

Interactive European Network for Industrial Crops and Their Applications

M.F. Askew

INTRODUCTION

Products from plants for both the food and non-food sector more than ever before are considered essential to the economy and well being of the EU. The drivers for change include: (1) sustainability of agriculture, the rural economy and industry at large; (2) environmental protection; (3) legislation and cost of non-compliance; (4) public opinion; and (5) international agreements of various types but with the common resolution of demanding renewable sustainable feedstocks e.g. Kyoto and WTO discussions.

Countries in EU-15 have varied in their interest in and uptake of biorenewable materials, but it is probably a fair summarization of the position to say that uptake of biorenewables overall has been most successful in Germany. The development of non-food crops in recent decades was caused by the Common Agricultural Policy of EU and was essentially an alternative land use set aside for cereals, especially wheat, and oilseeds; oilseed rape, and sunflower. Rensen and Munch (1984) summarized recommendations for dealing with surplus wheat, which they envisaged being at a high level in EU by 2000. Their recommendations were:

1. That the EEC stimulates co-operation between agriculture and industry, starting by establishing agricultural refineries as demonstration units in various EEC countries.
2. That the EEC revises its present tariff system regarding cereals and cereal products and changes it to a coherent, simplified set of rules designed to stimulate efficiency in cereal production and in the industrial use of cereals, thus creating the basis for an internationally competitive biotechnology industry in the EEC.
3. That the use of straw as a fiber source should be stimulated by supporting a modernization of the present industrial process to obtain competitiveness with the wood based industries.
4. That the production of agricultural commodities in which the EEC is deficient—maize for starch, feed protein, vegetable oil, and cellulose fibers—should be stimulated by quality related premium prices of present commodities and development of new crops.
5. That significant basic research programs should be established in the industrial manufacture of cereal based products, including genetic engineering of plants and micro-organisms, purification of cereal components and their processing and modification into final products.

Clearly, many policy changes have occurred since these primary recommendations were laid and certainly much research has been undertaken in the cereals area. Equally, change in world prices and increasing deregulation of markets through GATT/WTO negotiation have made agricultural crops more economically competitive as non-food feedstocks than in the past. However, the IENICA project (an Interactive European Network for Industrial Crops and their Applications) has confirmed that much of this potential (Table 1) has yet to be exploited.

Table 1. Global non-food products from agriculture.

Source	Non-food products (million t)		
	1998		2003 Global
	EU-15	Global	
Vegetable oils	2.6	12.5	19.8
Starch	2.4	15.0	28.4
Non-wood fiber	0.5	23.4	28.4
Total	5.5	50.9	70.7

Source: IENICA

Set aside has also played a part and to an extent has formed a *de facto* support scheme for some non-food crops. Helpful though that has been, it has to be recognized that where crops are grown with full area aid, for example, rapeseed for food then there is a disincentive to grow that same plant for non-food uses. Equally changes in some EU support schemes have discouraged the development of some non-food crops, for example flax, linseed, and hemp.

THE IENICA PROJECT

The initial IENICA project ran for 3 years. It was co-ordinated by Central Science Laboratory in UK and the German partner was Fachagentur Nachwachsende Rohstoffe, (FNR), Gulzow. The fundamental underlying objective of this project was to catalyze development of non-food products from plants through technology transfer; catalyzing contact between different sectors of the industry and characterizing markets.

The IENICA project has indicated that for development of renewables to occur, a number of key processes need to be put in place.

1. Establish systems that integrate the supply, manufacturing, and distribution activities through supporting infrastructure; this enhances economic viability.
2. Improve the understanding of plant metabolism, via functional genomics, to optimize the design or use for specific value-added processes; in addition to the use of current inherent components, exploring novel polymer production and use.
3. Ensure that the development of new processes with very high efficiency accompanies secondary processes that use all components as co-products and therefore eliminate wastes, this provides economic and environmental benefits.
4. Cross-check that specific goals and research targets are consistent with those of non-food market needs and specifications.
5. Develop approaches to ensure a consistency in supply and demand; keeping factors such as price/volume, performance, geographical location, quality, etc. within defined limits on an annual production basis; developing standards for these factors.
6. Establish formal vertically integrated partnerships where producer and user of non-food products act in unison.

