropping under irrigation occupied only 10% from all areas; the yield from these areas is nearly twice as high as the yield from non-irrigated areas.
- There is low interest in growing sugar beet because of the high price of materials and labour in its production and its low profitability. Also, old equipment of the processing factories (Bulgaria) needs replacement.
- Cultivation and processing techniques are important to satisfying consumer needs for carbohydrate products and inadequate understanding of the need to develop special varieties, growing techniques and novel processing is limiting use of carbohydrate crops in the non-food industry (Lithuania).
- Whilst the interest in the cultivation of non-food crops is increasing, in some accessing states there is limited experience of non-food industrial applications and significant improvement can be expected with the investment and know-how coming from the most advanced EU countries.
- Production capacity in Lithuania is underused for a number of reasons including a lack of contractual agreements with farmers, shortage of high quality raw material and lack of seeds of special varieties.
- Whilst the research in the field of potato breeding, cultivation and processing is very well developed the significant decrease in the Polish economy will reflect the potato research. The future development of technical, non–food applications of potato derivatives is a main object of intensive work currently being conducted by.
- Potato cultivation and production in Poland features extreme fragmentation and relatively low levels of marketed production. The farms producing potatoes for their own needs often do not use qualified planting material; also, the level of mineral fertiliser and chemical plant protection is still lower than in EU countries. Reflecting potato production on these farms at the country-scale shows a great degree variability. As a result of this situation there has been a lack of significant improvement in the level of potato yields for many years.
- In Poland, many of the farmers still do not have proper agricultural education and they sometimes rely on tradition and intuition. On the other hand the amount of well-educated farmers, who graduated from the agricultural universities grows constantly. Additionally, the process of adjusting the farmers to the needs of the potato market and the market for its products takes time.

Industrial Use

F

While a considerable number of industrial uses for carbohydrate crops have been identified, increasing effort is needed to develop higher value products and to improve the efficiency of industrial conversion processes. This should include optimisation of fractionalisation of all crop components. Particular emphasis is needed in the development of 'green products'. There is a need for stronger collaboration between the chemical industry and carbohydrate experts to develop product technologies to deliver new product and production processes.

This could be enhanced by an overarching EU strategy for biorenewables.

Additional constraints identified by the **EU-15 countries** since the previous report:

- Industry wishes to keep a maximum of flexibility and prefers to rely on the international markets for sourcing the raw materials at the best price or technical conditions. In some countries industry may be reluctant to address domestic agriculture in order to contract production volumes of a specified quality at a determined price.
- The capacity of agriculture to invest in industry seems too weak (Belgium)
- There has been no significant development of relations between agricultural production and domestic industries. Starch production from wheat develops on the basis of wheat availability on the market and without any contractual link with the cereal production sector. Nevertheless, the starch industry uses mainly local wheat and absorbs about one fifth of the national wheat production (Belgium)
- Potato starch producers meet tough competition especially from cheaper maize starch. Potato starch still has a better quality than maize starch, but the quality difference has diminished due a considerable quality improvement of maize starch (Denmark)
- Since 1998 Danish potato starch quota has been reduced by 5% and the Danish factories are concerned about the European Commission's decision to allocate quotas to the new members, especially Poland, and thus allow for an expansion of the wider European potato starch production.
- In France biopolymers are only produced at the pilot scale and are not widely marketed. Their high price limits their application in uses such as surgical materials that are biodegradable, or 'green' packaging for cosmetics. Clearly lower production costs would allow industrialists to increase their production capacity and branch into new markets.

Constraints identified by the **newly accessed states**:

- Production capacities in Lithuania are underused for a number of reasons including a lack of contractual agreements with farmers, shortage of high quality raw material and lack of seeds of special varieties.
- Potato and sugar beet processing is seasonal creating poor utilisation of processing equipment and increased production costs (Lithuania).
- In Poland, some of the equipment of the potato-processing companies needs modernisation; however, the low effectiveness of the potato industry mean there are not sufficient financial resources for this.

Economic

G

Price is a major barrier to development. European carbohydrate prices are not competitive in comparison with the world market prices and fossil fuel sources of carbon.

This is still relevant.

H

The impact of Agenda 2000, CAP reform and WTO negotiations on the production of non-food carbohydrate is likely to be negative for agricultural producers but positive for carbohydrate processors. The end result could be a reduction in the availability of European produced materials.

This is still relevant.

Constraints identified by the **newly accessed states**:

- A scarcity of a coherent strategy directed at the development of non-food crops is a major barrier in Lithuania. The market environment is complicated; there is no state support for potato growers or starch producers and this limits the development of the sector.
- A lack of permanent links between starch producers and potato growers on a long-term contractual basis is also a barrier to progress.
- Potato cultivation and production in Poland features extreme fragmentation and relatively low levels of marketed production. Haulage costs are very high; the prices of petrol are similar to the prices in EU countries, but simultaneously the income of industrial companies and average income of Polish inhabitants are much lower than in the EU.
- The high costs of implementing novel technologies for starch production for technical applications are the major barrier in quick and fruitful developments. The investment rate in the potato market has always been low, therefore the reproduction and modernisation of the fixed assets in potato industry is still not sufficient.

Environmental

> **I**
> *Carbohydrate crops produced by gene transfer, offer a potential to meet industry demands but are currently unacceptable to the general public in EU-15. It will be necessary to devise acceptable environmentally friendly production practices to minimise pollen transfer and public anxiety to enable commercialisation of these types.*
>
> Some GM potato clones with specialist starch composition already exist.

> **J**
> *Much of the benefit of products derived from crop carbohydrates are built upon biodegradability. These benefits must be seen to be maintained in all new products and consistency of biodegradability improved.*
>
> This is still relevant.

> **K**
> *The environmental benefits of products derived from crop carbohydrates are poorly understood by the general public. Education and promotion coupled with EU wide schemes to label environmental friendly products (as already exist in some countries) would enhance consumer demand.*
>
> This is still relevant.

- In Poland, it is reported that the sewage from the potato industry is troublesome. More careful and restrictive regulations regarding the disposal of wastes create additional needs of investment in the development of sewage and waste management.

Legislative

L
To enhance the development of crop derived carbohydrates and to meet International Agreements on Climate Change and Biodiversity an EU legislative framework should be established. This would be particularly aimed at extending the legislation with regard to identifying sustainable and biodegradable products and taxation of non-biodegradable packaging.

However, to be successful a full integration of all aspects of production, utilization and disposal of biodegradable packaging is essential.

M
European List of Notifiable Chemical Substances Regulations (ELINCS) and the European Inventory of Existing Commercial Chemical Substances Regulations (EINECS), are a major burden and constraint on industrial development and exploitation of new feed stocks from plants. Consideration should be given to ameliorating its impact for large and small-scale industries, otherwise R&D investment in new products will be seriously impaired.

In October 2003, the European Commission adopted a proposal for a new EU regulatory framework for chemicals: REACH (**R**egistration, **E**valuation and **A**uthorisation of **CH**emicals). Registration is the main element of REACH. Chemicals that are manufactured or imported in quantities of more than one tonne per year and per manufacturer/importer are registered in a central database.

Constraints identified by the **newly accessed states**:

- In many countries a special legislative framework to encourage the production or utilisation of carbohydrate crops is absent. In Bulgaria, however, the programmes of the State Fund 'Agriculture' are expected to provide aid to wheat and maize producers.
- In Romania, the absence of maize grain price and quality standards and measures to stimulate the use of the starch are limiting factors.

EC Actions

N
It would be helpful to long term research and investment by industry if the EU could produce a definitive long-term strategy governing industrial crops and ensure integration of policy making in all areas of EC.

This is still relevant.

O
There is continuing need for EU support of research and development. More of this support should be directed towards pilot projects to bridge the gap between scientific small-scale developments and full commercialisation and to create awareness of opportunity within the general public and in industry.

This is still relevant.

Constraints identified by the newly accessed states:

- The development of the carbohydrate sector in the accessing states in the near future, along with domestic factors, will depend a great deal on the outcome of EU negotiations over potato starch quotas. A direct payment level for arable crops as well as the capacity to use structural funds is also of great importance (although this seems unlikely with CAP reform and world trade discussions). In the Czech Republic in 2001 the production of industrial potatoes was expected to grow and that trend was expected to be maintained, but due to EU regulations for potato starch production a slight decrease is expected after joining the EU.

Communication

P

Communications between the main participants in the non-food carbohydrate, farmers, seed vendors, storage operators, research bodies, crusher, refiners and industrial users need improvement. Only by multi-path communication will confidence and requirements of all parties be defined and understood.

This is still relevant.

Q

Communication of the new carbohydrate products and their environmental benefits to industrial and domestic users will overcome the lack of knowledge and enhance product demand.

