IENICA

SUMMARY REPORT FOR EUROPEAN UNION

FIBRE CROPS

5.0 FIBRE CROPS

5.1 Introduction

At the IENICA 'Natural Fibres Performance Forum' Olesa & Placket summarised the current position on fibres:

For thousands of years, mankind has been strongly dependent on plant fibres for all kinds of purposes. Fibrous materials such as wood and bamboo have found particular application in construction. Other important uses have included tools, weapons and energy generation. A wide variety of fibres have also been used for the production of textiles, pulp and paper, and fibreboard.

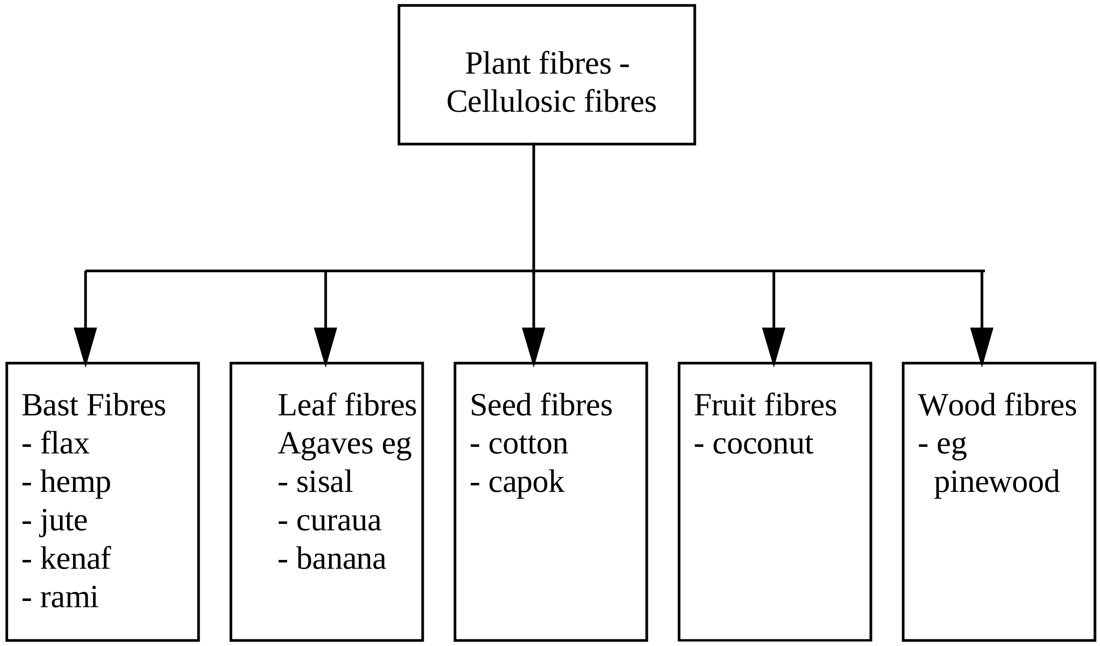
The development of synthetic materials (eg plastics) at the beginning of the 20th century, has caused the steady replacement of bio-based products. As a result of this change in raw material utilisation, combined with an enormous increase in energy and chemical demand, the world is now facing an ecological crisis. This crisis will greatly intensify with the expected growth in demand for industrial products in developing countries. It has been estimated that global industrial output will be five to ten times that of world production in 1987, when the world population stabilises some time in the 21st century, (Our Common Future 1987). Thus, the world community is facing a challenge of having to decrease pollution levels while at the same time, significantly increasing industrial output. Such predictions have led to a number of political initiatives, including support for enhanced industrial use of renewable resources (eg biomass) at the expense of non-renewable resources (plastic, glass fibres etc). Plant fibres may therefore face a renaissance, not only for past uses, but also for the manufacture of three-dimensional products by hot-pressing of fibre mats or by extrusion or injection moulding of plant fibres in combination with plastic.

An enhanced use of plant fibres for the manufacture of industrial commodities or niche products with minimal environmental impact requires knowledge of the basic properties of plant fibres. Those involved in the chain from growing the plants to the manufacture of fibre-based products, must have a basic knowledge of the performance and potential of those plant fibres.

In terms of change to natural fibres, it is to be noted that Germany occupies the most dominant position.

Plant fibres can be classified into 1 of 5 categories based on their anatomical source (see Figure 5.1).

Figure 5.1 : Classification of Plant fibres



The fibre crops, which are of current interest across the European Union are listed in Table 5.2 and current production levels in Table 5.1. The number of commercial species is relatively small and is amazingly consistent over EU.