The IENICA project has concentrated on identifying plants/crops or co-products with non-food use, markets, and constraints. It recognizes that huge amounts of research have been funded at the basic and strategic applied levels.

There appears to have been little demand from industry for non-food biorenewables (excluding energy which is not part of the IENICA project specification). The causes identified for this are: (1) lack of awareness of opportunities; (2) lack of financial need or incentive to change; (3) investment in current technologies and lack of capital to re-tool; (4) lack of clarity in the development of non-food renewables market in political and environmental sectors; and (5) lack of market organization and guaranteed supply of primary products.

In essence, there has been much “technology push” but in many non-food product sectors, little “market pull.” The fundamental concepts behind the IENICA project are to facilitate the correction of that imbalance in a systematic and sustainable manner through identification of crops, markets, products, and industry contacts.

MARKETS AND OPPORTUNITIES

The EU overview of the IENICA market report has been used as a basis for this part of this paper. A significant contribution to this report was made by Germany, through Fachagentur Nachwachsende Rohstoffe, but because in the practical situation markets are multinational an EU perspective has been taken.

Actions Needed at EU or European Commission (EC) Level

Six Priority Areas were identified:

1. EC regulation is not well focused in terms of non-food crops. There is a need to develop and promulgate a clear concise long-term strategy for non-food crops and products. This requires co-ordination and pro-activity between DGs Agriculture, Environment, Energy, Industry, and Research.

There must be a requirement laid upon EC/EU administration to develop a coherent strategy for non-food products from plants and act in concert with it when regulations are revised or proposed. Anomalies in EC regulations should be removed including: flax and hemp regime and non-food but non-traditional markets; impact of EINECS (European Inventory of Existing Commercial Chemical Substances) and ELINCS (European List of Notified Chemical Substances Regulations) on non-food products; and plant derived crop protection products.

2. The needs of industry and the potential of agriculture need to be better understood and more clearly addressed.
3. EC policy makers should consider the total benefits of crop derived non-food products through standardized life cycle analysis procedures. Benefits should be positively promoted through the inclusion of such bio-renewables in EC tender documents for contracts. Support should be considered for the development of bio-renewable product specifications and labels to educate and identify for consumers.
4. CAP has a market distorting effect in the oilseeds (food vs. non-food) and fibers (clothing textiles vs. novel uses of fibers) sector. This needs to be examined and corrected when regimes or CAP are revised and during WTO activities.
5. The whole issue of non-food crops and products should form a coherent package within Framework 6 Programme of EC. That package should be part of the structured EC strategy on non-food crops and must be focused on industry needs and development of the rural economy.
6. Blairhouse Agreement/EC-US oilseeds agreement. Definitive statements on the long-term standing and precise meaning of this agreement are needed.

Market Opportunities

For convenience, the market was segmented into 5 broad generic areas (oils, fibers, carbohydrates, speciality products, proteins), although it is essential to recognize that this has involved some generalization. (More details are available from the European Summary Report of IENICA available on the IENICA website.) Particular emphasis had been laid on the first 3, because of their impact on use of large areas of land.

Oils. Overall usage of vegetable oils and animal fats in the non-food sector of EU-15 is approximately 3 million tonnes (t)/annum. This excludes biodiesel fuels. Key market sectors are lubricants, paints and surface coatings, surfactants and oleochemicals. Considerable potential for expansion exists, including import substitution of both vegetable oils and tallow.