This is still relevant.

- In Poland, the dissemination of research results is carried out by the Extension Agronomy Centres. Unfortunately, farmers do not take enough advantage from the potential of the Centres. Many of the farmers still do not have proper agricultural education and they sometimes rely on tradition and intuition. On the other hand the amount of well-educated farmers, who graduated from the agricultural universities grows constantly. Additionally, the process of adjusting the farmers to the needs of the potato market and the market for its products takes time.

IENICA

~ SPECIALITY CROPS ~

Introduction[134]

"In Europe, an astonishing number of medicinal and aromatic plants are used on a commercial basis. The herbal market is growing at a rate faster than the pharmaceutical market".

Dr. Dagmar Lange, IUCN/SSC Medicinal Plant Specialist Group[135]

As was recognised in the last report, the speciality crop sector in Europe, as throughout the rest of the world, is extremely diverse and complex with little vertical integration; information is difficult to source from the large number of small and medium sized companies for commercial-confidentiality reasons.

Products in this sector are generally higher priced/higher value and are traded in lower amounts than mainstream products in the other sectors. Cultivation areas therefore tend to be relatively small and the market can quickly become saturated, severely impacting upon prices.

There is great diversity in the crops grown in this sector. In the European Union[136], medicinal and aromatic plants are cultivated on an estimated total area of 70,000 ha (1998)[137]. In all, 130-140 plant species are cultivated; this is approximately 10% of those native to Europe used on a commercial basis; the remainder are collected from the wild (see later).

In accessing the EU the Eastern European states bring with them a long history of production and use of these plants and products and interest and activities are significant, as described below. The trade of medicinal and aromatic plants in the countries has changed in recent years, largely owing to change from strictly organised and state-controlled trading systems based mostly on country-wide networks, to free and diversified markets, with an increasing number of competing, private companies[138]. This has resulted in increases in collection from the wild, a situation which is at best undesirable.

Speciality products which can be prepared from plant raw materials include:

- Essential oils
- Essential fatty acids (γ linolenic acid)
- Pharmaceuticals (human and veterinary)
- Herbal health products
- Inks, colourants and dyes
- Perfumes
- Personal care/beauty products
- Novel plant protection products
- A range of intermediate products from which the above are manufactured.

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[134] Key references for this chapter are:
- TRAFFIC: the wildlife trade monitoring programme of the World Wide Fund for Nature (WWF) and the World Conservation Union (IUCN) **www.traffic.org.** TRAFFIC's mission is to ensure that trade in wild plants and animals is not a threat to the conservation of nature.
- World Wide Fund for Nature (WWF) **www.wwf.org.uk**
- Working Group on Medicinal and Aromatic Plants (MAP's), established under the European Cooperative Programme for Crop Genetic Resources Networks. **www.ecpgr.cgiar.org**
- Rural and Agricultural Incomes with a Sustainable Environment (RAISE). **www.raise.org**

[135] At the 1st International Symposium on the Conservation of Medicinal Plants in Trade in Europe, June 1998

[136] Assumed to be EU-15 as figures are for 1998.

[137] TRAFFIC

[138] TRAFFIC

In 2001, a Working Group on Medicinal and Aromatic Plants (MAP's) was established under the European Cooperative Programme for Crop Genetic Resources Networks[139]. This Working Group is focussed on co-ordinating action and involvement in Europe, to contribute to the development of the conservation strategy of MAP's at the European level.

Science and Technology

The key elements in this sector were described in the original report, and these aspects remain:

- Many species, varieties and strains of plant are involved. Chemotaxonomic definition is critical to successful exploitation, particularly of some essential oils, but currently there is little systematic definition.

- The methods of extraction, purification and transformation used with speciality plant feedstocks vary considerably, according to intended end product. Novel extraction technologies offer new options for products (e.g. super-critical extraction). Currently these are largely unexplored opportunities.

- The demands of the end user are frequently ill-defined and often depend upon organo-leptic tests or olfactory skills which are difficult to quantify systematically. This is particularly so with perfumes and essential oils.

- Markets are international and highly competitive. Frequently, natural products are adulterated with dilutents to increase their volume. Traditional and long standing arrangements are difficult to change in some product areas.

- Waste products with little or no value can offer cheap alternatives to speciality grown crops. In terms of essential fatty acids (e.g. γ linolenic acid), these opportunities deserve further investigation but could impact adversely on primary specialist crop production.

- The protection of intellectual property rights (IPR) and registration procedures for naturally developed but extracted plant products is confusing and can be prohibitively expensive. Additionally, there is inconsistency in regulation; whole plants may be unregulated but simple extracts fully regulated.

- Consumer demand and market trends are frequently unpredictable, follow fashion and can be short-lived. As a consequence, the determination, execution and exploitation of RTD programmes is difficult.

- In many plant species, quality and proportions of desired plant-derived molecules vary according to geographical location and within the plant, method of growing, time of day, stage of physiological maturity and harvest method.

"Every company that uses plant-based ingredients in their products faces a number of sourcing challenges. Whether the product is a pharmaceutical grade drug or API; a personal care or 'cosmeceutical' product; a plant-derived medicinal extract; a traditional herbal medicine or a

[139] **www.ecpgr.cgiar.org**

functional food from a raw material sourcing perspective, the issues of ***quality, sustainability and traceability*** *are remarkably similar"*[140].

Production is currently on the basis of an individual plant, product or group of similar products and is therefore small-scale and potentially expensive. The primary exception is the pharmaceutical sector where massive screening procedures check tens of thousands of plant products and their metabolites each year.

According to the MAP Working Group, in Europe, at least 2000 MAP's are used on a commercial basis, of which 1,200-1,300 plant species are native to Europe. However, only around 130-140 plant species are estimated to be cultivated[141]; the rest are collected from the wild (as discussed below).

Reports from the IENICA partners in EU-15 show that interest in this sector is increasing, and in many countries the cultivated area is increasing, reflecting the overall consumer demands for natural products. Developments are inconsistent between countries however, and cultivation is still relatively limited. This is a sector which is likely to remain based on small areas. By far the most significant producer in EU-15, in terms of cultivation, is France. The main speciality crops in France are lavender and lavandin, and France produces 70% of the world supply of these. Very significant developments in both have been seen in France in recent years. The area of lavender has doubled since 1995 and is now around 5,000 ha (this increase followed a programme which offered production incentives, research support for more productive species and the promotion of its essential oil); the area of lavandin has increased by 40% since 1995 and is now approximately 19,000 ha. A corporation was set up in 1997 (CIHEF) as a market regulation tool, to maintain lavender and lavandin production levels. France also grows nearly 10,000 ha of medicinal plants and over 2,000 ha of aromatic plants.

Reported areas of research and development activities in the EU-15 countries include:

- *Austria*: Investigations into *Plantago* spp. for medicinal use
- *Denmark*: A new centre for medicinal plants and horticulture was set up in 2002 – 'Udviklingscenter Årslev'. There is also a research centre which works on the development of new plants, chemical analysis and testing of the effects. 20 varieties have been screened and 6 selected as potential commercial crops.
- *Finland*: Research into the cultivation, extraction and application of indigo from woad (*Isatis tinctoria*) and indigo (*Polygonum tinctorum*) and on the application of other plant-derived types for textiles. There is also interest in brown knapweed (*Centaurea jacea*) which may also have potential for biomass production.
- *France*: A research programme on dyes has shown promising results, but also shows that the high prices are a limiting factor.
- *Italy*: Research in collaboration with the pharmaceutical- and cosmetic-industry sector into plants containing biologically active compounds. Genotypes with different contents of compounds with antioxidant, antimutagenic, antimicrobial and antifungal properties are being tested.
- *UK*: Opium poppy (*Papaver somniferum*) has been grown in the UK as a source of opium for morphine and codeine since 2002: the area cultivated has dramatically increased from 466ha in 2002 to 1,509 ha in 2003 to meet production contracts.