Table 5.2: Fibrous Raw Material Production in EU - 1996

	Production (1,000 t ODM)	***Market Price ECU/t ODM***	***Relative Value****
Non Wood			
Cereal	92,650	47	100
Rapeseed straw	8,500	47	100
Miscanthus	0 or low	55-100	117-213
Non Wood with long fibres			
Flax (all uses)	21-25	175-235	372-500
Linseed straw	255	82	174
Hemp whole stalk	38	70	149
Hemp bast fibre	13	320	681
Kenaf whole stalk	0 or low	53-106	116-226
Kenaf bast fibre	0 or low	235-470	500-1000
Wood			
Eucalyptus	2,600,000	107	226
Poplars	1,728,000	175	372
Short rotation coppice	0 or low	70-90	149-191

Note: ODM = oven dry material
* Cereal straw = index value 100

Table 5.1 : Fibre Crop Plants in EU15 by Species and Country

Fibre Crops	Austria	Belgium	Germany	Denmark	Finland	France	Greece	Ireland	Italy	Netherlands	Portugal	Spain	Sweden	UK
Agave									✓			✓ C		
Arundo donax						✓	✓		✓			✓		✓
Cereal straws (excluding bedding)		✓ C	✓ C	✓ C	✓ P	✓	✓	✓	✓ C				✓ P	✓ C
Cotton							✓ C		✓ C		✓	✓ C		
Flax – long fibre	✓ C	✓ C	✓ C	✓ C	✓ C	✓ C		✓	✓ C	✓ C	✓ C	✓ C	✓ C	✓ C
Hemp	✓ C	✓ P	✓ C	✓ P	✓ C	✓ C		✓	✓	✓ C	✓	✓ C		✓ C
Kenaf (gambo)						✓	✓		✓		✓	✓		
Miscanthus		✓	✓	✓		✓	✓		✓	✓ P		✓		✓
Nettle (Urtica dioica)	✓		✓		✓									✓
Reed Canary (Phalaris arundinacea)				✓	✓ P				✓				✓ P	✓
Fibre Sorghum		✓				✓ P	✓		✓			✓		
Spanish Broom									✓					✓
New Zealand Flax									✓					✓
Halfa									✓					✓
China grass									✓					
SRC (non-fuel use)	✓ C		✓ C	✓ P		✓ C	✓							✓ C
Woody trees (Eucal/Poplar) for pulp	✓C	✓ C	✓ C		✓ C	✓ C	✓				✓ C			✓ C

‘C' denotes commercial production ‘P' denotes at pilot stage '✓‘ denotes scientific interest/development

5.2 Scientific and Technological Aspects

Considerable research has been devoted to the investigation of a wide range of historical fibre-producing species including *Arundo donax*, Kenaf and fibre sorghum in southern Europe; Miscanthus throughout Europe; and nettle and Reed Canary Grass in northern and western Europe. However, apart from cereal straw, an arable by-product and Short Rotation Coppice developed principally as a bio-fuel, only Flax and Hemp are currently commercialised sources of European plant fibres (see table 5.2).

A considerable area of flax and hemp were grown in the past in Europe for long fibre uses, principally textiles and cordage. While flax production continued at a modest level in France and Belgium, Hemp production was small and concentrated in France. The 1990s have seen a resurgence of interest in flax and hemp, as versatile low-input crops, which can in addition to fibre, produce useful products from virtually every part of the plant. These re-introductions, now grown on a commercial basis present new opportunities, use new agricultural practices and primary processing techniques, and seek new markets, not traditional ones. This renewed interest was largely stimulated by EU subsidy policy. However the availability of product has generated research and development in new processing and production technology and the development of new industrial uses, principally focused on short fibre.

The support given by the EU to hemp and flax appears to have created an interest in their production in some geographical areas, which are probably not appropriate eg Spain. However, revisions of Common Agriculture Policy (CAP) under EC restructuring of production aids will probably correct this, presuming it to be an administration linked phenomenon alone. Concern must be raised by recent proposals on flax and hemp aid by DG-Agriculture; these seem to conflict strongly with the increasing development of new industrial markets.

5.2.1 Long Fibre Plants

(a) Flax is a short poorly competitive crop and subject to lodging in wet conditions. Traditional production and primary processing techniques have been developed over a long period of time to produce high value long fibre material for the textile industry (see figure 5.2). Retting is very weather dependent, interest is being shown in fully controllable enzyme retting techniques, but these are high cost systems, which are only sustainable for high value products.

New production, harvesting and primary processing technology has been developed based on infield chemical and dew retting and non-aligned short fibre systems. This production is directed at new uses. However only now with the changes in EU support arrangements are field management factors affecting end product quality receiving attention.

This new technology has not been universally welcomed in administrative circles of the EC where more traditional production methods based on woven textile end users are preferred. Ideally, from the farm business perspective, both flax and linseed should be considered as the same crop and recognition given that seed, fibre and to a lesser extent shiv, are all co-products. For new applications of fibre where short-fibre is preferred by manufacturers, then dual-purpose linseed varieties could be ideal crops.