1. Bio-lubricants. The potential EU market is approximately 370,000 t/annum but currently less than 10% of that potential is exploited. There are significant environmental benefits for the use of bio-lubricants where high environmental contamination occurs.
2. Bio-printing inks. The EU market is in excess of 120,000 t/annum. Belgium has made considerable progress in using vegetable based printing inks, but elsewhere, particularly outside of Scandinavia, Netherlands and Germany, usage is very small. There are no technical reasons for this lag in uptake.
3. Bio-solvents. The EU solvent market is approximately 4 million t/annum of which 1.9 million t/annum are hydrocarbon solvents. Considerable health, environmental, and security benefits would accrue from substituting vegetable derived solvents for current fossil derived materials. At least 12.5% of total market could be vegetable derived but to date less than 1.5% has been achieved.
4. Linoleum—the EC demand for linoleum is likely to rise to 56 million m² by 2003. This will generate a 64% increase in linseed oil requirement, which could be produced in the EU. Total linseed oil usage in the linoleum market in Europe will therefore be 56,000 t/annum.
5. Surfactants—the EU market is currently in excess of 2 million tonnes/annum and increasing. By 2005, domestic household use of surfactants alone is likely to be 1.5 million t/annum. However, expansion of surfactant production from EU grown bio-renewable sources is limited by the inability of EU to produce vegetable derived short chain fatty acids, e.g. lauric acid. Alternative feedstocks for surfactants must therefore be sought from other EU crop plants, since lauric acid derived from transgenic plants appears uneconomic in cool temperate regions.
6. Polymers. The majority of polymers are derived from petroleum but certain products are based upon, or incorporate vegetable oil-based derivatives. There appears to be considerable scope for an expansion.

sion in the use of vegetable oils in polymer production. The most widely used polymer is erucamide, derived from HEAR, used as a slip agent in polythene film.

7. Paints and Surface Coatings. Increasing use is being made of bio-solvents by the paint industry as well as the use of alkyl resins and varnishes based on vegetable oils.

Fibers. EU industry uses both home grown and imported fibers (e.g. jute). There would be considerable benefit to industry, in terms of quality and reliability of supply, if they were able to substitute imported fiber with home-produced material. In terms of specific sectors within the fibers market, clothing textiles form the traditional component and novel uses, (e.g. automotive parts), the new and developing component. The total clothing textiles market in Western Europe is projected as 7.9 million t for 2001 with a 10% increase expected by 2006. Of the textiles market, approximately 40% is supplied by natural fibers, of which wool and cotton are dominant. Undoubtedly, small and perhaps valuable niche markets exist for hemp, flax, and silk derived textiles. In the case of the former two crops, progress in development will be enhanced by technological development, although cost and fashion trends will limit potential. It should be noted that small amounts of non-traditional short fiber flax are currently spun with wool. The future of this market requires examination.

The new fibers market sector includes matting based products (e.g. simple filters, growth media, geotextiles), which tends to be lower value and composites (e.g. automobile parts, building composites) which tend to be higher value. The automotive sector should be considered as a primary market driver for the short to medium term future with Europe, producing about 18 million cars and light vans annually. Proven uses amount to 10 kg fiber/vehicle and potential likely uses in the same vehicles up to 10 kg fiber/vehicle more. Current estimate of maximum market, based upon existing automobile production, is 350,000 t/year of fiber, amounting to about 1 million t of primary product.

In insulation products plant fiber is being used to replace glass fiber, giving health, energy, and environmental benefits.

While the wood-based panel industry, producing particleboard, medium density fiberboard etc., is based on small roundwood and wood residues, there is some potential for substitution with annual fibers. However these will have to be price competitive to obtain a market share.

Paper and pulp provide options for utilization of agricultural wastes (e.g. straw) or specially produced crops (e.g. reed canary grass, *Miscanthus*). Market potential is virtually infinite but costs, processing scale, and market instability limit progress. Similarly, to reduce costs and allow sustainable economic production, scientific and technological developments are essential in terms of cellulose content, impurities, and exploitation of secondary metabolites.

Carbohydrates. Starch markets in EU and elsewhere are well developed and organized. Estimates of total EU starch market for the year 2000/2001 are 7.3 million t/annum of which 3.7 million t is in the non-food sector, 1.4 million t in paper and cardboard making, 1.1 million t in plastics and detergents and 1.2 million t in fermentation and other technical uses. Additionally, smaller markets exist in water purification, cosmetics, toiletries, pharmaceuticals, paints, and agrochemicals. Several of these latter offer high potential for added value, but limited tonnage. The development of biodegradable plastics is currently very limited.

Speciality Products. The speciality products sector offers considerable potential for bio-renewables, often at high value (e.g. personal care products), but at relatively low volume. However the market is volatile, reacting rapidly to supply and demand changes. Specifications are frequently ill defined and processing/formulation details severely restricted because of commercial pressures.