[140] Theoblad, T., Walker, I., & Stewart, C (2003) *Quality and Risk Management in Botanical Supply Chains* Pharmaceutical Manufacturing and Packing Sourcer, Winter 2003
[141] MAP Working Group

Commercial activities in some of the newly accessed states are much more significant and although they generally occupy only a small percentage of land, cultivation can be relatively large. Main activities include:

- *Bulgaria*: 32,000 ha of essential oil plants (rose, lavender, coriander and mint; this area has increased because of increased interest and support through a state fund). 3.9-4.3 tonnes of rose oil are produced each year from 43,000 tonnes of rose flowers. This is mainly for perfumes and most is exported.
- *Hungary*: 10% of worldwide medical morphine and 30% of that used in Europe is from one Hungarian factory. 8,000-10,000 tonnes of dry poppy capsules are produced each year. Additionally, 214 plant species are sold for medical purposes.
- *Lithuania*: 6,500 ha of caraway is grown for alcohol, soap and perfume applications.
- *Romania*: Around 12,000 ha of medicinal and aromatic herbs are grown each year. 28 new varieties have been created in Romania and cultivation techniques established for around 50 species. The new varieties have increased production (a 6-33% increase in quantity) and increased the content of active principles by 12-45%.
- *Poland*: Up to 35,000ha of herbal crops are cultivated; 20,000 ha of this are medicinal plants and herbs for pharmacy and cosmetics. In addition, some natural plant protection products are produced in Poland, used in horticulture, based on active substances contained in garlic, rapeseed oil and other crops, including cereals.

Much of the scientific development reported by the Eastern European states concentrates on varietal breeding and the improvement of crop cultivation techniques. Activities and areas of research reported to IENICA include:

- *Czech Republic*: Methods of plant cultivation and procedures appropriate for isolation, identification and characterisation of plant-derived compounds that can serve as pharmacological tools or drug prototypes.
- *Hungary*: Breeding of cultivars and agro-technical developments; analysis of plants, extracts and standardisation; chemistry and analysis of natural antioxidants; biotechnology – the production of transgenic plants for processing secondary metabolites; new methods of isolation of active compounds, including supercritical fluid extraction.
- *Israel*: Research into methods of biological control of *Pectinophora gossypiella* and *Bemisia tabbaci* by the use of rope dispensers which release a pink pheromone. Also, investigations into some local plants as potential sources of essential oils and oleoresins with interesting biological activities.
- *Lithuania*: Isolation, fractionation, chemical (i.e. chromatography, mass spectrometry, nuclear magnetic resonance) analysis and technological investigations of active substances.
- *Romania*: The creation of some superior genotypes compared with the ones currently cultivated. This is an efficient way of increasing production and its stability, as well as quality.
- *Poland*: Research into natural dyes, to be applied to natural fibres.

Overall, breeding is used to increase production capacity; improve resistance against diseases, damaging agents and fluctuations in environmental factors, and increase the content and quality of active principles.

A major problem in the Eastern European states is that equipment is often old-fashioned – both the equipment for the extraction and processing of the active components and also the equipment for the identification and analytical characterisation of active components.

A major aspect of this sector is that many species are collected from the wild, rather than specifically cultivated; estimates suggest[142] that 90% of MAP's native to Europe are collected from the wild for commercial use; from the 1,200-1,300 European plant species used on a commercial basis, only 130-140 plant species are cultivated. This equates to at least 20,000-30,000 tonnes per year of wild-collected plant material in Europe[143]. TRAFFIC estimates that about 150 species are reported to be threatened in at least one European country as a result of over-collection from the wild. This can have environmental issues and threaten plant species as a result of over-collection, destructive harvesting techniques and habitat loss and change. A significant factor in this collection from the wild is the lower prices of wild collected plant material compared with cultivated material. International organisations such as WHO, IUCN and WWF have programmes focussed on this issue, because of over-exploitation, habitat loss and alteration. As a result of the activities of these organisations and the guidelines for national strategies provided to Member States, national development programmes in some European countries have caused the acreage covered by MAP's to gradually increase. Sustainable use of MAP's in Europe can be achieved by further introduction of 'wild' plants into cultivation. However, conservation measures for a species generally only begin once it has already become endangered, largely due to a lack of information to assess whether levels of trade are unsustainable. Of paramount importance is the conservation of supplies for the future.

Collection from the wild is a particular problem in the newly accessed states, where the deregulation of state-controlled commerce has resulted in increasing wild-collection. As reported by the IENICA partner countries, in Estonia, most herbs for health products are collected from the wild; in Hungary, approximately 25% of total production (120 plant species) is collected, with an output of 10,000-15,000 tonnes of dried plant material each year; in Romania around 155 varieties of medicinal and aromatic plants are collected from the wild (750-850 tonnes/year)[144].

In Western Europe, strong emphasis is placed on traceability and reproducible quality in this sector, and this can pose difficulties for some of the new states. In Romania, production has decreased from 23,000 ha of medicinal and aromatic plants in 1993 to around 12,000 ha today. This is due to the large dispersion of cultivation areas which has not allowed the satisfactory traceability or reproducible quality which are requested by the more severe requirements in production enforced by European legislation[145]. The development of an EU compatible regulation and subvention systems of the sector, including harvesting, processing, production and marketing of raw materials, extracts and final herb products is essential.

It is noted in the report from Hungary that, traditionally, dried plants are supplied to rural distributors who export the material. This is changing, however, and farmers are often now in direct contact with importers and processors, which can lead to problems because farmers are generally not skilled in foreign business. In addition, efficient production depends on information, knowledge and research, and whilst this is improving, the lack of funds and Government financial assistance is the main problem.

There is increasing focus and market demand in both EU-15 and the newly accessed states upon the organic production of speciality crops. It is suggested that 'bio-certified' production could help to launch small-scale production of a small number of species, in countries where the market

[142] TRAFFIC
[143] TRAFFIC
[144] Figures from TRAFFIC suggest that: in terms of volume, 30-50% of medicinal and aromatic plant material in trade in Hungary is wild collected, 50-70% in Germany, 75-80% in Bulgaria and almost 100% in Albania and Turkey.
[145] Information from the IENICA national report for Romania

is not yet significantly developed. Organic production gives lower productivity but higher quality (and so value).

Legislation[146]

Some medicinal and aromatic plants that are in trade in Europe are subject to international, European and national legislation for their protection and conservation.

On an international level, some of these plants are affected by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). Their inclusion requires that specimens of the species in international trade must be accompanied by special permits.

On a European level, the Convention on the Conservation of European Wildlife and Natural Habitats of 1982 (Bern Convention) lists six species of medicinal and aromatic plants.

At EU level, CITES is implemented by Council Regulation (EC) No. 338/97 and Commission Regulation (EC) No. 939/97, and various amendments. In addition to the 47 CITES-listed medicinal and aromatic plant species listed in this regulation's Annex B, seven others are listed in Annex D, which means that their trade within the EU should be monitored. Council Directive 92/43 EEC (EC Habitats, Fauna and Flora Directive) lists 10 medicinal and aromatic plant species; three in Annex II, one in Annex IV(b), and six in Annex V(b). The Directive aims to promote the conservation of natural habitats and of wild fauna and flora within the EU.

Legislation on protection of endangered medicinal and aromatic plant species is present in almost all European countries. Bulgaria has set up a quota system which renders the collection of 23 plant species illegal without prior authorisation: each year quantities to be gathered vary considerably according to species and regions. In all, 341 medicinal and aromatic plant species are affected by the combined national legislation of Bulgaria, France, Germany, Hungary, Spain and Turkey, affording either full or partial protection.

Markets

Medicinal and aromatic plants are normally traded in dried form, although they may be traded fresh or preserved in alcohol. Plant parts may be traded in their whole form, or comminuted (i.e. cut, powdered)[147]. There is a trend towards trading cut plant material[148]. Most manufacturers in Europe and North America buy from large wholesalers (some of the biggest of which are in Germany); this assures manufacturers that stocks are of a reliable quality and are available at known prices. Overall, this makes the purchase of herbal materials easier and more economic. More direct sourcing is the preferred option only for manufactures which have very specific standards (e.g. organic, ethical, community trade) and which are able to charge higher prices for the extra costs incurred. Generally in producer countries the plant material is bought from collectors and cultivators by various types of traders, including local dealers, village co-operatives and district traders. It is then passed on to wholesalers, manufacturers or directly to retailers. The wide range of manufacturers involved can include those engaged in the production of pharmaceuticals, extracts, cosmetics, foods and colouring agents. Material of a species which has entered the wholesale or manufacturing sectors may have originated from various harvesting areas within countries, or it could have been imported. This makes it very difficult to identify

[146] Source of information in this section: TRAFFIC; **www.europa.eu.int**; the European Directorate for the Quality of Medicines (**www.edqm.org**) and the European Agency for the Evaluation of Medicinal Products, EMEA (**www.emea.eu.int**)
[147] WWF
[148] TRAFFIC

sources of materials and to impose quality controls. The lengths of trade chains and the perceived need to protect information lead to a lack of transparency. A direct consequence is that those at the start of the chains (producers and collectors) have little idea of the market value of the MAP's which they are supplying, nor the means to discover the value added from source to end-use. In former Eastern Bloc countries, the trade has changed in recent years from strictly organised, state-controlled systems based mostly on country-wide networks, to free and diversified markets with an increasing number of competing private companies. This has had significant negative effects on the sustainability and conservation of MAP's because previous quotas and controls are now largely ignored. Only Bulgaria still has a relatively well-controlled MAP trade.