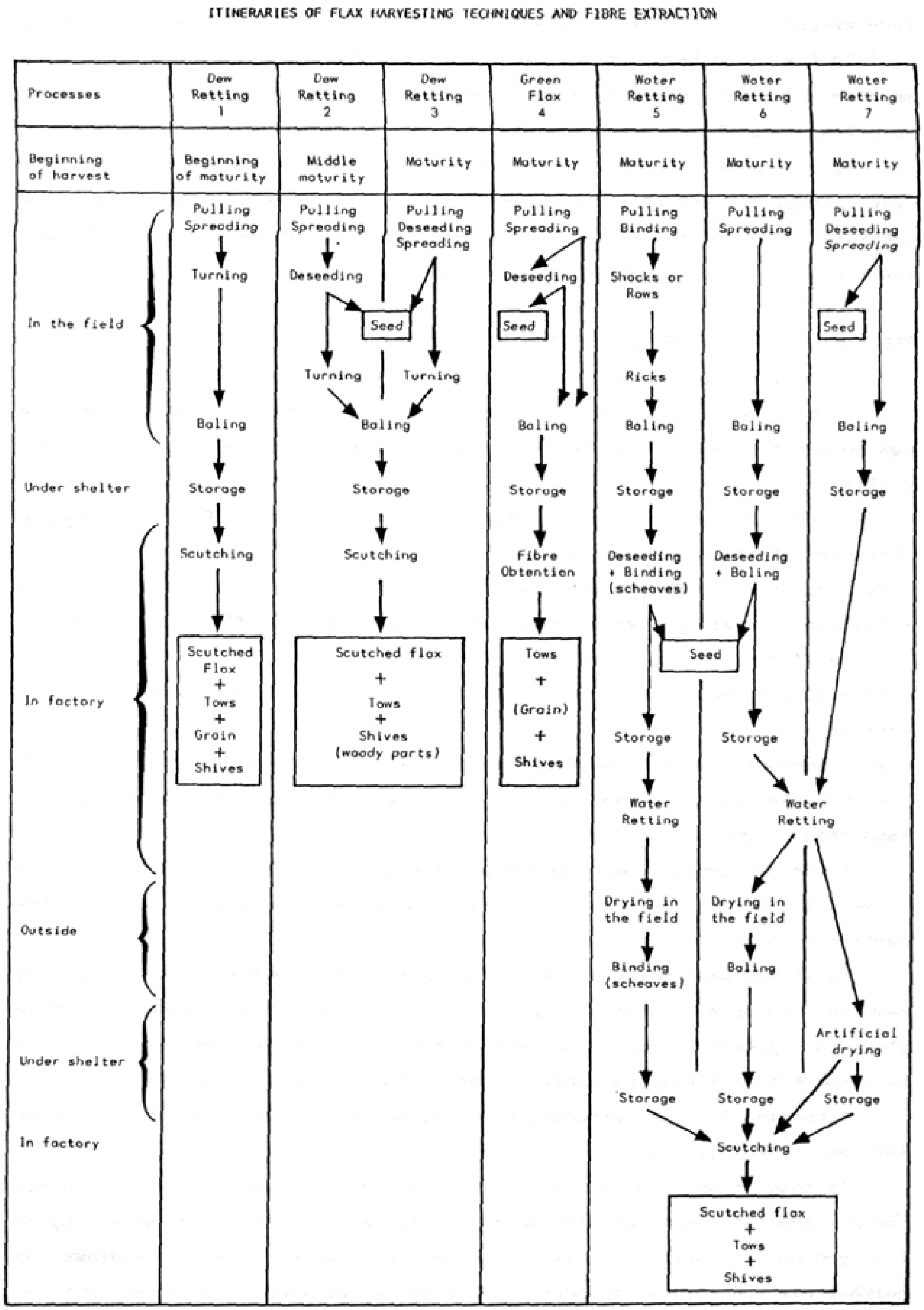
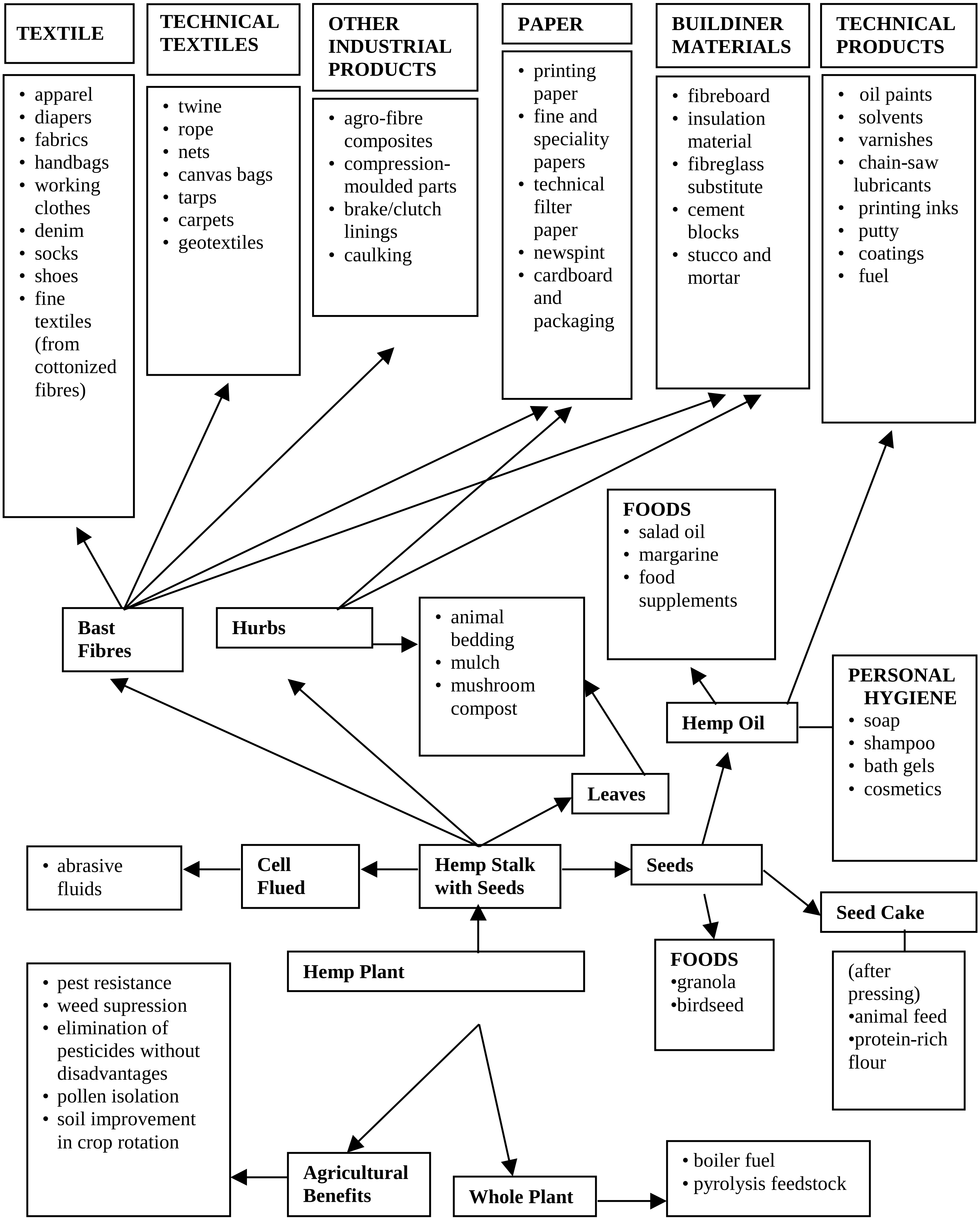