Market segments include: essential oils; pharmaceuticals; popular health products; colorants and dyes; perfumes; personal care/beauty products; novel plant protection products; and intermediates for processing

Essential oils markets worldwide are approximately 45,000 t/year and rising. However, that estimate includes an uncharacterized tonnage that could not be produced in EU. Aromatic plants have a world market in excess of 50,000 t/year. Estimates of medicinal plant markets suggest 70,000 t/year. European collection of aromatic and medicinal plants amounts to 20,000–30,000 t/year. Approximately 200 species, which are native to Europe, are involved. The European herbal supplements market is valued in excess of €7 billion/annum and demand is rising.

The global dyes market for textiles is in excess of 700,000 t/annum, with an estimated market value in 2000 of more than €4.5 billion. It seems unlikely in the extreme that plant derived dyes could supply anything

more than a minor part of this market. However, that minor part could be a valuable niche market.

Protein Crops. The use of protein derivatives from plants has not been subjected to the breadth of exploitation as other non-food crop market sectors. Current production of protein isolates and concentrates is 1 million t/year. Undoubtedly, this tonnage will increase, although currently the timescale for this is indefinable. The most promising areas for EU produced non-food proteins use is in packaging and labeling, 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 recognized. Key development will probably occur with proteins from plants as secondary products.

Constraints and Opportunities on Development

Some major generic constraints were identified and reported earlier in this paper; more specific issues of constraint and opportunity are reported here.

Legislative.

1. The requirements of anti-narcotics legislation limits the expansion of the hemp crop and in some countries (e.g. UK) adds to production costs. Development of nil THC hemp varieties and rapid diagnostics for THC containing hemp should be progressed since demand for hemp feedstocks is well established.
2. The European List of Notifiable Chemical Substances Regulations (ELINCS), and European Inventory of Existing Commercial Chemical Substances Regulations (EINECS) both apply to plant products. These are considered by industry to be expensive and constraining (e.g. in high viscosity esters) and their role and applicability to plant products should be reviewed.
3. Legislation on re-use of lubricants could offer good opportunities to expand vegetable oil use. Similarly, regulations on bio-lubricants for sensitive areas would be beneficial to the environment and should be considered EU-wide.
4. Demands for enhanced biodiversity are being progressed. The role of non-food crops, especially of novel species, should be considered in this context.
5. The regulation of plant protection and plant health products appears to be anomalous for plant derived materials: whole plants are exempt but plant components are not. These regulations should be reviewed and, if appropriate from a risk viewpoint, revised.
6. The legislation relating to all aspects of non-food crops or products should be unified across EU, since trade in these products is trans-national.
7. An EU series of standards regulating description and quality of bio-renewable materials and products should be developed in partnership with industry. It should be based upon environmental benefits. Such a scheme should be built on the principles of the Blue Angel or White Swan Eco-marks.
8. European Union regulation on wastes and waste disposal, including packaging should include aspects of bio-renewables that are beneficial to the environment.

Technical and Scientific.

1. There is a generic need to identify and characterize genotypes and cultivars with particular uses in provision of bio-renewable produce. This will not be easy in sectors like that of essential oils, where chemotaxonomy forms the only realistic taxonomic base. These characteristics should be available on websites like IENICA. Particular emphasis should be laid upon market “pull.”
2. Industry and agriculture need to be linked in a proactive manner to facilitate the production of standards and specifications against which plant produce can be measured and assessed. Short, interactive vertically integrated production chain needs to be stimulated.
3. Whilst many extraction and purification techniques for plant products are well proven, there is a need to undertake continued development and refinement in order to keep pace with market needs and to identify higher value products. Equally, there is a pressing need to indulge in lateral thinking to develop novel extraction and purification procedures which also allow the exploitation of desirable secondary metabolites.
4. Agronomic and physiological studies need to be linked to sustainable economic production and end products quality parameters. These studies should include understanding of linkages with primary and secondary plant metabolites; modeling approaches should be included since they inter-relate existing

research results and highlight areas of poor knowledge. These studies are particularly important for herbs and plants producing essential oils where much dubious data exists in the literature.