The largest global markets for medicinal and aromatic plants are China, France, Germany, Italy, Spain, the UK and the US. The increased global interest in the use of MAP's, and the increasing demand on raw materials by various processing industries (pharmaceutical, food, cosmetic, perfume) have resulted in a vast and expanding market in the last decade. In Western Europe, medicinal plant consumption is estimated to have doubled in the last decade[149]. Estimates suggest[150] that, in the US and Europe, the trade has typically been growing at an average of 10% per year[151], driven by the popularity of alternative treatments and the increasing official recognition of the benefits of traditional medical systems involving herbal preparations.

In 1999, the world market for herbal remedies was US$19.4 billion[152], with Europe leading (US$6.7 bn), followed by Asia (US$5.1 bn), North America (US$4 bn), Japan (US$2.2 bn) and the rest of the world (US$1.4 bn)[153].

Europe is a major world trader in MAP's. As mentioned earlier, at least 2,000 MAP species are traded, of which two thirds (1,200-1,300 species) are native to the continent. The most popular botanical medicines sold in Europe in 1996 were formulated from gingko, ginseng, garlic, echinacea and evening primrose – see Table 1.

Table 1 Top Retail Products in Europe, 1998

Product	Species	Country	Annual Sales (US$ m)
Tebonin	gingko	Germany	200
Ginsana	ginseng	Germany	50
Kwai	garlic	Germany	40
Efamol/Epogam	evening primrose	UK	30
Echinacin	echinacea	Germany	30

Source: WWF Factsheet: Trade in Medicinal and Aromatic Plants

According to figures from TRAFFIC, Europe imports about one quarter of annual global market imports of MAP's each year are into Europe. Between 1992 and 1996, imports came from more than 120 countries, with 60% of material coming from outside Europe, mainly from Asia and Africa. It is likely[154] that European imports are well above 500,000 tonnes/year. Germany is the

[149] MAP Working Group
[150] WWF
[151] Other figures give an increase in the average annual volume of MAP's utilised in the EU of 21% since 1992.
[152] A figure supported by the IENICA national report for Germany
[153] WWF
[154] WWF

leading European importer, accounting for one third of both the volume and value, with France, Italy, Spain and the UK among the other 12 leading importing countries.

The 12 leading exporting countries in Europe are led by Germany, Bulgaria and Poland, with Germany accounting for one fifth of the volume and one third of the value. Germany has a large re-export trade and is the major European trader in MAP's, being the pivotal country in intra-European trade and acting as a link between markets in eastern and south-eastern Europe and those in the north and west. Between 1992 and 1996, TRAFFIC figures suggest that Europe exported an average of 70,000 tonnes of MAP's annually, 20% to non-European destinations, mainly North America. 60% of exports were from just 5 European countries – Germany, France, Italy, Spain and UK.

In Europe, countries exporting more than they import are Bulgaria, Hungary, Poland, Turkey, the Czech Republic, Croatia and Romania. Bulgaria is the most important source country for European MAP's, with average net exports of 7,000 tonnes/year – this is 60-70% of MAP's produced or harvested in Bulgaria.

The intra-European trade in medicinal and aromatic plant parts is very large, about 40% by volume of all European imports and over 80% of all European exports. As mentioned Germany is pivotal in this.

Not withstanding this information, it is impossible to give an overall comprehensive market appraisal for the full range of speciality plants and plant products. Market demand and prices are highly variable and react quickly to market supply, magnitude of potential harvests and their quality.

Essential Oils

Essential oils are highly concentrated, highly volatile, aromatic substances extracted from various parts of plants and trees (e.g. flower, bark, seed, leaves or roots, or from the whole plant). They are usually captured by steam distillation, although there are various other methods, including by hydrocarbon solvent extractions (although the solvents can leave undesirable residues). Supercritical carbon dioxide extraction can also be used; this is a relatively new method offering a safe and environmentally benign way of extracting the essential oil.

The chemistry of essential oils is complex; most consist of hundreds of components, such as terpenes, alcohols, aldehydes and esters and for this reason a single oil can be used to help a wide variety of disorders. In addition, due to their tiny molecular structure, essential oils applied to the skin can be absorbed into the blood stream. They can also reach the blood as a result of the aromatic molecules being inhaled. Once in the bloodstream the aromatic molecules interact with the body's chemistry.

Essential oils are used in the food industry as flavouring, in the cosmetic industry for fragrances and in the pharmaceutical industry for their functional properties. The primary markets are the flavour and fragrance industries, including soft drinks, food and perfumery companies. These industries consume nearly 90% of the worlds essential oil production. These commercial markets require reliable supplies of a consistent, high quality, price competitive product.

UK GIFNFC[155] figures suggest that world production of the different types of essential oils ranges between few hundred kilograms and several thousand metric tonnes per year. The global production of essential oil was 60,000 tonnes in 2000, which was valued at 466 million Euros (an

[155] Government Industry Forum for Non-Food Crops (**http://148.252.1.12/gifnfc/index.asp**)

average of 7,700 Euros per tonne) and this is growing at around 4% per year. Included in this are 4,000 tonnes of mint oils and 1,600 tonnes of lavender oils. The US is the largest user of essential oils, importing an estimated 305 million Euros of essential oils in 2000. Much of the expected growth in the demand for essential oils comes from industries that are responding to a growing consumer demand for natural alternatives for food, cosmetics, toiletries and medicines.

Ten major essential oil crops account for 80% of the world market for essential oils. The remaining 20% of the world essential oil market comprises over 150 crops. The major consumers of essential oils are the USA (40%), Western Europe (30%) and Japan (7%)[156].

Table 2 The World's 20 Essential Oils, 1993

Essential Oil	Species	Volume (tonnes)	Value ($x10^6)
Orange	*Citrus sinensis* (L.) Osbeck	26,000	58.5
Cornmint	*Mentha arvensis* L. f. *piperascens* Malinv. ex Holmes	4,300	34.4
Eucalyptus cineole-type	*Eucalyptus globulus* Labill., *E. polybractea* R.T. Baker and other Eucalyptus species	3,728	29.8
Citronella	*Cymbopogon winterianus* Jowitt and *C. nardus* (L.) Rendle	2,830	10.8
Peppermint	*Mentha xpiperita* L.	2,367	28.4
Lemon	*Citrus limon* (L.) N.L. Burm.	2,158	21.6
Eucalyptus citronellal-type	*Eucalyptus citriodora* Hook.	2,092	7.3
Clove leaf	*Syzygium aromaticum* (L.) Merr. and L.M. Perry	1,915	7.7
Cedarwood (US)	*Juniperus virginiana* L. and *J. ashei* Buchholz	1,640	9.8
Litsea cubeba	*Litsea cubeba* (Lour.) Pers.	1,005	17.1
Sassafras (Brazil)	*Ocotea pretiosa* (Nees) Benth.	1,000	4
Lime distilled (Brazil)	*Citrus aurantifolia* (Christm. & Panz.) Swingle	973	7.3
Native spearmint	*Mentha spicata* L.	851	17
Cedarwood (Chinese)	*Chamaecyparis funebris* (Endl.) Franco	800	3.2
Lavandin	*Lavandula intermedia* Emeric ex Loisel	768	6.1
Sassafras (Chinese)	*Cinnamomum mic*ranthum (Hayata) Hayata	750	3
Camphor	*Cinnamomum camphora* (L.) J. Presl.	725	3.6
Coriander	*Coriandrum sativum* L.	710	49.7
Grapefruit	*Citrus paradisi* Macfady	694	13.9
Patchouli	*Pogostemon cablin* (Blanco) Benth.	563	6.8

Source: Lawrence, B M (1993) *A planning scheme to evaluate new aromatic plants for the flavour and fragrance industries* In: J Janick and J E Simon (eds.), New Crops. Wiley, New York p620-627

The most significant production of essential oils in Europe is in France and Bulgaria. 65 tonnes of lavender oil was produced in France in 2000 (30 tonnes were produced in 1992) and 1,350 tonnes of lavandin oil in 2001. In 1997 the French essential oils interprofessional corporation – CIHEF – was created, allowing the professionals to work together in a legal framework and to maintain national productions of lavender and lavandin. Before the creation of CIHEF lavandin was submitted to wide fluctuation of prices and each crisis led to underproduction and overproduction periods.

In Bulgaria in 2002, 32,000 ha of essential oil crops were grown, the main crops being rose (1,500 ha); lavender (2,900 ha); coriander (26,900 ha) and mint (140 ha). The area has seen an increase due to increasing interest from farmers plus financial support from the state fund.