Figure 5.2 : Systems of Traditional of Flax Harvesting and Fibre Extraction.

From: "Welcome to the World of Hemp" by J W Roulac


TEXTILE
• apparel
• diapers
• fabrics
• handbags
• working clothes
• denim
• socks
• shoes
• fine textiles (from cottonized fibres)
TECHNICAL TEXTILES
• twine
• rope
• nets
• canvas bags
• tarps
• carpets
• geotextiles
OTHER INDUSTRIAL PRODUCTS
• agro-fibre composites
• compression-moulded parts
• brake/clutch linings
• caulking
PAPER
• printing paper
• fine and speciality papers
• technical filter paper
• newspint
• cardboard and packaging
BUILDINER MATERIALS
• fibreboard
• insulation material
• fibreglass substitute
• cement blocks
• stucco and mortar
TECHNICAL PRODUCTS
• oil paints
• solvents
• varnishes
• chain-saw lubricants
• printing inks
• putty
• coatings
• fuel
FOODS
• salad oil
• margarine
• food supplements
Bast Fibres
Hurbs
• animal bedding
• mulch
• mushroom compost
PERSONAL HYGIENE
• soap
• shampoo
• bath gels
• cosmetics
Hemp Oil
Leaves
• abrasive fluids
Cell Flued
Hemp Stalk with Seeds
Seeds
Seed Cake
Hemp Plant
FOODS
•granola
•birdseed
(after pressing)
•animal feed
•protein-rich flour
• pest resistance
• weed supression
• elimination of pesticides without disadvantages
• pollen isolation
• soil improvement in crop rotation
Agricultural Benefits
Whole Plant
• boiler fuel
• pyrolysis feedstock

(b) Hemp has a wide range of potential uses (see figure 5.3), since fibre, pith, seeds and seed oils all have ready and to a degree unique market niches. Unfortunately, the presence of the psychotropic agent THC (delta 9-tetra hydrocannabinol), in fibre hemp, albeit at very low levels, relative to high drug hemp (eg variety Super Skunk) creates drug policing problems and is a limiting factor in its expansion. To minimise this problem, work is in progress to produce cultivars with zero THC, and to develop visual or simple field diagnosis tests for these types.