5. Processing and extraction procedures which are environmentally benign should be considered as high priority and special effort put into their development, validation, and economic demonstration.
6. Studies should be instigated to assess the extent to which initial processing of primary product can be undertaken in the production locality. This could benefit rural employment whilst reducing total production and transport costs.
7. The role of transgenic technologies in providing opportunities for novel and especially sophisticated molecules is important. Assessments need to be made of real market opportunities, since not all are economic, (e.g. lauric acid from rapeseed).

Environmental Issues. Comparative life cycle analysis studies of major environmental pollutants (e.g. NO_x, CO₂) should be undertaken and the relative positions of fossil derived and bio-renewable feedstocks confirmed. Priority should be given to the promotion of bio-renewable production where the benefits of the bio-renewable are proven (e.g. rape oil vs. phthalates). Within this requirement standardization of LCA procedures is essential.

Economics.

1. The key issues in successful introduction of bio-renewables are unit cost and comparative performance. These aspects need to be assessed and defined for specific uses of oils, fibers, carbohydrates, protein, and speciality products. A total and real cost appraisal is essential for long-term sustainability.
2. Industry must be given incentives to change its practices where bio-renewables are shown to have overall benefits.
3. Efforts must be made to ensure exploitation of all plant components as primary and co-products. This would enhance economic and environmental sustainability. This means that crops like flax and linseed should be considered as bi-functional, requiring a change in EC perspectives.
4. New technologies often have a degree of uncertainty in their success. EC should continue to support and promote demonstration projects but these must be linked to realistically appraised market potential.
5. It is anticipated that all bio-renewable non-food products will undergo continuous improvement, particularly in terms of market orientation and reduction in true unit cost. This should be encouraged.
6. Logistical studies, including transport modeling, should be instigated to reduce cost of collection, packaging, and transport of bulk primary products like plant fibers in particular.
7. Structured contract systems and arrangements between producers, processors, and end users of bio-renewables are essential for success. EC should actively promote these relationships and develop "model structures."
8. The potential for import substitution with home grown bio-renewables in EU should be assessed. This could lead to considerable practical and economic benefits for agriculture, rural economy, and industry in EU-15.

Other Issues.

1. Bio-renewable products are generally viewed as desirable, environmentally beneficial, and healthy. Active management of this image must be undertaken to maintain and build upon it where bio-renewables have economic and sustainable markets. Presumably this is an EC DG Environment role?
2. It must be noted that bio-renewables could be produced by traditional or organic methods. Both technologies have market places but efforts must be made to maintain and confirm identity of produce from each.
3. Those in EU-15 who are issuing tenders for contracts should be obliged to include specifications for inclusion of bio-renewables where performance and true cost have been shown to be superior to existing materials. Environmental benefits should be included in true cost assessment.
4. The potential for competition between bio-renewables should be recognized. Such competition could occur in a number of sectors, e.g. plastics, adhesives, polymers.

CONCLUSIONS

Whilst considerable data on crop species and their metabolites existed from both national and European Commission funded studies little collated or critical evidence existed on extract of markets or market specifications for non food crops in European Union. The objective of the IENICA project was to correct the deficiency through a series of reports and technology transfer events supported by a website (www.csl.gov.uk/ienica). Whilst co-ordination of the project was undertaken in UK, 14 EU member states were assessed by their national representatives in the IENICA project then individual reports collated centrally and presented on the website. Approaches were regulated through a structure and protocol. Significant market opportunities for biorenewables were identified in the oils, fibers, carbohydrates, and speciality product sector although degree of exploitation was variable between EU member states. Constraints were also identified and reported. Surprisingly it was concluded that industry was not necessarily keen to take up new products, and sometimes they were even unaware of the opportunities available to them.

Without doubt scientific and technological developments have developed so as to permit the exploitation of biorenewable products. Some key areas are still incomplete. They include (1) political and administrative co-ordination of effort; (2) awareness of opportunities in all sectors of industry; (3) assessment of environmental benefits; and (4) focused technology transfer

REFERENCES

Rexen, F. and L. Munch. 1984. Cereal crops for industrial use in Europe. EU Commission EUR 9617 EN. IENICA website: www.csl.gov.uk/ienica