It is noted in the Polish report that application in this sector is limited by the economic problems of the companies producing and processing herbs. There has been a significant decrease in the number of these companies, as well as a reduction in the essential oil distilleries. Domestic

[156] Australian New Crops (**www.newcrops.uq.edu.au**)

production of essential oils is therefore much lower in the 1980's, being replaced by cheaper imports and facing strong competition from synthetic oils. Also, marketing and advertising is expensive and is a significant constraint for SME's. The total use of essential oils in Poland is 60 tonnes per year.

IENICA has published a Market Information Sheet for essential oils (see **www.ienica.net**), with information on crop specification, vegetable raw material specification, component specification, market and market potential as well as a list of vegetable material and essential oil producers. Information is provided for the following plants:

- Garden Angelica - *Angelica archangelica* L.
- Caraway - *Carum carvi* L.
- Coriander - *Coriandrum sativum* L.
- Sweet Basil - *Ocimum basilicum* L.
- Damask Rose - *Rosa damascena* Mill.
- Garden Sage - *Salvia officinalis* L.
- Clary Sage - *Salvia sclarea* L.
- Garden Thyme - *Thymus vulgaris* L.
- Lemon Balm - *Melissa officinalis* L.
- Lavender - *Lavandula angustifolia* Mill., *Lavandula hybrida* R.
- Milfoil - *Achillea millefolium* L.
- Common Fennel - *Foeniculum vulgare* Mill.
- Peppermint - *Mentha piperita L., Mentha crispa* L.

For further information on essential oils see www.ienica.net for the Essential Oils Market Information Sheet.

Medicinal Plants
The market is divided into:

a) Medicinal - 'over the counter' drugs, with proven disease-related claims for activity and subject to licensed medicine controls. These products are controlled by large companies because they require large budgets to develop, test and market new products. Generally characterised by integrated production chains.
b) Herbal supplements/remedies – Improvement of well being. The market comprises a large number of products including herbal teas, preparations and natural remedies. Limited regulatory control; known, used and adopted partly because of their long record of use.

The World Health Organisation estimates that up to 80% of the worlds' population relies mainly on herbal medicine for primary health care. In China, traditional medicine is largely based on around 5,000 plants which are used for treating 40% of urban patients and 90% of rural patients. In 1991, more than 700,000 tonnes of plant material were used for the preparation of medicines in China, of which 80% were collected from the wild[157].

In industrialised countries, plants have contributed to more than 7,000 compounds produced by the pharmaceutical industry. Around one in four of all prescription drugs dispensed by western pharmacists are likely to contain ingredients derived from plants. Cultivation has replaced collection for the supply of some essential drugs used in modern medicine.

[157] WWF

Pharmaceutical companies have moved away from natural products because of the benefits of combinatorial chemistry and high-throughput screening. The reasons for this are complex but include a belief in greater returns per unit of expenditure, better control over intellectual property and a realisation of the inherent difficulties in managing a plant-based supply chain[158]. Nevertheless, *"the structural complexity and proven activity of phytochemicals remains an inspiration for many companies with development pipelines to fill, and the derivation of natural compounds can both improve efficacy and give a powerful IP position"*.

Many widely-used drugs that were first extracted from plants or inspired by research into the active principles in plants, are now synthesised. The best known example is probably aspirin, chemically related to a compound that was first extracted from the leaves and bark of the willow tree (*Salix alba*), and a herb, meadowsweet (*Filipendula ulmaria*).

In recent years the most popular herbal remedies in Europe and North America have been gingko, ginseng, echinacea and garlic. While scientific testing of herbal medicines is increasing, understanding and reporting their efficacy and possible side effects from trials – if carried out at all – have necessarily been undertaken retrospectively. However, herbal medicines are an essential and growing part of the international pharmacopeia. Knowledge of their medicinal properties is growing as a result of research and testing, which will make them an increasingly safe alternative or a preferred option to western medicine. *"However, much of the market relies on unsustainable sourcing by underpaid collectors – a precarious foundation for any industry. Customers need to know what they are buying and to understand how they can influence the security of their supplies"*[159].

The previous IENICA report (2000) noted that the global market for herbal supplements exceeds $15 billion, with markets worth about $7 billion in Europe (37% of which is in Germany), $2.4 billion in Japan, $2.7 billion in the rest of Asia and about $3 billion in North America. The US market is growing at a rate of about 15% per year. Estimates suggest similar growth rates in other areas. These figures are confirmed by PhytoPharm Consulting in Germany[160], which gives the European market for botanicals as herbal medicines, over-the-counter, and dietary supplements falls somewhere between US$6.5 billion and US$7 billion. The IENICA national report for Germany gives a worldwide turnover of herbal medicines and food complements of US$20.3 billion in 2003 (an increase from US$12.4 billion in 1994). Even though the increase has slowed during recent years, it is still a growing market, which is due to a shift in health and nutrition awareness. Within the European community, the biggest markets for phytopharmaceuticals are Germany and France, which comprise two-thirds of the total EU market. This is shown in Figure 1. In Germany many of the herbal medicines are registered as drugs, prescribed by doctors and reimbursed by healthcare providers, indicating just how accepted in mainstream medicine they are. However, in England, Belgium and the Netherlands, botanical use is limited to dietary supplements, as in the US.

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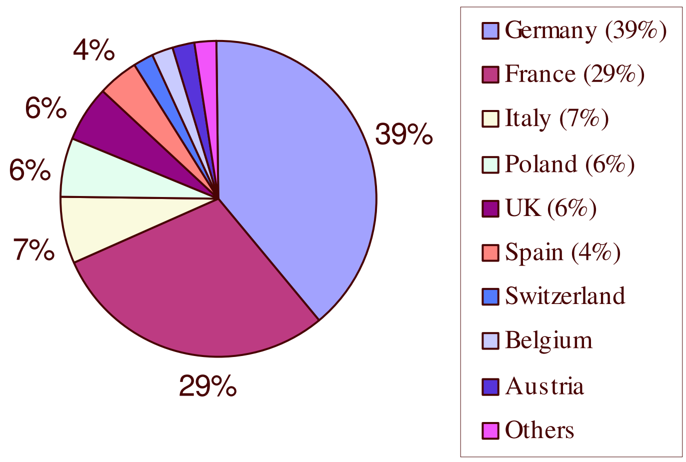
[158] Theoblad, T., Walker, I., & Stewart, C (2003) *Quality and Risk Management in Botanical Supply Chains* Pharmaceutical Manufacturing and Packing Sourcer, Winter 2003
[159] WWF
[160] **http://www.analyze-realize.com**

Figure 1 European Herbal Market, 2002, Market share % based on value sales
Total Market: approximately US$3 billion, ex factory



Source: EMEA Herbal Medicinal Products Working Party, 2002

The most significant part of the speciality plants grown and collected from the wild in Europe, both EU-15 and the newly accessed states, is for medicinal uses. Imports are significant as domestic production only meets a small proportion of demand (i.e. 5-10% in Germany, 30% in France). About 30% of the prescription free remedies in Germany are herbal medicines. The area in Germany is approximately 5,400 ha, with 15 species dominating 82% of the cultivation area. In Bulgaria, another major producer of speciality plants in Europe, around 40 plants are grown for the pharmaceutical industry and herbal remedies. A large proportion of these are exported as raw material (most European countries are net importers of products).

With the rapidly developing growth of this market, pharmaceutical companies are positioning themselves to compete for the approved herbal pharmaceutical market of the future. They will probably define three levels of control: control of the raw materials (the plants); control over the extraction/processing/manufacturing process; control of the final product. Advances in analytical techniques, such as Gas Chromatography (GC), Gas Chromatography-Mass Spectroscopy (GC/MS) and other separation techniques will help to characterise and standardise the complicated botanical mixture and support patent claims.

Council Regulation 2309/93 EEC, of July 1993, laid down Community procedures for the authorisation and supervision of medicinal products for human and veterinary use, and establishing a European Agency for the Evaluation of Medicinal Products (EMEA). IN 2001, the EMEA established a permanent Working Party on Herbal Medicinal Products. With delegates from all EU-15 countries this Working Party has a mandate to:

- Develop new guidance on quality, safety and efficacy and of common criteria for interpretation
- Establish and regular update of a common understanding of existing legislation and guidelines

In April 2004, the Traditional Herbal Medicinal Products Directive (2004/24/EC) was published in the Official Journal of the EC, amending, as regards traditional herbal medicinal products, Directive 2001/83/EC on the Community code relating to medicinal products for human use. These amendments, among other things, will provide for a simplified registration procedure, to be implemented from 2006. This therefore offers good chances to launch new herbal products and general growth in the next 2-3 years.

