IENICA

Interactive European Network for Industrial Crops and their Applications

REPORT FROM THE STATE OF

FRANCE

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Executive Summary

In the wake of the saturation of traditional markets for European agricultural production, regulations were promulgated in the 1990s that have considerably modified agricultural operations. A number of convergent incentives have combined to increase interest in non food uses for crops. These are:

- Programmes to set aside farmlands, leaving them fallow, and the option of planting industrial crops on these lands;
- Tax exemptions for biofuels, and plants to tax environmentally toxic products;
- Emergence of many national and Europe-wide programmes designed to stimulate research and industrial work on new market outlets for these crops (AGRICE, ALTENER, European demonstration programmes, etc.);
- Environmental stakes that weigh in favour of industrial processing of the crops;
  - Crop - low input requirements for certain crops
    - preservation of biodiversity in soils
  - Product - compostability
    - recyclability
    - renewable feedstock
- Consumer demand for products that respect the environment and the body (cosmetics);
- Preservation of the socioeconomic landscape (jobs, self-sufficiency, exploitation of lands that can no longer be planted in mass-grown traditional crops).

A number of studies have been carried out with a view to developing non-food uses of these crops, and have highlighted many potential applications for industrial crops processed for non-food uses.

- Highly promising possibilities are emerging for oilseed plants, a sector in which biolubricants, surfactants obtained from feedstock derived from agricultural resources, and various additives for plastics, paints, inks and plant protection products are already produced on a medium scale.
- Starch from grains also has a strong potential for applications in the pulp and paper industry, where its use is on the rise. Starch in various forms (native, modified or hydrolysed) can be recovered and converted to valuable products- glues, surfactants, sequestering agents, absorbent materials, fermentation substrates- for a wide range of markets. European regulations adopted in 1985 and instituting a system of production rebates have reinforced the development of thes market outlets.
- Fibre plants may also find various applications in paper making, textiles and the construction industry, given their high lignocellulose content and specific agronomic characteristics such as suitability for cultivation on soils not adapted to mass-grown traditional crops, moderate input requirements, crop diversification. In the medium term they are sure to find their place in European crop plantings.

- Medicinal, aromatic and perfume plants, traditionally processed for pharmaceuticals and cosmetics, are likely to find new outlets as a result of the search for new properties and as a response to consumer demand for so-called “natural” products.

All of these activities are in a position to develop their non-food outlets in the short or medium term. A number of obstacles remain, however, that are a hindrance to the real expansion of non food uses for these crops.

Nonetheless, a number of proposals that are broadly applicable for all these feedstock can be formulated as of now at the European level:

1. Construct a regulatory framework that fosters the development of products derived from agricultural resources.
2. Consolidate a long term policy that pays particular attention to industrialists’ needs regarding a stable supply of feedstock.
3. Set up a partnership involving all the actors of these various branches of activity, in order to ascertain and co-ordinate production capacity and demand for raw materials.
4. Lastly, and more globally: create a full- fledged non-food market that is not dependant on fluctuation of production and/or prices of crops destined for food markets.

The merits of biocompatible products are manifest, and they deserve to be taken into consideration in the present European context in which environmental concerns and social development are high priorities.

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OILSEED PLANTS: Oils and their uses

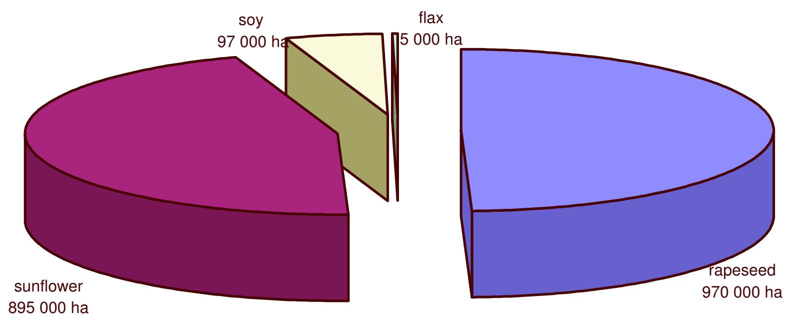
1. OPPORTUNITIES

1.1. Production and composition of oilseed plants in metropolitan France

The number of fields planted in oilseed plants in France more than quintupled between 1970 and 1990, attaining approximately 1/5 (2 million ha) of major croplands (10 million ha). Oilseed production is primarily concentrated in rapeseed (970,000 ha in 1997) and sunflower (900,000 ha), and to a lesser extent in soy [34]. In addition to these major crops smaller units exist or are being developed for specific applications (flax, erucic rapeseed, oleic sunflower), as well as marginal crops (cameline, crambe) for which applications are still uncertain, but for which the added value potential is emerging.

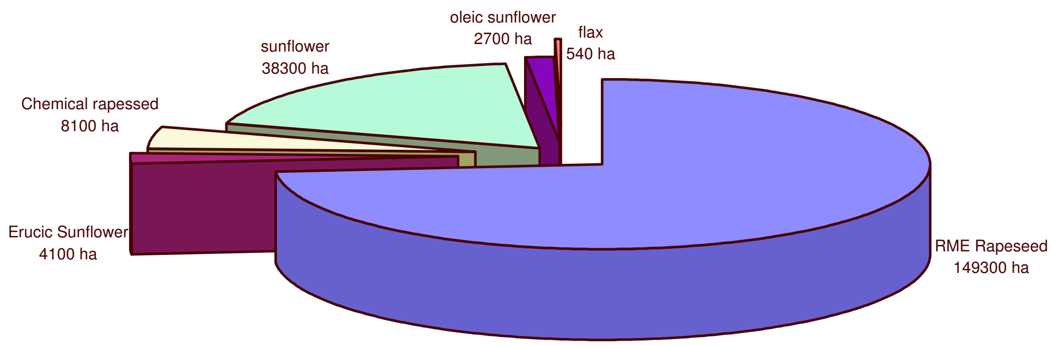
The following graph represents the proportion of these different crops relative to total oilseed production (1997 estimated figures from SIDO).

Principal oilseed crops grown in France (Planted area)



Of these croplands, industrial crops on set-aside lands break down as follows (1997 estimated figures from SIDO).

Industrial crops on set-aside lands (Planted area)



All together these croplands generated a harvest of 5.8 million tonnes (MT) of oilseed in 1997, including 3.4 MT of rapeseed, 2.1 MT of sunflower, and 280,000 T of soy.

i. Rapeseed and sunflower production practices [17]

RAPESEED

Winter rapeseed is grown on 970,000 ha in France, of which 159,000 ha are industrial crops on set-aside lands (1997 estimated fig ures from SIDO). Sowing density is a maximum of 4kg/ha (40 to 60 seedlings/m²).

YIELD (1998 quintal/ha)	**TOTAL COSTS** (FF)	Inputs **NITROGEN** (national average U/ha)	Inputs **PHOSPHATES** (national average U/ha)	Inputs **POTASSIUM** (national average U/ha)	Inputs **SULPHUR** (national average U/ha)
33	2000 - ¼ N - ¼ weed control - ½ P.K.S, insecticides, fungicides...	180	90	130	75

Rapeseed is physiologically mature when the seed attains 35% humidity; in practice the harvest is brought in at between 9 and 15% humidity (commercial norm = 9%).

SUNFLOWER

The area planted in sunflower is currently 900,000 ha, including 40,000 on set-aside lands; sowing density is 60,000 seedlings/ha, i.e.; 70,000 to 80,000 seeds/ha.
Sunflower is relatively tolerant of dry conditions; where soil amendment is concerned, specific practices are application of boron-rich fertiliser as this mineral promotes good development of the capitula. Treatment to prevent diseases and self-propagation are similar to those used for rapeseed.

ii. Cultivation products and byproducts

Rapeseed and sunflower are grown mainly for their oil-rich seeds. The composition of the seeds is characterised as follows (in % of dry product) [source : ITCF]:

	Proteins	**Lipids**	**Fibres**	**Starch + small sugars**	**Minerals**
Rapeseed					
Sunflower	21	40	30	8	1

The oils are made up mostly of triglycerides (over 98%) which are triesters of glycerol and of fatty acids.