For maximum fibre yield it would be ideal to have the option to grow a very late flowering hemp variety, but unfortunately, such an approach would not comply with EC regulations on seed formation, prior to harvest.

Current EU approved varieties are restricted to French sources, limiting crop improvement. A range of harvesting processes are being developed to meet the needs of individual countries. Primary processing systems still depend on old technology, but problems remain to make them effective.

5.2.2 Short Fibre Crops

(a) **Cereal straws** are by-products from the cereal industry, which have long been targeted as sources of fibres for board and paper industry but few commercial developments have occurred. Harvesting and transport costs add significantly to what is perceived as a low value material.

(b) **Miscanthus** has been shown to be a highly productive C4 grass species. While expensive to establish it has a long projected life. While not fully winter hardy in northern Europe it is ideally suited to western and southern Europe. While its primary market is as a bio-fuel, a number of alternative markets utilising its short fibre components have been identified. There are difficulties in nomenclature and taxonomy such that early work undertaken on the crop 10 years ago, may not be wholly applicable today.

(c) **Reed Canary Grass** is a lower productive alternative to *Miscanthus* developed in Scandinavia as a source of short fibre for paper pulp. Ideally suited to low temperatures and poor soil conditions.

(d) **Short Rotation Coppice** is willow and poplar coppiced in a 3 yearly cycle. It has been developed primarily as a source of bio-fuel. The rather immature short fibres have however been shown to have a limited range of alternative uses.

5.3 Markets

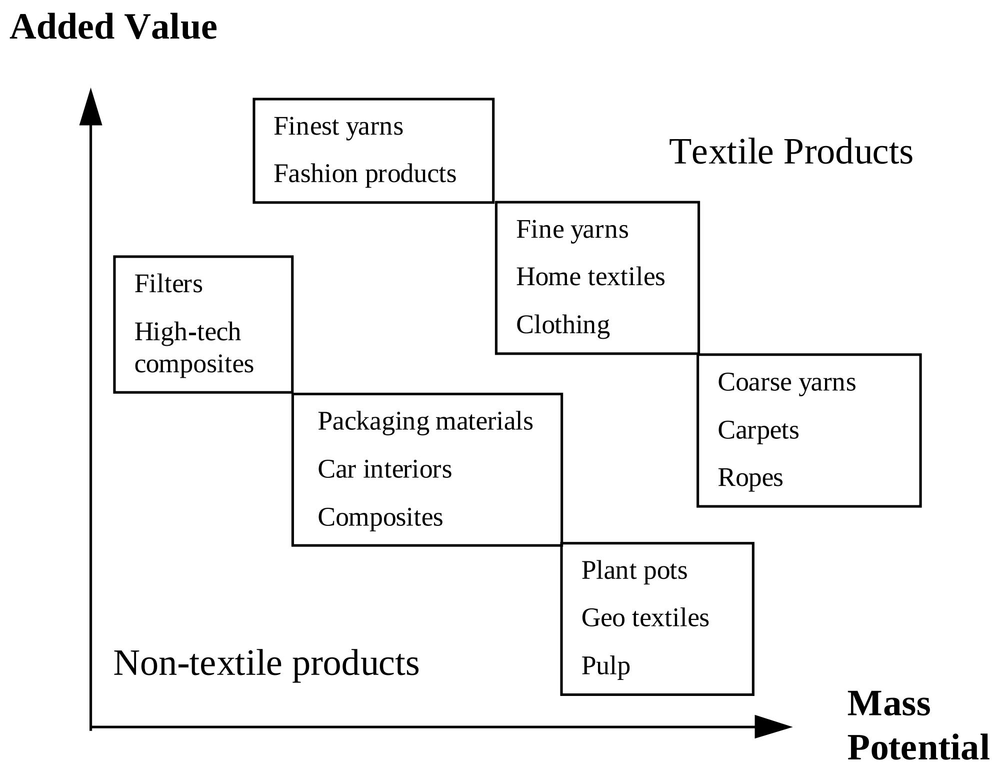


Figure 5.4 : Added value versus volume potential of bast fibre products

Figure 5.4 illustrates that the market potential for high quality, high value textile products is limited, new uses for increasing production must be focused on the high volume but lower value markets. Table 5.3 quantifies the fibre specifications and quality criteria for a range of market applications. The information illustrates that each market has very specific requirements. To be able to utilise all grades of fibre produced it is important to separate and to direct each component to the appropriate market. Fibre cleanliness (low shiv content) is an important characteristic, which many flax and hemp processors find difficult to achieve.