Perfumes and Cosmetics[161]

A large number of the plants grown or collected for their speciality uses throughout EU-25 have applications in cosmetics and perfumes and this is a growing industry, with the increasing recognition of the benefits provided by plants. In Germany, 5% of the speciality crops are used in the cosmetics sector.

For thousands of years the fragrance industry relied entirely on natural feedstocks such as flowers, wood, leaves, roots and animals. This changed in the 19th Century with the development of synthetic organic chemistry. Nature-identical ingredients could be used to replace rare or expensive natural chemicals and non-naturally occurring ingredients could be used alongside natural oils to produce new fragrance effects i.e. Chanel 5 (1921) – the first to use non nature-identical chemicals. This offers new smells, originality and improved performance. Many of the synthetic materials (both nature identical and non-nature identical) can be prepared either from vegetable (hence renewable) or mineral (hence finite) sources and the balance between these depends on a variety of factors.

Feedstocks currently used by the fragrance industry are:

- Essential oils } Always from renewable materials
- Isolates and derivatives }
- Petrochemicals

The majority of fragrances are made from both renewable and petrochemical sources.

This industry can be segmented as follows:

- Industrial scents (detergents): Cost price is the determining factor in this sector. The only sustainable substances are those that are cost-competitive with imported or synthetic products e.g. lavandin.

- Cosmetics and perfumes: This sector comprises essentially body care products but many include a mixture of materials, including perfume, in formulations. There are a number of plants with historical basis for skin treatment e.g. *Calendula* but little scientific data. The Body Shop has significantly increased interest in this type of product.

- Alcohol-based perfumes: This sector uses essential oils and other plant extracts, but must allow for competition from synthetic products (where creativity is far from exhausted) and international competitors. These factors have induced a steady fall in producer prices.

Fragrances are extracted from plants using one of three basic techniques[162]:

- Expression: the simplest technique; oils are forced out by physical pressure. The product is called expressed oil and the method is commonly used to produce citrus oils.
- Distillation: Either by dry distillation, steam distillation or hydrodiffusion. These methods are common to obtain essential oils, like lavender oil.
- Solvent extraction: Solvents like ethanol, benzenes, petroleum ether, acetone, hexane and ethyl acetate are commonly used. Carbon dioxide has also been developed as a useful

[161] Some information in this section sourced from Charles Sell, Quest International (**www.questintl.com**)
[162] Green Chemistry Network (**www.chemsog.org**)

solvent; it is easily removed and does not have problems with residual levels. However, the high cost of liquefying carbon dioxide limits its use.

Speciality Chemicals – colourants, dyes[163]

Natural dyes are a class of colourants extracted from vegetable matter and animal residues. They can be broken down in the following categories:

Table 3 Categories of Natural Dyes

Colours	Chemical Classifications	Plant Sources (common names)
Yellow and Brown	Flavone Dyes	Weld, Quercitron, Fustic, Osage, Chamomile, Tesu, Dolu, Marigold, Cutch
Yellow	Iso-quinoline Dyes	Barberry
Orange-Yellow	Chromene Dyes	Kamala
Brown and Purple-Grey	Naphthoquinone Dyes	Henna, Walnut, Alkanet, Pitti
Red	Anthraquinone Dyes	Lac, Cochineal, Madder (Majithro)
Purple and Black	Benzophyrone Dyes	Logwood tree
Blue	Indigoid Dyes	Indigo, Woad
Neutrals	Vegetable Tannins: gallotannins, ellagitannins and catechol tannins	Wattle, Myrobalan, Pomegranate, Sumach, Chesnut, Eucalyptus

Source: RAISE

Indigo is the primary natural dye, with an estimated 16,000 tonnes produced worldwide.

Historically, natural dyes were used to colour clothing or other textiles, and by the mid-1800's chemists began producing synthetic substitutes for them. By the early part of this century only small percentage of textile dyes were extracted from plants. Figures from the UK GIFNFC suggest that, of a world market for textile dyes worth £2.5 billion, natural dyes are 1% of this. Lately there has been increasing interest in natural dyes, as the public becomes aware of ecological and environmental problems related to the use of synthetic dyes. Use of natural dyes cuts down significantly on the amount of toxic effluent resulting from the synthetic dye process.

Natural dyes generally require a mordant, which are normally metallic salts of aluminium, iron, chromium, copper and others, for ensuring the reasonable fastness of the colour to sunlight and washing. Issues with natural dyes are that only a few natural dyes have good all round fastness and most natural dyes produce comparatively dull shades. These limit application in some market sectors e.g. personal apparel.

As reported by RAISE, an important issue to note is that industrial dye manufacturers started to develop new 'organic dyes' which have largely replaced the heavy metal-based inorganic synthetics while preserving the same colour quality with minimal toxic residue, in an effort to decrease the environmental burden. This development has started to erode natural dyes' domestic

[163] Much of the information in this section is sourced from RAISE

market share in the US and EU. US demand for organic colourants, including dyes and organic pigments, is forecast to increase by nearly 4% per annum to more than $3 billion in 2003[164]. As a result of this increase, natural dyes will exhibit decline again in the textile sector within the next five years as well as suffer from intense competition and strong downward pricing pressure from Asian (principally Chinese and Indian) imports. Larger growth is expected in the natural colourants market for food, drugs and cosmetics where certain dyes, such as carmine and annatto, are used regularly. Smaller amounts of natural dyes are also used in colouring paper, leather, shoe polish, plastics and paints.

US import figures show that Italy, the Netherlands, France, Germany and Ireland are source countries for natural dyes (Italy, the Netherlands and France in the top 5 source countries).

Eurostat figures show that, in 1998, the EU[165] imported 5,538 tonnes of natural dyes and preparations, including natural colourants (an increase of 64% from 1994), as shown in Table 4. This import market had a value of 63million Euros in 1998, with an increase of 46% from 1994. The primary importers in Europe for natural dyes and colourants are Germany (32%), France (17%), Italy (14%) and the UK (10%). The EU (and US) import market supply of natural dyes is dominated by Mexico. As Table 4 shows, the EU also imports from China, the US and Peru, most significantly. It is expected that China's import market share (20% of the EU market in 1998) will increase, as it now produces over 500 varieties of natural and organic dyes, which account for 25-30% of total world output today. It is expected that the natural dyes import market share will stabilise (due to organic dyes, as described above), while natural colourants import market share will increase, as consumers demand higher levels of natural ingredients in foods.

Table 4 EU Imports of Natural Dyes and Preparations, 1994-1998, Volume (tonnes)

Source	1994	1995	1996	1997	1998
Mexico	1,513	1,796	1,446	1,175	1,257
China	213	296	516	887	1,136
United States	431	510	343	757	782
Peru	165	327	479	592	761
India	87	113	136	252	294
Poland	2	3	8	117	172
Tunisia	147	127	92	96	135
Kenya	10	78	49	27	124
Switzerland	198	168	171	193	117
Ethiopia	75	47	36	122	112
Others	543	649	692	630	648
TOTAL	**3,384**	**4,114**	**3,968**	**4,848**	**5,538**

Source: RAISE

This is a much smaller sector in EU-25 than most of the others but is gaining interest and development. Research is reported in, among others, Finland and France (i.e. research into indigo from woad and *Polygonum tinctorum* in Finland) and in Italy 6-7 ha of plants (woad – *Isatis tinctoria*, safflower – *Carthamus tinctorius*, weld – *Reseda luteola*, madder, *Rubia tinctoria)* are grown for use as colourants in textiles, food and pharmaceuticals.

IENICA experts from University of Gembloux in Belgium[166] suggest the following patterns in the use of natural dyes in Europe:

[164] RAISE
[165] Assumed to be EU-15 as 1998 figures
[166] André Falisse and Corina Scubli, Crop Production Department, Gembloux Agricultural University (2003) IENICA International South Europe Symposium: Non-Food Crops: From Agriculture to Industry, Bologna, Italy

- Textiles: Growing demand for 'fashion' wear and domestic textiles (housing) in relation to 'organic agriculture' and an 'ecological way of living'
- Paints & varnishes: Depends on regulations, legislation
- Arts & crafts: Pigments, colours. Unpredictable development
- Inks: Demand and supply exist; demand could increase
- Edible dyes and related (medicinal, cosmetics, health & body remedies): Demand and supply exist; current supply is less than the growing demand.

Quality standards for natural dyes vary widely. The problem arises with standardisation of the colours as no two dye lots are identical. While paint manufacturers might be interested in the uniqueness of each batch of colour produced, technicians in the pharmacology, food and textile industry need total consistency. This latter group has attempted to standardise natural dyes by imposing a colour index that attempts to classify and name them.