Fatty –acid composition of oilseed oils (in % of total fatty-acid composition) [18]:

	Acids	**Rapeseed**	**Erucic rapeseed**	**Sunflower**	**Oleic sunflower**	**Soy**	**Flax**
Lauric	**C12:0**	-	-	-	-	-	-
Myristic	**C14:0**	-	-	-	-	traces	-
Palmitic	**C16:0**	4-5	4-5	5-7	2-3	8-13	4-6
Stearic	**C18:0**	1-2	1-2	4-6	4-6	2-5	2-3
Oleic	**C18:1**	58-62	10-16	15-25	76-82	17-26	10-22
Linoleic	**C18:2**	20-22	10-16	62-70	9-13	50-60	12-18
Linolenic	**C18:3**	7-9	7-9	traces	traces	6-10-	60-70
Erucic	**22:1**	traces	45-55	-	-	-	-

The fatty-acid composition is very important for non-food uses of these oils, due to the fact that their properties depend on the length of the carbon chains and the degree of saturation.

The byproduct of oil extraction from the seeds is filtercake which is made up of a mixture of different components, including cellulose (11%) and proteins (38%). Filtercake is currently sold primarily as animal feed. Research is underway aimed at finding complementary markets in new sectors (in response to GATT restrictions on industrial crops on set-aside lands, limiting filtercake in animal feed to a maximum of 1 MT of soy filtercake equivalent).

iii. New technologies and their impact on production

Production yields are rising sharply (quintal/ha, [34]):

	1973	1981	1986	1988	1990	1991	1992	1993	1994	1995	1996	1997
Rapeseed	19	21	28	28	28	31	27	27	25.5	32	33	35

Various concomitant factors explain these advances:

Genetic improvements:
- selection of more productive plants (selection of varietal, hybrids)
- selection for resistance to phoma lingam (a fungal disease for which there is no truly effective treatment
- selection for resistance to lodging

Improvement of agricultural technical pathways:
- devising more effective planting techniques (soil preparation, early sowing, weed control, etc.)
- agricultural pathways involving more economic use of inputs.

In addition to raising yields, work is currently underway to try and increase the oil content of the seed, and adjust the fatty-acid composition to the specific needs of non-food uses. To begin with, classic selection techniques were used to achieve this evolution. Today, thanks to transgenic techniques, it is possible to foresee conversions that meet the specific requirements of different oil-based activities, in particular the oleochemical industry where the demand for oleic acid is strong.

1.2. Industry

In 1992 the WTO oilseed agreement was upset by the Blair House agreement that stipulated a maximum guaranteed limit of roughly 5 million ha of oilseed cropland in the European Union; as compensation the CAP allows non-food crops on set-aside lands [27]. At this point the diversification of uses became a major focus of research for the oilseed industry, and new markets are emerging.

i. Raw materials requirement for industry

The oil content of the seed orients processing towards direct use of the oils, of separated component elements or derivatives that may be modified to a greater or lesser degree. Some 2.8 MT of oilseed are processed by trituration in France, for the most part sunflower (1.5 MT), rapeseed (0.8 MT) and soy (0.5 MT). Rapeseed oil (33%) and sunflower oil (56%) make up 88% of vegetable oil produced in France. Globally speaking (including exports and

imports) the oil markets in France process 1 MT, of which 0.7 MT are destined for food uses and 0.3 MT for industrial applications [34].
The industrial use of oils is turned towards five main applications:

1. production of rapeseed methyl ester (RME) used as a biofuel (150,000 ha grown on set-aside lands in 1997, a variable figure depending on the quotas of set-aside lands).

~~3.~~2. production of biolubricants
~~4.~~3. exploitation of surfactants with variable and controlled properties
~~5.~~4. various other industrial uses (plastifying agents, paints, etc.; see section 1.2.iii)
~~6.~~5. marketing glycerol byproducts.

To achieve these objectives, raw materials are needed at all stages of oil conversion and processing:

- raw or slightly modified (polymerised or insufflated) oils
- basic lipochemicals (fatty acids, esters, fatty alcohols, fatty amines, glycerol)
- substances derived by oleochemical blending.

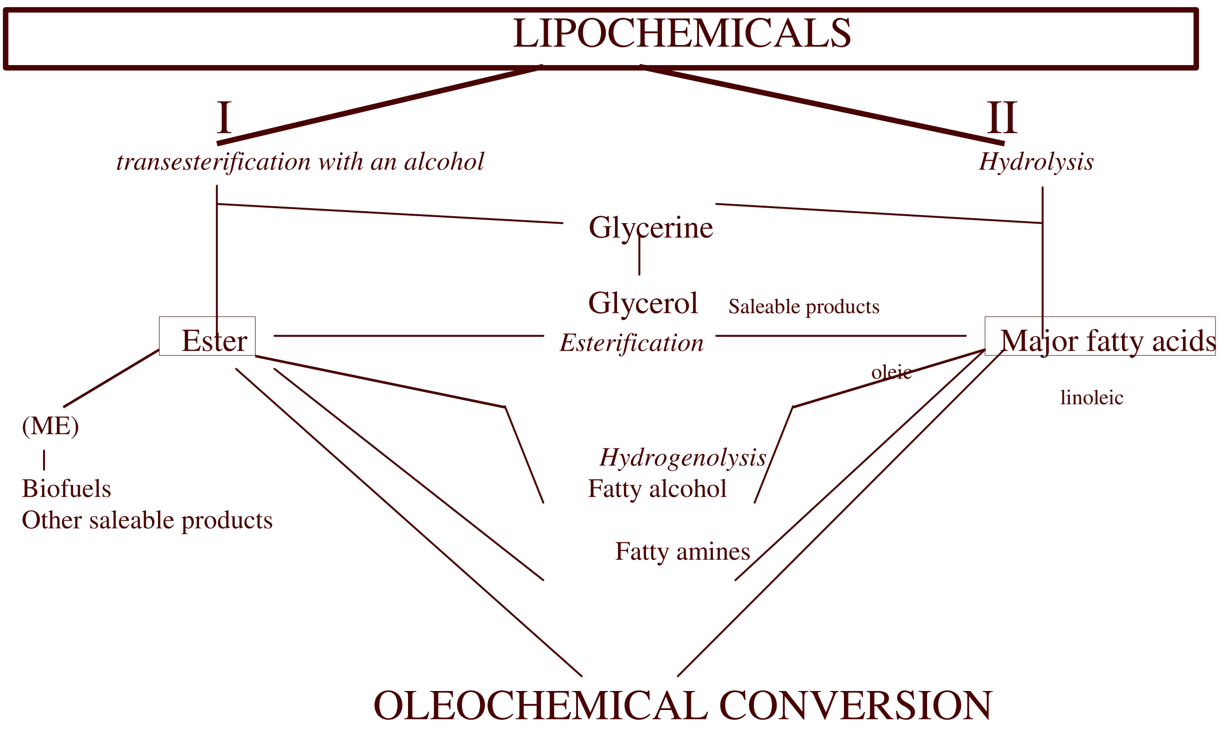
Natural lubricants are prepared according to the following sequence [16]:

sowing — cultivation and harvest — trituration — refining — lipochemicals — formulation — packaging

(Preparation of 1 tonne of lubricant requires 1 tonne of oil, i.e. 0.7 ha of rapeseed, and 1 ha of sunflower.)

The diagram below outlines the processes for conversion of oils into lipochemical products; two initial treatment pathways emerge, I and II (figures for production in Europe) [27].

Triglycerides (98 %): Glycerol + fatty acids (90 % MM TG)



Principal conversions	Desired result	Example of area of application
Hydrogenation	Saturation	Improving viscosity of **lubricants**
Fractionated distillation	Separation of carbon chains of different lengths	**Surfactants:** • long chains = emulsifiers, softeners • short chains = wetting agents, detergents
Crystallisation	Separation solid fraction: saturated fatty acids = stearine liquid fraction: unsaturated fatty acids = oleine	➢ **Soaps** ➢ **Formulation for paints and varnishes**

ii. Needs for species of specific composition

To improve the quality and lower the cost of processing biomolecules, in order to be competitive with mineral, animal (the BSE crisis) and tropical oils and create new market outlets, the fatty-acid composition of the seed must be adapted to meet industrialists' specific needs. These improvements are now being achieved through industrial processing, or farther upstream via genetic improvement of plants (notably genetically modified organisms– GMOs).
The most sought-after profiles are:

- Oleic acids (80% in oleic sunflower replacing palm and tallow oleines which represent a European market of 130,000 to 150,000 tonnes at 6 to 8 FF/kg: lubricants)
- Erucic acids (minimum 45% in erucic rapeseed; world market = 25,000 tonnes: polymer additives or lubrication if 70% erucic acid)
- Ricinoleic acids (87% in ricinoleic rapeseed; significant reactivity for many applications, European market = 90,000 tonnes)
- Lauric and myristic acids (surfactants).