Technical Yarns	Mechanical bonded non-wovens	Various fields of application as reinforcing fibre	Friction Linings	Paper Production
Fibre Length • **Mean fibre length** 50-100mm • **CV$_H$** < 70% **Fineness** • **Mean fineness** 5-20 dtex or 20-86µm	**Fibre Length** • **mean fibre length** 20-70mm • **CV$_H$** < 50% **Fineness** • **mean fineness** ≤ 5 dtex or ≤ 20µm **Fibre-Fibre-adhesion** High	**Fibre Tenacity** • **tensile strength** 70-1100 N/mm^2 or 47-73 cN/tex • **elongation** ≥ 2% • **E-modulus** 40-70 kN/mm^2 **Fibre length** • **mean fineness** 3-25mm/ ≥ 25mm • **short fibre length** ≤ 10% **Fineness** • **mean fineness** 3-17 dtex or 10-74µm **Fibre-Fibre-adhesion** zero **Trash** almost free of dust and wood	**Fibre Length** • **mean fibre length** 0.1-10mm • **CV$_H$** 50% **Fineness** • **Mean fineness** 10-20µm **Density** 14.-1.5g/cm^3 **Surface Area** 1500-10000cm^2/g **Moisture** 8-10% **Flash point** 300-600ºC	**Fibre Length** • **mean fibre length** 4mm • **Long fibre length** 8mm • **Long fibre length** 1mm **Impurities** • **Trash contents** ≤ 10% • **Fibre fragments** ≤ 10%

Table 5.3 Market requirement of fibre specifications and quality criteria for specific applications. After Kessler *et al* (1999)

5.3.1 Textiles

While this has been the primary focus of long fibre producers, it is not a primary concern of the IENICA project to examine textile markets in depth, since these are dominated by cotton and synthetics. Moreover the limited markets for flax and hemp tend to be driven by fashion except in some Central and Eastern European Countries.

Additional markets for lower quality woven and non-woven fibre includes furniture, floor covering, geotextiles, automotive and industrial and horticultural matting. There is scope for replacement of synthetic fibres in these types of product but European fibres are also in competition from tropical fibres. However many of these products (and some other novel uses of fibres) are of low value (eg geo-textiles) and it is therefore difficult to invest in their production and processing as a primary business objective. Similarly, if change of feedstock involves changes in processing equipment, then additional investment may be a limiting factor.

5.3.2 Pulp and paper

A major market for short fibres but dominated by wood fibre. Generally large-scale operations, which require an assured supply of constant quality raw product and are likely to remain almost exclusively customers of the timber industry. However there are niches for hemp and flax in speciality papers with potential to replace some imported abaca, sisal, jute and cotton waste and for enhancing pulps based on recycled paper. Currently there are 31 mills throughout the World using flax/hemp, but only 3 in Western Europe.

Processes to utilise straw have been investigated in the UK, Kenaf and Fibre Sorghum in France and Italy. In Finland the Kraft process has been adapted to use reed canary grass. Pulp made from reed canary grass has been successfully made into paper, which ran at 1,400metres/minute. Similarly *Miscanthus* spp. has been used in pilot tests for Kraft pulps in UK; its technical potential appears satisfactory.

5.3.3 Wood-based panels

The wood-based panel industry is based on small roundwood and wood residues and produces particleboard, medium density fibreboard and oriented strand board. The industry as a whole is characterised by having high turnover but relatively modest profits, and raw material costs represent a significant proportion of production costs. Accordingly, any strategy that can reduce production costs e.g. the use of lower cost or higher performance raw materials, is likely to be considered very seriously. The separated, non-fibre component of crops like flax and hemp can be used as substitutes in particle boards. Experiences in the UK with the company Compak have shown it technically feasible to produce board of 600-800kg/m^3 using MDI resins. These match or even exceed standards set for boards of more traditional construction. Several fibre plants offer opportunities for use in medium density fibreboard (MDF). The wood-based panels industry probably offers the best opportunity for bulk usage of agricultural raw materials

5.3.4 Fibre reinforced composites

To improve their mechanical properties, fibres of different origins are added to thermoplastic or duroplastic plastics in the production process. Common materials for reinforcement are glass fibres and synthetic fibres. While waste disposal problems are the strongest arguments for the replacement of these reinforcing materials by plant fibres, additionally they can provide equal or better performance (see figure 5.5), reduce product weight by about 15% and have very reactive surface chemistry. Glass fibre causes skin irritations and respiratory problems, which can be reduced by the use of plant fibres.