The decline in the natural dye industry was confirmed at an industry workshop in the UK, held by the Government Industry Forum for Non-Food Crops. Industry experts noted that, in the UK, the dyeing industry has declined from a value of over £100 million in 2000 to an estimated £50-£60 million in 2002. It was suggested that the decline of the textiles base is unlikely to be revitalised, as it is a capital-intensive industry. Very few dye houses in the UK have new capital to invest in the industry.

Recommendations for increasing natural dyes' market share include[167]:

- Improve plant yields and dye concentration of targeted botanicals
- Establish long-term sustainability and dye yielding substances
- Increase technical ratings, lower costs and improve reproducibility for the textile markets
- Develop a full spectrum of quality natural dye extracts (primary colours and black) along with the best application technology and ecological processes
- Develop the necessary technology to apply natural dyes to wood, floral, leather, cosmetics, paper and personal care products
- Develop a global marketing strategy to educate the consumer on the economic, ecological, aesthetic and social advantages of natural dyes

RAISE suggest that:
"Developing countries figure prominently in this equation because of their low labour rates that will help offset the higher costs of the natural dyeing process. In addition, many developing countries have long traditions of natural dye use, and possess a constant supply of raw materials to extract dyes. Natural-dyed products thus represent a good opportunity for value-added exports from countries that already are world leaders in textile manufacturing, but on the whole the natural dye market does not show signs of much expansion, as industrial dye manufacturers fight to secure a growing market share for their organic substitutes."

Novel Products
This is an area which is seeing some significant developments and increasing interest. The last report showed two developing areas:

[167] RAISE

- Bulk production of pharmaceutically-active proteins such as antibodies and industrial enzymes from plants. There has been considerable research activity and the interest is now in their application to a wide range of problems related to agriculture.

- Agricultural pesticides and sprout suppressants. Carvone, a volatile component of Caraway oil has been shown to suppress sprouting of potatoes. Recently the attractant pheromones produced by sexual female aphids has been identified and a plant source identified for future development. The area of biocides has been shown to be very promising in Italy, and is nearing the commercial production of antiparasitic products based on glucosinolates from Brassicas. Also, cruciferous crops (mostly radish and mustard) were grown for soil disinfestation from nematodes on 5,000ha in 2003. Activities reported in Israel include: rapeseed oil, used to enhance the effect of other plant production chemicals (used in tobacco farming to inhibit the growth of side stalks); sunflower seed oil and the juice from the tobacco leaf) as insecticides.

There is significant market potential[168] for natural anti-microbials, and increasing legislative pressure covering the use of chemicals in food and the growing problem of anti-microbial resistance are driving industrial interest.

Anti-microbials are agents that are designed to reduce or mitigate the growth or development of microbial organisms. Their use leads to either death or arrested growth of the target microorganism. Since their discovery in the early 1900's, anti-microbial agents have transformed the prevention and treatment of infectious diseases and are now used across a very broad spectrum of markets.

In 2000, the global market for all anti-microbial compounds was estimated to be almost $40 billion and a high growth rate is forecast. The US dominates the market with a 41% share. The most prominent sector is the pharmaceutical market, which will drive growth over the next ten years, doubling itself to $69 billion. There are four main sectors, reflecting the largest market opportunities for existing and novel agents:

- Hygiene (both industrial and domestic)
- Food and personal care
- Pharmaceutical and animal health
- Plant health

These are complemented by a broad spectrum of other industries including drinking and industrial water treatment, textiles, leather and plastics, paints, coatings and adhesives, pulp and paper production, petroleum, metalworking fluids and wood preservatives.

There are a large number of agents and applications leading to a very complex market.

The majority of industries predominately use synthetic anti-microbial agents. These have been designed and developed to fulfil specific roles in each application. Naturally occurring anti-microbial agents are abundant in the environment and are produced by plants, animals and microorganisms. Their activity has been demonstrated naturally occurring anti-microbials have found commercial applications (tea tree oil and neem oil are successful examples), such that the scientific study of natural pesticides is becoming recognised as a very practical endeavour.

[168] GIFNFC

There is a range of market drivers for the development of new anti-microbials including:

- Consumer demand for minimal processing and limited use of synthetic chemicals in food, hygiene and personal care products
- Regulatory pressure to reduce the volumes of toxic chemicals used in industry
- The growing problem of anti-microbial resistance
- Legislation to cover all of the above

Economists estimate that research and development for a new product requires at least a 10 year investment and that investment can only be recovered if the product has a market value in excess of $100 million. Investment into plant derived compounds is limited as only a small number of plant derived products fall into this category of novel products.

The worldwide market for biocides is estimated at £2.7 billion per year and is growing at 4% per year. However, in Europe the biocides industry is undergoing a dramatic transformation as a result of the EU's Biocidal Products Directive (98/8/EC) of 1998. This is aimed at establishing a single European market in biocides by introducing a harmonised authorisation system based on assessment of risks to people and the environment, together with consideration of efficacy. The Directive requires the authorisation of a wide range of biocidal products that currently do not require authorisation, including disinfectants, preservatives and a number of other specialist products, as well as non-agricultural pesticides currently approved. The Directive will not apply to products already subject to European legislation including plant protection products, human medicines, veterinary medicines, medical devices or cosmetics.

If plant derived products with biocidal claims are to be approved under the Directive, approval for use in the EU must be obtained. This is an extremely costly process and it is predicted that many small and medium sized businesses will not survive. It is estimated that it will cost the biocides industry £340 million to meet the new requirements.

Despite these barriers, there are vast opportunities to be exploited for the use of anti-microbials from plants, especially as legislation becomes stricter and consumer demand for natural products increases. Within the hygiene industry it me more difficult to identify strong broad-spectrum anti-microbials from plants, due to the nature of the compounds. However, in pharmaceutical and animal health, there are many opportunities for the development of alternatives to the currently used synthetic drugs.

Barriers to Progress

Barriers as identified in the original IENICA report are outlined below in boxes A-Q; whilst some improvements have been made these issues still exist and still hamper the development of the industry. Additional constraints and issues raised by the newly accessed states are also described.

Crop Production

A

The large number of plant species involved means that the potential for improved plant productivity and management is limited, except for those species being developed by major pharmaceutical companies. Identification of most important species for support is desirable. Cultivation methods which reduce labour input are essential to enable EU producers to compete on the world market. Organic production systems are likely to be required to maximise product price, particularly *in the human health product market. This poses problems of developing efficient and sustainable organic production systems. Traceability is a key element in crop production.*

This is still relevant.

B
The identification of threatened species, which are currently harvested from wild stands is important to ensure environmental sustainment and a continued supply of plant material. A domestication programme should be short or alternative species identified.

More effort is needed in this area though the issue is more complex than just producing a former wild plant in cultivation.

C
Many species require hand harvesting, resulting in high production costs. While some progress has been made further effort is required in this difficult area.

This is still relevant.

D
Efficient processing is important, most crops are processed using well tried technology. The development and application of new processes is important to maximise product extraction efficiency.

These novel technologies may well offer new opportunities to exploit minor metabolites from commodity crops too e.g. oilseed rape.

Additional constraints identified since the previous report:

- The cost of establishing a field of a speciality crop can be prohibitively expensive and take some considerable time from establishment to first harvest (e.g. ginseng in Denmark; three years to establish, costing around 80,000 Euros). In addition, for a new crop suitable extraction facilities may not exist and the crude material may need to be exported.
- Market saturation from similar products can limit the development of any one plant. This is particularly true for competition between the Eastern European and former Soviet Union countries and can result in stagnation or a decrease in prices. Producers from other regions (e.g. Egypt, Israel, Morocco and China) have heavily increased the oversupply.

Constraints identified by the **newly accessed states**:

- Whilst the interest in the cultivation of non-food crops is increasing, in some accessing states there is limited experience of non-food industrial applications and significant improvement can be expected with the investment and know-how coming from the most advanced EU countries.
- The decrease in area cultivated in Romania since early the 1990's is due to the fact that the large dispersion of cultivated areas has not allowed development of a satisfactory traceability and reproducible quality of the vegetable material, as European legislation requires.
- Modernisation of production machinery is required in many newly accessed states.
- Comprehensive statistics and information on the production and markets of specialist crops are scarce. Growers and producers underestimate the relevance of know-how and innovations.