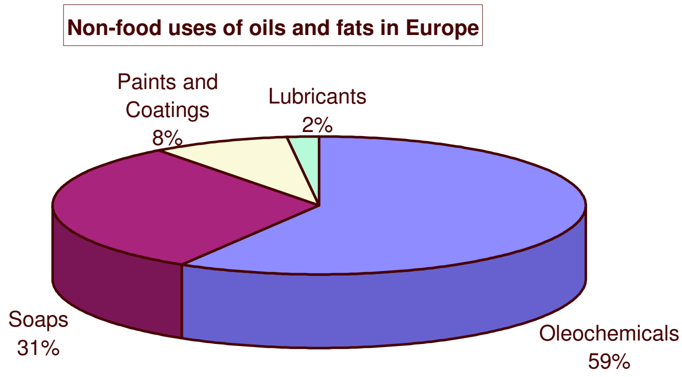
Some of these profiles are beginning to be exploited in France: erucic rapeseed is grown on around 4,000 ha, while oleic sunflower covers 2,600 ha. These operations are still small-scale, and are slated to expand, given the strong industrial demand for oils rich in these particular fatty acids.

Other more marginal species could also find a place in French plantings:

- Ricinus (castor bean) (90% ricinoleic acid). Although supported by the EURORICIN demonstration programme that ended in 1995, ricinus is not grown in France today because the plant is not well suited to the climate for one thing, because of the restrictions of mechanical harvesting for another, and because of the plant's high allergenic action, necessitating isolation when in storage. Ricinoleic acid is nonetheless a highly reactive hydroxide acid much in demand in the lipochemicals industry.
- Crambe is valued for its erucic acid content (55%) which can be used in making lubricants.
- Cameline although it has little to offer in terms of specific fatty acid profiles, is sturdy and has very high crop yields (30-35 quintals/ha) which could make it attractive for industrial sectors that are looking for polyunsaturated fatty acids (paints, varnishes) or in sectors such as cosmetics where the pleasant-sounding name of the plant could be a marketing advantage [27-31].
- Flax (60-70% linoleic acid), grown on a small scale (average market: 10,000 to 20,000 tonnes/yr) but with prices levels that converge with those of other oilseed crops (130-145 FF/ quintal) could expand to meet the demand of ink, paint and linoleum manufacturers, if farmers were given technical support, particularly at harvest time.

iii. Outlets, industrial processes and the market for oils and oil derivatives

Overall consumption of oils and fats in the 15-member European Union amounted to approximately 16 MT in 1997, all sectors together. An estimated 15% to 20% were intended for non-food uses (2.5 to 3 MT).
The main market outlets are divided up as shown in the following graph [source: USDA 1996 PSD-View].



The fats used are mainly derived from animals (tallow: 44%; mostly beef, from the United States), followed by tropical vegetable oils such as copra, palm and palm-nut oil (40%). Over the last ten years feedstocks have diversified to include rapeseed, sunflower and soy oils (16%) [27].

Lipochemicals

This industry converts oils and fats into lipochemicals that can be used in the manufacture of lubricants and detergents in particular. The fatty acids, methyl esters, fatty alcohols and fatty amines produced are marketed in purified form or in commercial blends such as stearines (350,000 T produced in Europe), oleines (130,000 T) polyunsaturated blends (80,000 T) lauric-myristic and caprylic-capric blends (250,000 T), and other formulations (350,000 T).

The principal potential outlets are described below :

Soap industry

Soaps originally made by saponification of oils and fats are increasingly replaced in industrial countries by detergents derived from petrochemicals or lipochemicals (fatty alcohol). However the latter are made up of a blend of fatty acids (tallow and palm) that do not correspond to the saturation criteria for fatty acids derived from European vegetable oils (rapeseed), which are too high in mono-unsaturates and polyunsaturates. As a result the proportion of European vegetable oil in the composition of soap cannot exceed 10% to 12% [27].
This outlet for oils produced in metropolitan France may represent a potentially attractive market, although one that will be saturated in the short or medium term.

More promising directions for development are described in detail below.

Lubricants and drilling fluids

These two markets are growing rapidly, but are dominated by petroleum-based oils whose ecotoxicity has been sufficiently demonstrated. The aim is thus to replace some of this production with vegetable-oil-based lubricants (first-generation lubricants: 2-4 FF/kg), esters and ester derivatives (2nd and 3rd generation lubricants: > 10 FF/kg, depending on degree of conversion). The features of these vegetable oils are:

- compliance with the most stringent biodegradability standards (95% in 21 days) (2: 15), a characteristic which is particularly attractive in sensitive environments (forests, aquatic environments)
- ecotoxicological innocuousness
- stricter quality criteria for specific applications (performance of natural esters: anti-wear properties, good viscosity index, good low-temperature performance)
- amelioration of worksite pollution problems and work-related illnesses due to the use of toxic mineral oils.

Due to thermal constraints, it is difficult to formulate vegetable-oil-based lubricants for use in 4-stroke engines. Large quantities of additives must be used, greatly reducing the advantages in terms of biodegradability and low ecotoxicity of the lubricants. Potential markets are therefore mainly in non-recovered oils, including:

- oils for chains (rapeseed oil)
- drilling fluids (oil esters)
- hydraulic fluids (oils and esters)
- oils for concrete casings and framework (rapeseed oil).

Vegetable oils can be used directly in formulation with an antioxidant for applications at temperatures not exceeding 70°C, or polymerised or oxygenated/hydrogenated.

Further chemical conversion yields higher quality lubrication:

- modification of the triglyceride structure (the glycerol is replaced by a polyol: isosorbitol, neopenthylpolyols, etc.)

- modification of the hydrocarbon chain by ozonolysis or other blending procedures yielding fatty mono- or diacids that are then combined with an alcohol. There are various fatty acid/alcohol/ester combinations, yielding different esterified derivatives.

Oil quality can also be enhanced by the use of additives, in proportions varying with oil type. It is important that the additives as well comply with biodegradability and ecotoxicity standards, in order to preserve the environmental qualities of the lubricants.

Environmentally compatible additives are listed in the following chart :

Type of additive	Desired qualities
Sulphurised fatty esters	extreme pressure
Sulphonates (sodium, calcium, amines, etc.) in a soluble vegetable matrix	anti-corrosion
Succinic esters	anti-corrosion
Long-chain amines and amides	anti-corrosion and emulgation
Xanthanes and other polysaccharides	viscosity enhancer
Tertio butyl phenols	anti-oxidant

These lubricants are particularly well adapted to markets in non-recovered oils or applications subject to accidental losses. Oleochemical esters could open the way to automobile lubrication.

Conversion pathways, chemical composition and properties of lubricants and drilling fluids are summarised in the charts below [6:19]:

LUBRICANTS		
conversion process	**chemical compound**	**properties**
• **transesterification** • **hydrogenation** • **dimerisation of esters** • **isostearate: byproduct of ester dimerisation**	• vegetable oil esters • vegetable oil dimer esters • isostearic acid ester	1. lubricant properties 2. viscosity properties 3. thermally stable 4. stable when oxidised 5. biodegradable

DRILLING FLUIDS			
chemical composition	**conversion process**	**chemical compound**	**properties**
• **primary fluid** • **emulsifier**	• oil esterification • polyglycerol synthesis and esterification • sophorolipids by fermentation	• Vegetable oil esters (isopropyl, butyl) • polyglycerol esters • sophorolipids	1. thermally stable 2. low sensitivity to salt 3. biodegradable
• **viscosity enhancer**	• polysaccharide synthesis by fermentation	• xanthanes and new polysaccharides: gellanes, scleroglucane	1. thixotropy 2. filtrate reducer

Markets

In 1996 4.88 MT of lubricants were consumed in Europe, including 911,000 T in France. The European market for natural lubricants amounts to approximately 75,000 T sold primarily in Germany [16:9]. Vegetable oils could be substituted for an estimated one million tonnes of lubricants in the medium term, corresponding to roughly 20% of current European consumption, broken down as follows: 5% as feedstock for the preparation of synthetic lubricants, 5% for non-recovered lubricants, and 10% for high-risk applications.