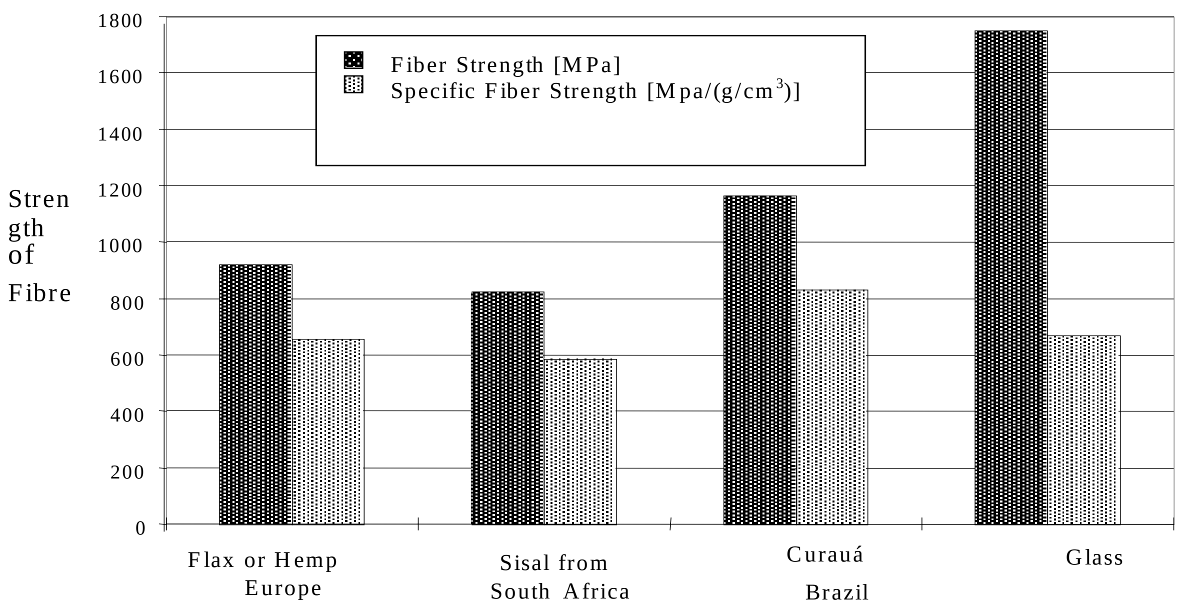


Figure 5.5: Specific strength of plant fibres compared with glass

With composites, the properties of the final product are determined by a number of plant fibre characteristics. These include surface chemistry (eg waxes and in-organics such as silica) and fibre aspect ratio in particular. In addition, other factors such as thickness, fibre percentage, and amount and type of bonding agent (if any) are important. The wide variety of fibre types, fibre preparation techniques and possibilities for fibre surface modification, open up opportunities to tailor such composites to specific end-product requirements.

The original processing technology was based on the hot-pressing, bonded/needle-punched and air-laid fibre mats. New technology is allowing the use of natural fibre granular composites for injection mouldings.

The major market identified for the application of this new technology - the replacement of fibreglass with plant-derived fibres, probably from hemp or flax - is the automotive industry. This will have considerable benefits in the workplace, the environment generally, will permit recycling and should reduce energy consumption in production of motor vehicles and improve their day to day fuel economy. Schuhe (1999), showed this graphically in the Mercedes Benz E-Class motor car [See Figure 5.6].