- Breeding and seed production is being developed too slowly for market need.
- More emphasis on breeding for tolerance to diseases is required.
- Obtaining a vegetable-based product involves complex research and there is often a lack of co-ordination between the different research areas. In addition, old-fashioned approaches are common amongst researchers.
- The cultivation of specialist crops depends on the requirements of the end-use industries as well as on market prices. These are regulated by the world market and in many cases it is more advantageous to import special crops or raw substrates from Asia or Latin America because of their lower cost than to grow them in Europe.
- Traditionally in Hungary the dried plants are supplied to the rural distributors and they export the raw material to foreign countries; the processing is carried out in these countries. Recently the situation has somewhat changed and farmers are often in direct contact with importers and processor companies. However, this requires people skilled in foreign business, who are often not available at the farm level.
- In Poland, it is reported that the main issue limiting the development of research in the scope of medicinal plants is insufficient financial government support. Efficient support would allow: the elaboration of novel cultivation technology helping with the introduction of new herbal species or modification of good agriculture practices for already cultivated species or cultivars with a new direction of application e.g. for medicine, nutrition or cosmetics; breeding new cultivars, which provides high quality raw material into medicinal plant processing (thereby increasing cultivation profitability); introduction of modern plant protection products; protection of Polish natural resources of domestic medicinal plants; implementation of novel methods for the dissemination of research results.
- A low level of applied agronomic practises (Poland).
- Not many registered plant protection products (Poland).
- Low level of mechanisation (Poland).
- In Poland, there is a significant dispersion of the herbal plants cultivation area (20,000 farms).

Industrial Use

E
Traditional uses are generally well developed, but there is scope for the substitution of synthetic and imported materials. New uses, particularly those with potentially high value products, need continued development. Particular attention should be given to medical and novel uses and the substitution of synthetic products.

This is still relevant.

F
Specification of quality requirements are generally poorly defined, improvement can help whole industry.

However, this may mean a new approach being development by end users, since basic organoleptic or traditional visual standards are often used at present.

Additional constraints identified since the previous IENICA report:

- Industry wishes to keep a maximum of freedom and prefers to rely on the international markets for finding the raw materials at the best price or technical condition. Industry is reluctant to address domestic agriculture in order to contract production volumes of a specified quality at a determined price (Belgium).

- The capacity of agriculture to invest in industrial processing is too weak (Belgium).
- In France, a steady drop in producer prices for alcohol-based perfumes has been seen, induced by international competitors, although the French industry has performed well in export markets.

Constraints identified by the **newly accessed states**:

- Limited investment capacities of small producers; small and marginal production; out-of-date production facilities (Lithuania).
- Not enough drying facilities (Poland).
- The production of modern cosmetics requires novel technological systems, allowing high quality production according to the requirements of ISO standards and the requirements of the Polish regulations, which permit these products on the market. The requirements allowing for the registration certificate are on the European level (Poland).

Economic

> **G**
> *Crop production is generally high risk, with crop performance and quality and end product price volatility. There is need for greater co-operation and some sort of vertical integration amongst producers, processors and end product manufacturers to ensure improved economic returns from more stable production, assured production systems and improved product quality.*
>
> This is still relevant.

Additional constraints identified since the previous report:

- Whilst speciality products are very promising in terms of environmental impact and scientific advances (e.g. plant dyes), the economic cost is still a limiting factor (from 10 to 100 times more expensive than mineral pigment depending on the colour)

Constraints identified by the **newly accessed states**:

- The farmers of some accessing countries who have grown medical plants and herbs may find it difficult to compete with the Western European and world market, although the quality and also the quantity of some species are much superior than in the other supplier countries. The low price of the labour intensive production can be a benefit in these countries.
- Few legislative and economic measures are directed to the development of non-food crops is a major barrier (Lithuania).
- Increased competition is faced from producers in the Mediterranean region and in Africa.
- Not enough stabilised markets for herbal raw materials (Poland).
- In Poland, the producers of herbal raw material are not associated in the powerful producer co-operatives.
- There is low financial support for scientific research in the field of medicinal plants (Poland).
- In Poland, it is reported that the application of domestic herbs and essential oils for cosmetics and aromatherapy is limited by the economic problems of many companies producing and processing herbs. A significant reduction in the number of earlier existing companies is observed, as well as a reduction in the number of distilleries of essential oils. Therefore, the domestic production of essential oils is much lower than in the 1980s, replaced by imports, which are available more cheaply. There is a strong competitiveness with artificial fragrances and essential oils. Marketing and advertising is expensive and it is a significant constraint in the development of small and medium sized enterprises producing herbal cosmetics.

- Regarding natural dyes, there is strong competition with artificial dyes, and natural dyes are more expensive than synthetic (Poland).
- It is reported that, in Poland, natural products for crop protection are produced mostly for horticulture purposes and large amounts applied at a plantation scale would probably be too expensive, as prices are rather high. The registration process is long and the Ministry of Agriculture and Rural Development grants the relevant certificates. The effectiveness of the natural crop protection products is not as immediate as that of traditional pesticide, which also constrains large-scale applications. Additionally, there are no taxes on synthetic pesticide - seldom up to 3% - to facilitate the application of biocides on a large scale. There is strong competition with chemical crop protection products.

Environmental

H
The transfer from wild harvesting, particularly of vulnerable species, to cultivation is a major environmental challenge. It is essential to maintain consumer confidence and product demand.

This remains a significant issue in this sector, particularly with regards to the newly accessed states. An EU-wide strategy needs to be developed in this area.

I
While the natural status of products derived from plants is reasonably well known in the herbal remedy/cosmetic area, they are less well communicated to the general public in other areas. Education and promotional events coupled with EU wide schemes to label natural, environmentally friendly products would enhance consumer demand.

This is still relevant.

J
Many plant species require minimal or no (organic) inputs of chemicals and fertilisers and are therefore environmentally desirable. Identification of their production status (e.g. organic) should be encouraged and further labelling introduced.

With the increased interest in natural and ‘pesticide-free’/‘fertiliser-free’ herbs there is an increased interest in organic production, although production as measured by tonnage is lower in these systems than in traditional farming systems. An ‘accredited organic MAP-producer’ status is desirable to exploit and manage this trend.

Legislative

K
To enhance the development of plant products and to meet International Agreements on Climate Change and Biodiversity an EU legislative framework/strategy should be

established. This would be particularly aimed at extending the legislation with regard to identifying sustainable and organic products.

It should also cross-link objectives in the various related strategies in the European Commission.

L
The legislation regarding the licensing and monitoring, particularly of herbal products, appears to vary across the EU. There is need to formalise this situation to protect the consumer: a review and recommendations for action are required.

This is still relevant.

M
The protection of intellectual property rights (IPR) and registration procedures for naturally developed plant products is confusing and can be prohibitively expensive. Clarification and simplification is required to encourage further innovation.

However, it has to be recognised that in some instances there is no likelihood of IPR being achieved. Should the European Commission carry costs of developments for the public good in such cases?

Constraints identified by the **newly accessed states**:

- In many countries a strategy to encourage the production or utilisation of speciality crops is absent.
- In Poland, it is reported that the main issue limiting the development of research in the scope of medicinal plants is insufficient financial government support.
- In Poland, the cultivation of several special species is regulated or forbidden: *Papaver somniferum*, *Digitalis* sp., and *Cannabis sativa*. Special, official permissions are required to cultivate those plants, provided by local authorities and the Ministry of Agriculture and Rural Development.
- All products, which could influence human health must be tested, approved and certified (registration certificate). However, very restrictive processes of certification take a very long time and involve high costs for the producers, which significantly limits the fluency in the development of cosmetics production on a herbal basis (Poland).

EU Actions

N
The status of specialist crops within the CAP is confused and few benefit from the support given to mainstream agricultural crops. This policy should be reviewed.

The status is still confused. Clarification of rules under CAP reform and a definitive, coherent, strategy for biorenewables overall, is essential.

O
Plant product specifications are poorly defined; to assist the EU trade specifications should be introduced to standardise product qualities.

This is essential though a challenging requirement.

Communication

P
Communications between the main participants in the specialist crop area, farmers, seed vendors, storage operators, research bodies, processors and industrial users need improvement. Only by multi-path communication will the confidence and requirements of all parties be defined and understood and implemented.

This is still relevant.

Q
Communication, through promotional programmes of the new products and their environmental benefits to industrial and domestic users, will help to overcome lack of knowledge and enhance product demand.

This is still relevant.

Annexes

A: Largest oilseeds and oils imports/export flow 2003
B: FAOSTAT Oilseeds Data, 2004
C: Fediol Oilseeds and Oils Data, 2002
D: Crushing of Main Oilseeds, 2003
E: Foreign Trade in Starch Products
F: Statistics for Bulgaria
G: Statistics for Cyprus
H: Statistics for Czech Republic
I: Statistics for Estonia
J: Statistics for Hungary
K: Statistics for Israel
L: Statistics for Lithuania
M: Statistics for Poland
N: Statistics for Romania
O: Statistics for Switzerland
P: References

Annexes available from the IENICA website: www.ienica.net