The market outlets for lubricants and drilling fluids are specified in greater detail in the following tables:

Lubricants other than 4-stroke engines (source: Europalub 1995):

APPLICATIONS	FRENCH MARKET (T/YR)	EUROPEAN MARKET (T/YR)	PRODUCT TO BE REPLACED

2-stroke engine oil	11 500	75 000	mineral oils
hydraulic fluids	100 000	570 000	glycol polyalkylenes
machining oils	60 000	450 000	polyol esters
non-recovered oils	15 000	30 000	polyol esters, glycol polyalkylene
oils for concrete casings and formwork	9 000	40 000	
grease	30 000	100 000	glycol polyalkylene

Drilling fluids:

APPLICATIONS	EUROPEAN MARKET (T/YR)	PRODUCT TO BE REPLACED
Primary fluids	80 000	diesel fuel mineral oils
Emulsifier		synthetic surfactants
Viscosity enhancer	- polyacrylamide 42 000 - xanthanes 110 000	water-soluble polymers: - polyacrylamides - xanthanes

Many companies are preparing for the likelihood that more stringent legislation will impose a tax on the use of environmentally toxic lubricants. Some examples are given below [16).

- NOVANCE uses a thousand tonnes of vegetable oil produced in metropolitan France to produce biolubricants.
- MOBIL is readying a production line for clean lubricants (AGRICE programme).
- A SNCF/SHELL/BP partnership is working on lubricants for greasing railway track (around 700 T/yr).
- The construction/public works sector is interested in oils for concrete casings that reduced worksite pollution and work-related illnesses (6000 T of oil applied to the inner surface of concrete moulds and forms. Vegetable ester formulations are already being marketed for these applications (for example, by supplier Pieri FINA).
- Vegetable-oil-based products are now used as cutting fluids in the aeronautic industry (smaller quantities required and better working conditions).

Major industrial groups such as ELF, FINA, TOTAL and SHELL, among others, are developing applications.

However, for the most part these applications involve tropical oils (palm-oil, copra, palm-nut oil). At the same time, the constant readjustment of agricultural policy and the risk of fluctuating quantities, quality and price of feedstocks worries industrialists, and hampers industrial exploitation of vegetable oils.

Surfactants

Surfactants are made up of two components: one hydrophilic, the other hydrophobic. Up until now these two parts have been composed primarily of molecules of fossil origin. As the demand for biodegradable and non-aggressive products (cosmetics) has grown, manufacturers have a strong incentive to substitute plant-derived molecules for these components, sugars for the hydrophilic substances, oils for the hydrophobic substances. The search for higher value uses for the byproducts of biofuel production has also contributed to the development of new surfactant applications (RME glycerol, beet pulp, wheat bran pulp).

Surfactants are used in a great many applications, notably in cosmetics, household and industrial detergents, pharmaceuticals. To a lesser extent they are used in paper making, construction materials, plastics, etc.
These surfactants possess different ionic and hydrophobic characteristics, depending on the type of processing used, giving them properties that can be tailored to specific needs. Accordingly, vegetable-based surfactants can replace a broad spectrum of fossil surfactants.

Generally speaking, surface agents fall into four categories, by degree of ionicity [18]:

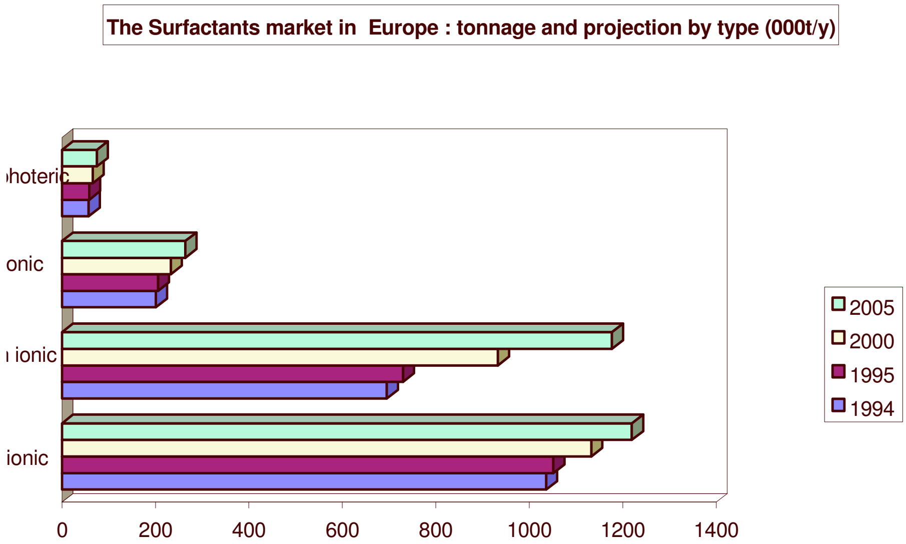
Category	**Example of compound**	**Comment**
Anionic	• Sulphonated alpha methyl esters	Detergents to replace petrochemical alkylbenzene sulphonates
Non-ionic	• Ethoxylated fatty alcohols • Alkylpolyglucosides	Share of global surfactants market rising very rapidly (see section 1.3.i)
Cationic	• Fatty amine salts • Quaternary amine salts	
Amphoteric	• Betaines	Foaming, anionic or cationic depending on the pH of the solution

There are many ways to obtain surfactants; in this regard it should be recalled that the fatty acids used to obtain surfactants from oilseed products determine the final characteristics of the hydrophobic component of the product:
C12-C14 short-chain fatty acids (lauric, myristic) are suited to wetting and detergent applications, C6-C22 long chains are suitable for use in emulsifying and softening solutions.
Controlled foam detergents are obtained by hydrogenation of erucic acid (producing behenic acid).
Surface agents are derived directly from fatty acids, methyl esters of fatty acids, fatty acid derivatives (ethoxylates, sulphates) or fatty amines.

New processes have recently emerged that associate a hydrophobic component made up of fatty alcohols with a hydrophilic component derived from byproducts of starch and sugar processing (wheat bran and straw, beet pulp – see below, section on Higher value for byproducts of sugar and starch processing, ARD process). Using these processes, compounds that are doubly natural (alkylpolyglucosides) can be obtained; these products are very well tolerated by the skin compared to fossil surfactants, and are particularly promising for applications in cosmetics.

The diversification and expansion of surfactant markets provides an incentive for the broad range of research now being conducted, aimed at developing economically profitable processing techniques and tailoring quality to the specific needs for each type of application.
Markets

Total production of surfactants in Europe currently exceeds two million tonnes, 500,000 tonnes of which are produced in France. Forecasts for 2000 and even up to 2005 are optimistic, and project strong annual growth, particularly for non-ionic surfactants with an average annual growth rate of 5%. Current and projected production figures are given in the graph below (source: ARD).



The largest amounts of surfactants are consumed by the household detergent industry, representing over one million tonnes today, rising to a projected 1.5 MT in 2005. This sector has an annual growth rate of 3.5%, and very strong market potential. Similar growth rates are given for the formulation of plastics and elastomers (130,000 T currently, 182,000 T in 2005) and for cosmetics (140,000 T currently, 195,000 T projected for 2005). The latter is potentially a very large market outlet for vegetable-based surfactants and emulsifiers, by virtue of their low-irritant qualities and the interest in natural compounds manifested by manufacturers of personal care products, despite prices which at 80-100 FF[1] remain high compared to fossil surfactants (roughly 20% more expensive for long-chain fatty surfactants). It should be noted that no lipochemical products such as fatty rapeseed alcohols are produced in France from oilseed crops grown in metropolitan France, that could compete with long-chain lipochemical derivatives imported in France for surfactant production.
French crops provide no competitors for short-chain derivatives (fatty acids from exotic plants), and market prices for short-chain fatty surfactants from fossil resources are lower (5 to 30 FF at the most, depending on the application), making it harder to compete with them.

Doubly natural surfactants are sold in France by NOVANCE and SOLIANCE, a subsidiary of ARD, for applications in cosmetics (see the section on Higher value for byproducts of sugar and starch processing).