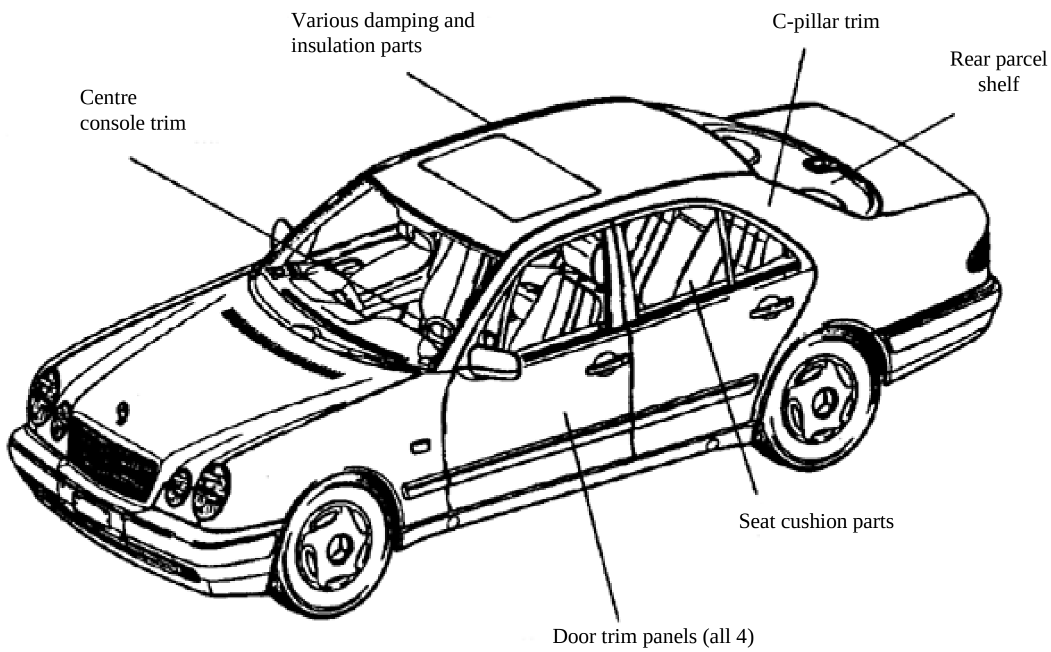


Figure 5.6: Plant fibre applications in the current Mercedes-Benz E-Class

The conclusions of Mercedes Benz here were that this is indicative of the potential for plant fibres in the automotive sector.

An important step towards higher performance applications was achieved with the door panels of the Mercedes-Benz E-Class. The wood fibre materials previously used for the door panels were replaced by a plant fibre-reinforced material consisting of a flax/sisal fibre mat embedded in an epoxy resin matrix. A remarkable weight reduction of about 20% was achieved, and the mechanical properties, important for passenger protection in the event of an accident, were improved. Furthermore, the flax/sisal material can be moulded into complicated 3-dimensional shapes, thus making it more suitable for door trim panels than the previously used materials.

Automotive components including natural fibres are currently being used by the following vehicle manufactures.

- - Fiat
- - Ford
- - Mercedes Benz
- - Opel
- - Peugeot
- - Renault

- - Volvo
- - VW

The usage 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.

With world automobile production of 58 million light vehicles per annum, of which 30% is Western Europe, then potential markets are approximately 18 million vehicles and approximately 175,000 to 350,000 t.p.a. respectively

5.3.5 Fibre/Cement Composites

Plant fibres have also found application in production of cement-based composites. For example, wood fibre-reinforced cement products are widely available and combine the 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. World-wide, research is continuing on the incorporation of alternative fibres and the use of new processes to manufacture such cement-based composites.

5.3.6 Packaging materials

The introduction of new regulations regarding the disposal of packaging waste materials by commerce and industry as well as consumer pressures, are beginning to create new opportunities for the introduction of natural fibres. In the EU, the annual consumption is of 12 million tonnes of paper and board, 6 million tonnes of plastics and over 100,000 tonnes of expanded polystyrene for packaging. Low-grade moulded (short fibre) pulp products have the potential that might displace expanded polystyrene in some applications.

The market for agricultural and industrial twines, polypropylene and sisal is significant. Polypropylene sales have increased progressively as a proportion since its introduction in the 1960's with a corresponding decline in sisal usage. The price advantage of polypropylene is a major factor. The increasing need for biodegradable materials to meet the new waste regulations should stimulate new opportunities for the introduction of natural fibre tying media.

5.3.7 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.

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

5.3.8 Insulation products

The European market for glass fibre in insulation (about 460,000 tonnes in 1991) or the larger rock wool market is being challenged by long plant fibre. The requirement is to develop efficient, integrated growing and processing operations to produce products competitive with jute produced in India or Bangladesh. Progress is being made and currently flax fibre products have been successfully commercialised in Germany, where a medium term projection is for 10% of market share.

5.3.9 Polymers and plastics

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.

5.4 Barriers to Progress

5.4.1 Crop production

Flax, hemp, *Miscanthus* and reed canary grass are likely to be the most important crops in the medium term, but little plant breeding, 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.

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.

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

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.

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 largely depend 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.

5.4.2 Industrial Use

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.

5.4.3 Economic

Price is a major barrier to development. Competition is with fossil fuel derived synthetic materials and tropical fibres.

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.

5.4.4 Environmental

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.

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.

Most fibre crops require low inputs of chemicals and fertilisers and are therefore environmentally desirable, low input systems should be encouraged and suitable labelling introduced.

5.4.5 Legislative

To enhance the development of crop derived plant fibres 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.

5.4.6 EU Actions

The proposed changes in CAP policy regarding fibre crops appear to be a significant barrier to progress. The impact of Agenda 2000 should be reviewed, particularly aspects impacting on the support for hemp and flax production and to ensure newer fibre crops receive similar support to established crops.

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 should be lifted. EC policy with regard to approval of new cultivars is a barrier to progress and should be reviewed.

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

There is continuing need for EU 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.

5.4.7 Communication

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

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