[1] 1 ECU =6.60 FF

Other potential industrial applications [18-27]

Additives for plastics

Several families of additives derived from vegetable oils can be used in formulating plastics. These additives are generally basic lipochemical compounds (esters, amides, amines) or derivatives thereof. They fall into three main groups, by function:

- lubricants
- antistatic agents
- stabilising agents

Lubricants improve the plastic properties of PVC by lowering the viscosity of the molten polymer and/or by reducing friction between the resin and the metallic surfaces of moulding devices. These lubricants are subdivided into two groups, according to their affinities with the resin:

1. External lubricants (in particular stearic acid in flexible PVC)
~~3.~~2. Internal Erucamides are used in this domain: these erucic acid derivatives are attractive for their slipperiness and anti-sticking properties.

Antistatic agents are primarily cationic or non-ionic derivatives of fatty acids: quaternary ammonium salts, fatty acid or ethoxylated fatty amines.

Paints and coatings

Polyesters obtained by polycondensation of fatty acids and of various polyols, depending on the desired operational features, are the base for alkyde resins that form reticulated films with variable drying times and have many paint and varnish applications. Quick-drying alkyde urethanes are derivatives of these resins with a promising future.
The oils used are derived from flax, ricinus (castor bean), sunflower and soy plants.
Organic-solution paints could account for 60% of this market and water-dispersion paints for 40%.

NOVANCE uses several thousand tonnes of vegetable oil in its paint division.

Ink manufacture

The oxidability of vegetable oil is a drawback causing de-inking problems. This drawback could be exploited in the context of recycling paper not intended for long-term conservation. The Belavoid and Coates and Lorilleux companies are looking for new formulations with this in mind.
In addition, certain vegetable oils can decrease smudging of freshly printed inks, when used in offset inks currently composed primarily of mineral oils.
Vegetable oils can also be used in creating paper products for food packaging [2:119].

Media for phytosanitary products and oil additives

Vegetable oils are known as active concentrated media with insecticide and rat-poisoning properties, and are already exploited as such. Furthermore, vegetable oils and especially their esters can be used as heavy solvents for insecticides and fungicides (the "Phytorob" line marketed by the ROBBE company). Methyl esters are also used in aerial pulverisation (rapeseed ester in the beet herbicide Bolero, in K-Obiol ULV6) and as an insecticide medium during grain storage [18-31]. Oleic vegetable oil esters used as pesticide additives can reduce the quantity of pesticide used while improving its performance [20]. (One example is Actirob B, a herbicide additive containing 885 g of esterified rapeseed oil per litre [18-31]).

Results obtained by INRA researchers in Dijon show in particular that alkyloleates facilitate leaf penetration by the herbicides studied. This effect is variable, however, depending on

- the plant species
- the ester used
- the herbicide applied [2:121].

ONIDOL supports a programme in France focusing on the study of the fate in the ground of vegetable oils used as solvents in phytosanitary formulations. The aim of this programme is to arrive at a specification standard that guarantees both good product performance and respect for the environment.

Rubber manufacture

Rubber products represent one of the main uses for stearine in France. Stearic acids and to a lesser extent oleic, lauric and palmitic acids, are used in approximately 2% solution to activate vulcanisation by sulphur bridge. This could be a significant outlet for rapeseed oil.

Nylon production

ATOCHEM is readying a nylon 11 based on undecanoic amino acid, a derivative of ricinoleic acid. As for nylon 13, it can be obtained by splitting erucic acid and then polymerising brassylic acid [18].

Textiles

Ethoxylated fatty alcohols are used as lubricants and antistatic agents in the spinning of synthetic fibres.

Higher value for byproducts of industrial processing, notably for energy uses: production of rapeseed methyl ester biofuel (RME)

The European ALTENER programme (1997) and the French air-quality law (adopted 30 December 1996) have spurred the development of the biofuel processing industry. Oil-ester processing activity currently yields 300,000 T of rapeseed ester, from 300,000 ha of cropland, generating 30,000 T of glycerine and a large amount of filtercake(approximately 400,000 T) currently used in conventional animal-feed processing. To make this production profitable without upsetting the European market for glycerine, currently 180,000 T, new markets must be found for glycerol products.
New outlets have been enumerated in a number of studies by INRA, ONIDOL, INPT, the NOVANCE group and IFP, with support from AGRICE.
The classic programmes for creating saleable products from oils as described in preceding sections are also applicable to glycerol:

- markets for polyols, sorbitols, TMP, etc.

More innovative pathways to added value can also be envisioned:

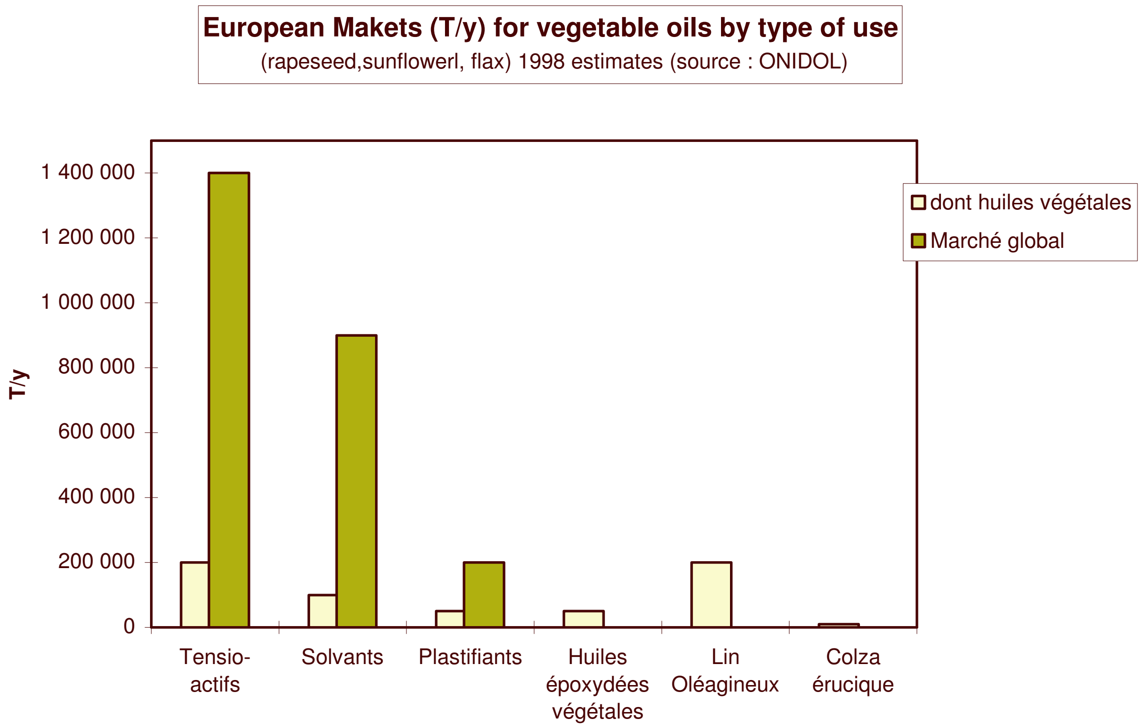
- esterification of polyglycerol, for use in making detergents, in pollution clean-up or as drilling fluid. The industrial potential of polyglycerols is being studied under the FAIR programme by a group of partners including the companies NOVANCE, HENKEL, NOVAOL, the ENSCR institute and the universities of Orleans and of Madrid.
- Glycerol can be used directly or in a slightly modified form in processes designed to prevent shrinkage of lumber, and to augment resistance to fire, insects and microorganisms (AGRICE, XYLOCHIMIE, Université de Nancy).
- By chemical reaction glycerol can be converted to glycerol carbonate (a solvent obtained by several laboratory procedures designed by INPT), to glycidol or to glycerol carbonate esters.

- Glycerol can be converted by fermentation to 1,3-propanediol (INRA Montpellier, Université de Nancy, ENSA Toulouse, AGRICE/ADEME).

Rapeseed filtercake has been tested in new applications such as biodegradable plastics (INRA Nantes).

In addition to byproducts of biofuel manufacture, non-saponifiable compounds from the refining of vegetable oils in general are attractive for the food processing and cosmetics industries. Non-saponifiable products are composed of natural anti-oxidants and phytosterols that an be used as additives and intermediate agents in the processing of fine chemicals. Phytosterols and tocopherols (α-tocopherol = vitamin E) are very promising as products with high added-value. ONIDOL and AGRICE support studies designed to optimise extraction of these compounds.

1.3 Markets



Lubricants: 5,300,000 T/yr
600,000 T/yr of which are vegetable oils

Sectors	Lubricants	Surfactants	Solvents	Epoxydated oils	Plastifying agents	Oilseed flax	Erucic rapeseed
surface area of potential development (ha)	480 000	160 000	100 000	50 000	40 000	270 000	10 000

1.4 Environment

see annex 3.

2. BARRIERS

Industrial exploitation of agricultural products is a recent concern. Idling of land imposed by agricultural policies and the economic advantages afforded by the lower cost of raw materials derived from industrial-use crops on set-aside lands are the causes behind much of the research aimed at exploiting these lands. In parallel, encouraged by the implementation of a tax policy favouring biofuels, production in France has developed rapidly, and a number of studies are underway aimed at making this activity profitable.

In addition to problems of a scientific nature, many technical, environmental, legislative and economic constraints must be taken into account.

CONSTRAINTS AND MEASURES TO BE TAKEN FOR THE DEVELOPMENT OF NON-FOOD USES FOR OILSEED CROPS IN FRANCE

Constraints	Focus	Proposals
Scientific / Technical	• Feedstocks	• Enhance the intrinsic qualities of plants to meet specific industrial needs (fatty acid profiles). Ex: rapeseed 00
	• Flax, ricinus (castor bean), crambe crops	• Optimise and adapt agronomic practices to the metropolitan climate, optimise and ensure regular yields. Ex: selection of varietals
	• Industrial processes	• Adapt processes to vegetable substances substituted for fossil substances • Optimise conversion pathways and the formulation of products and byproducts • Develop economically viable processes for new products and those requiring fine chemicals techniques.
Environmental	• GMOs and other plants selected by transgenic and mutagenic techniques	• Draw up environmentally friendly cultivation practices
	• Biodegradability and ecotoxicity	• Confirm biological innocuousness of existing "biologically grown" formulae • Develop additives suitable for environmentally compatible formulations
	• Overall assessment of the processing activity	• Avoid cross-media pollution transfers

Legislative	• French legislation (not favourable or non-existent) • European legislation • World markets	• Establish a legislative framework conducive to development: - of marginal crop species, aimed at diversifying crop cover (special regimen of per-hectare subsidies - of environmentally compatible products (ex: mandatory use of biolubricants in fragile areas, tax rules for exploitation of fossil carbon). • Establish a specific long-term status governing industrial crops • Ascertain the potential market in Europe in relation to available lands .
Economic	• Crops • Industry • Internalisation of costs	• Enhance the intrinsic qualities of plants to meet specific industrial needs (fatty acid profiles), in order to streamline extraction-purification procedures. • Optimise industrial processes and convert byproducts to saleable commodities in order to lower production costs • Quantify external costs
Communication	• Advertising • Marketing	• Set up demonstration projects geared to feasibility studies • Respond to consumer demand for information on "biologically grown" products

3. PRIORITIES: Strengths and weaknesses

Pedoclimatic conditions in France are sufficient to support close to 2 million hectares of cultivated lands, representing 20% of total arable land area.

In addition, many directions for potentially fruitful work in terms of industrial processing of non-food crops and products have been identified, thanks to the diversity and breadth of action of research bodies in France, led by INRA and the CNRS. In many cases this research work has received financial assistance from partners in the AGRICE scientific interest group.

Development of these markets is still hampered, however, by the following factors:

1. **Absence of a favourable legislative framework**
   Unlike certain European countries, France has no tax or regulatory policy to incite industrialists to move into production or processing of bio-compatible products.

~~3.~~2.**No long-term policy**
   Incessant reform, in particular of the mandatory set-aside of croplands, makes it hard to ensure stable production levels of feedstocks. This stability is crucial to the development of markets (regular supply in terms of quantity, quality and price).

~~4.~~3.**Weak links between the actors involved**
   Efforts must be made to give shape to the partnership bringing together all these actors– farmers, seed vendors, storage operators, research bodies, industrialists and AGRICE– and clarify their needs.

~~5.~~4.**Structural organisation of fine chemicals markets nationally and internationally**
   Diversify and optimise oleochemical processing industries.

Despite the handicap of these restrictions, two paths show strong potential for development in the medium term. These are the use of biolubricants in 2-stroke engines and as hydraulic fluids, and the incorporation of plant-based surfactants in detergents and cosmetics. These products are equal to or better in performance than competing fossil-derived substances, and the industry would rapidly expand under a legislative framework aimed at encouraging their production and processing.
The other types of value-added processing described here require further work to improve performance, lower cost prices, or enhance industrial exploitation.

BROAD CONCLUSIONS

Set up **full-fledged production of non-food crops**, not restricted to use as a buffer to regulate markets, via **a coherent long-term policy in support of sustainable development**.

The advantages of bio-compatible products are incontrovertible:

⇒ **Environment**: Substitution for fossil carbon =
- **↘ depletion of resources**
- **↘ greenhouse effect**

⇒ **Economy:** External costs conducive to **↘ investment in pollution abatement**

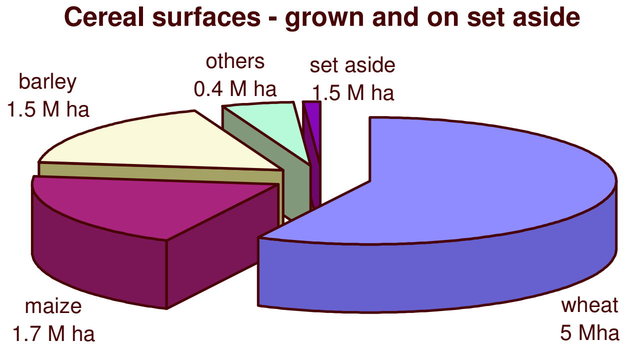
⇒ **Social:**
- response to **consumers' desires**
- **local development**
- **creation of jobs in the European Union.**

1. OPPORTUNITIES

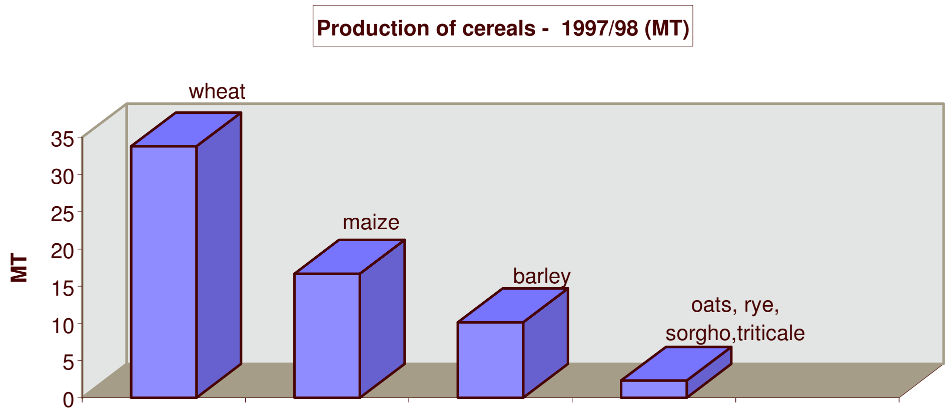
1.1 Science and technology

i. Plant species: grain crops

With current production standing at 6.3 MT of grains (97/98), France is the largest European producer for this activity. The proportionate land area planted for each crop is shown in the following chart (30):



The production volumes generated are represented in the graph below (30):



Due to their high starch content, maize (U.S. corn) and wheat constitute the main feedstocks for starch processing. Study of starch and its byproducts focuses particularly on their many non-food applications.

ii. Wheat and maize production practices (28)

- Wheat

The type of wheat used for starch extraction is soft wheat ("medium hard" in breadmaking flours). It is grown throughout France, particularly in the northern and central regions, most often in its winter wheat form.

Wheat cultivation practice requires a rising rate of nitrogen fertiliser input, within the limits imposed by the risks of lodging, in order to increase crop yields. The total nitrogen input (3kg/quintal of grain) is divided into three doses (when suckers are trimmed, at the start and during sprouting). To obtain very high yields, total input may reach 200 kg/ha.

In contrast, wheat requires very little P and K.

The table below summarises the treatment sequence :

		sowing	shoots	3 leaves	start trimming suckers	mid-way trimming suckers	end trimming suckers	ears 1 cm	1 knot	2 knots	swelling	earing	flowering	grain formation
weed control	before sowing	before germination		after germination	early		late						after earing	
nitrogen	N fertiliser			1st input				2nd input	3rd input					
growth regulator					protec-tion	against	risk of	lodging						
insecticides	action against	attack by insects			*citadelle*	plant-lice	slugs					plant-lice	cecidomyia	
fungicides	seed treatm.								1st		2nd		3rd	

- <u>Maize</u>

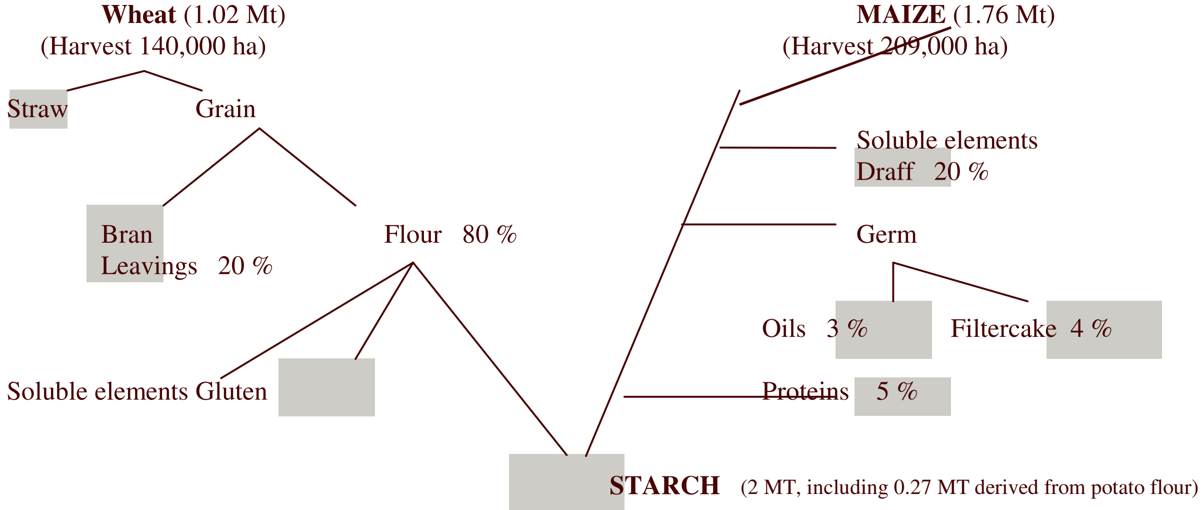
Dentate and dentate/horny maize can be used for starch processing. Yields in France have reached the levels attained in the United States, i.e. 77 quintals (7,700 kg)/ha.
Out of 2 million hectares planted in 1995, 700,000 ha were irrigated. The maize crop is grown essentially in the western half of France, but is increasingly planted in the western zone, with varieties adapted to metropolitan climatic conditions. Being originally a tropical plant, maize has exacting needs in terms of temperatures (germination at temperatures higher than 6°C) and water (500 L of water for 1 kg of grain, equal to 4,000 m^3/ha for a harvest of 80 q (8,000 kg)/ha or 12T of dry matter. In many regions in France irrigation is of prime importance.
Broadly speaking, maize can be cultivated as follows:
Sowing density is from 85 to 100,000 seedlings/ha for a late variety, and from 50 to 75,000 for early varieties. Nitrogen is applied in a single dose (12 to 13 kg of total N/total dry matter produced, including N available in the field plot. Fungicide treatment can in most instances be avoided, given the natural resistance of maize. Inversely, several courses of treatment against insect attack are necessary (plant-lice, etc.). Various weed control strategies can be employed, generally using simazine and atrazine. Because of recent increases in atrazine concentrations in groundwater, different types of weed killers are increasingly used. The harvest date is determined by the humidity of the grain, which is a very important quality factor for starch processing (ease of separation of component substances). Grain humidity must be 30% at threshing to attain 15% after silo drying.

iii. Cultivation products and byproducts

The starch and protein content of the grain kernels are decisive quality factors for industrial non-food processing. Yields of chemical compounds are given in the following table (source: ITCF and INRA).

		WHEAT	**MAIZE**
YIELD	(T/ha)	9	11
DRY MATTER	(T/ha)	7.7	9
SUGARS	(T/ha)	5.8	7.2
	% dry matter	78	70
PROTEINS	(T/ha)	0.8	0.7
	% dry matter	12	11.5
LIPIDS	% dry matter	2.1	6.0
FIBRES	% dry matter	5.6	11.4
MINERALS	% dry matter	2.3	1.1

It should be noted that the quality of the nitrogen input during cultivation alters the proteins/starch ratio (↑N = ↑proteins).
Starch processing generates many byproducts, outlined in the following diagram:



All of these byproducts are currently sold to the animal feed industry, an essential outlet. But many other applications with higher added value are now being developed.

iv. New technologies and their impact on production

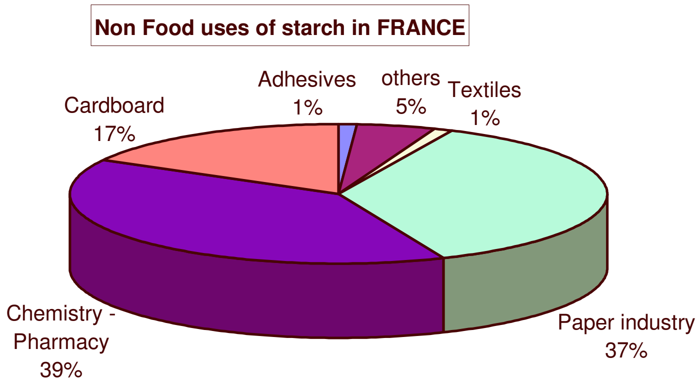
The rate of increase in grain crop yields has now reached 2 quintals (200 kg)/ha/yr. This pace seems to be levelling off. It can be attributed to seed selection and improved cultivation techniques. In addition, where maize is concerned, improvements in storage conditions and quality, notably control of grain humidity, make it possible to obtain grain better suited to starch fractionation.

1.2 Industry

Since the early 1990s research and industrial interest in starch has been spurred by the stagnation of traditional grain markets (human foodstuffs and animal feed), coming on top of a policy of rebates for starch use. Many potential uses have been identified, which have been more or less developed to date. Many of these aim for higher value in starch processing by using starch byproducts in industrial applications with high added value.

i. The demand for raw materials

Aside from foodstuffs, starch is used mainly in the paper and paperboard industry. In the last ten years however a strong demand has developed in the chemicals and pharmaceuticals sectors.
Starch production in France comes to 1.9 MT, 55% derived from maize, 30% derived from wheat, and 15% potato starch. Non-food industries absorb 60% of this starch, distributed among the sectors shown in the following chart (USIPA 98):



Other: construction materials, foundry, extraction industries, etc.

This volume of starch generates by-products in the quantities given in the table below:

Grain	Starch %	Starch Tonnage	By-products %	By-products tonnage
Maize 1.76 MT	63	1.11 MT	• Draff and solubles 20% • Oil 3% • Filtercake 4% • Proteins 5%	352 000 t 52 800 t 70 400 t 88 000 t
Wheat 1.02 MT	55	0.561 MT	• Leavings 20% • Solubles 10% • Gluten 8%	204 000 t 102 000 t 81 600 t

Potential applications for these by-products are described in section 1.2.iii.
Extraction of wheat or maize starch engenders production of starch wash, that must undergo various conversions in order to meet the needs of industrial users. There are two major conversion processes: dry starch processing converts the starch wash to raw starch or starch modified by thermal or chemical action, and glucose processing that yields starch sugars and derivatives after hydrolysis. These feedstocks are used in an increasing number of industrial sectors.

ii. Demand for species of specific composition

While all forms of starch can undergo all types of conversion, each has its own behavioural features, depending in particular on the amylose/amylopectine ratio (varying between 18% and 33%). Non-food industries are particularly interested in amylose, a linear compound. The type of starch must be chosen accordingly, considering economic constraints and technological conditions. Hydrolysis treatment is preferable for maize and wheat starches, while dextrines, ethers and esters are manufactured primarily with potato or cassava starch.
Waxi maize, which has a high amylose content, is grown on a few tens of thousands of hectares in France. Industrial users however often prefer a standard-quality feedstock which is available in large supply and at stable prices.

iii. Potential non-food applications for starch

Starch fractionation is now a well mastered technique, even if there is still room for improvement. Maize starch processing has been practised since about 1945, and industrial techniques are not likely to change much in the present age. Wheat starch processing is more recent, dating from about 1985, and the process is still undergoing significant change.
The main companies active in starch processing in France are:

- Amyval
- Amylum
- Avebe
- Cerestar
- Chamtor
- Roquette (French)
- Staral/Syral (French

Starch obtained by fractionation has many applications: raw or modified starch is used as a viscosity enhancer and binder in papermaking. In 1997 240,000 T of starch were used to make paper pulp, 43,000 T in bulk pulping, 178,000 T in glazed and corrugated board, and 18,000 T in art papers. These applications were distributed across the following specialities:
- writing papers 141,000 T
- packaging 84,000 T
- special papers 13,000 T

Starch is also incorporated into the pulp made from post-consumer paper, to reinforce the fibres and thus improve the technical characteristics of recycled paper.
The adhesive qualities of starch are used to make corrugated paperboard.
These applications are well known, and are now expanding, due to increased consumption of paper and paperboard, and in particular as a result of the development of cationic starches that are still very little used in France.
The second major starch-consuming sector is the chemical industry. This sector has registered the strongest growth. Via fermentation, starch hydrolysates are used to produce many active principles used in pharmacy and healthcare (antibiotics, vitamins, hormones, biopolymers). Derivatives are also used in hygiene products (super-absorbent starch in disposable nappies), detergents (water softeners and enzymes), paints, adhesives, etc.
For technological reasons and in order to make the most of recent advances in biotechnology, industrialists have for many years chosen to use glucose syrups as a carbon source for fermentations. The price gap between world grain prices and European prices has been a major handicap hampering mass production of certain specialities for which the substrate represents between 30 and 70% of production costs (manufacture of citric acid and amino acids). In 1986 new regulations were passed granting a rebate for starch use to industrial users which has partially corrected this distortion. In France, consumption of starch hydrolysates was multiplied by 9 between 1986 and 1993, replacing imported molasses. However, in recent months misguided application of these regulations has made it increasingly difficult to use starch in economically acceptable conditions, and industrialists are waiting for a regularisation of these rebates.
Outside of these classic uses of starches in papermaking and fermentation, new market outlets are emerging that draw their value from the capacity for biodegradability:

- starch derivatives in plastics; despite a cost price that is not yet competitive with petroleum products, these products are slated to find uses as surgical materials that can be biologically broken down, or as certain kinds of packaging for cosmetics
- in detergents, where they can be used as surfactants.

Biodegradable plastics

Starch can be used in this type of material in three different ways:

- adjunct in conventional plastics (6% starch)
- blended with synthetic polymers (60 to 75% starch)
- as a thermoplastic starch itself (75 to 95% starch + other grain-derived compounds).

Materials derived from raw amylaceous matter

In France the AGRIPACK company produces packing material from maize starch. The beads obtained are spherical and calibrated at approximately 15 m in diameter. Between 10 and 12,000 m^3 of packing beads can be produced from 100 ha of irrigated maize (transport costs account for 30 to 40% of the sale price). A 20% share of this market could be supplied with industrial crops on 2,000 ha of set-aside lands.

Biopolymers

Biopolymers are produced by fermentation. The most common compounds are polyhydroxybutyrate (PHB) which fetches 150 to 170 FF[2]/kg for a world production of 5,000 T/yr, polylactic and polyglycolic acid (4,000 to 20,000 FF/kg), prolylactones, and chitosan.

These compounds are not widely marketed in France. Their high price limits their applications to noble uses such as surgical materials that are biologically broken down, or "green" packaging for cosmetics. But lower production costs would allow industrialists to increase their production capacity and branch into new markets.

The products on the market are MATER-BI, NOVON, BIOPOL, ECO-PLA, produced respectively in Italy, the United States and the United Kingdom.

These biodegradable plastics are suitable only for short-life-cycle applications, i.e. 20% of the total market for plastics, along with a strategy for recycling synthetic plastics which have qualities that are indispensable for many applications.

Currently production of biodegradable plastics stands at a few tens of thousands of tonnes worldwide, but could reach one million tonnes by 2000 if new regulations governing the use of fossil carbon or non-biodegradable packaging are adopted.

Detergents

The potential applications for starch or starch derivatives are particularly attractive in detergent manufacture, an industry with large-scale production. Studies have shown that 60 to 75% of washing powders could be replaced by biodegradable products.

Of roughly 1,700,000 tonnes of detergents consumed in France each year, 1,400,000 could be supplied by agriculture, after processing, broken down by product as follows (source: ITCF):

Compounds	% in washing powder	Tonnage/yr	Substitute product
Surfactants	8-14	350 000	Amphiphile derivatives of glucose
Alkaline agents	10-20		
Sequestering agents	20-30	900 000	• Citric and gluconic acids • Modified starches
Whiteners	10-20	50 000	Sugars and acetylated polyols that release hydrogen peroxide
Ancillaries	• Enzymes : 0.3 • Anti-deposit agents (CMC) : 1 • Optical bluing agents : 0.2		
Adjuncts	• Scents • Colour dyes • Volume agents		

In France the company HENKEL-SEPPIC produces **surfactants** from agricultural products (3,000 to 4,000 T/yr), particularly glucose syrup for the hydrophilic head and copra oil for the hydrophobic tail. These are (ionic) alkylpolyglucosides, more commonly known as APGs. These can be modified by cationisation, anionisation or esterification, according to the application. They can be used in the formulation of dishwashing liquids, detergents, liquid soaps and various other cleaning agents.

Citric and gluconic acids (complexing agents for ions in solution in wash water) are produced by fermentation of glucose derived from starch, and they are already used in some cases as substitutes for sequestering agents. Gluconic acid is used mostly in cleaning and anti-corrosion products, and citric acid in household detergents.

A factory with a nominal production capacity of 40,000 T was recently built in Alsace by the Austrian group Jungbunzlauer.

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[2] 1 ECU = 6.60 FF

Sugars and acetylated polyols such as glucose pentacetyl are used as whiteners, and have a very high capacity for complexing heavy metals after decomposition, they contain no nitrogen and are entirely biodegradable.
All of the biodegradable compounds, can, when substituted for phosphates, limit eutrophication phenomena in bodies of water.

Other starch applications

The diverse characteristics of starch make it suitable for many applications, which have been more or less developed to date. They are relevant to the following sectors:

- **Adhesives and glues,** for manufacture of corrugated paperboard (90% of adhesive use in papermaking), paper bags, wallpaper…
  Various processes have been perfected by the CERESTAR company located in France: Stein-hall, No-carrier, Minocar. The ROQUETTE company is also a leader in this field in France.
- **Textiles,** for preparation of weaving production lines and printing of cloth. But this demand is falling off rapidly, in proportion to the growing use of synthetic fibres, and in 1993 consumption came to only 8,000 T in Europe, of which 1,500 T in France.
- **Chemicals industry,** as fermentation substrates (amino acids, antibiotics, vaccines, prosthetic devices…), as a direct substrate– excipient, binder, coating, active principal (sorbitol), tissue substitute (blood serum: starch ether).
  Pathways for development in this domain involve cyclodextrines in particular, for their specific ring structure, and polylactic acids for the manufacture of biocompatible and bioresorbable prosthetic devices.
- **Building and construction**: amylaceous products are in common use as additives, to regulate drying (glucose syrup), as binders, anti-freeze and a retarding agent for concrete (gluconic acid).
- **Lubricants**, in association with basic vegetable oils for the manufacture of biolubricants.
- **Agrochemicals**, as binder in the make-up of fertilisers, modified starch allowing controlled release of phytosanitary products by encapsulation, seed coatings.
- **Super-absorbent products**: grafted starches that retain up to 1,000 times their weight in water, in disposable nappies, as a talc substitute, or root coating in semi-arid zones.
  The potential market is estimated to reach 100,000 T/yr in Europe in 2000.

Starch, modified or not, can be used for its flocculent, binding or gelling characteristics in **mining** for selective ore separation, or as dust agglomerate; in **metallurgy** in the fabrication of foundry moulds and unmoulding of parts; in **pollution clean-up** to fix metallic ions; in **paints** as a thickener and stabiliser for emulsions.
The BIODECAP company has instituted a new use in France, with support in the form of an prize for grain science achievement awarded by French grain companies and AGPM. In this application a grain by-product (starch) is used to strip painted surfaces, particularly aeroplane bodies. This company is now located at the Le Bourget airport in France, and is aiming to exploit 5,000 ha of land by 2000.

iv. Non-food uses for flours and by-products of starch processing, sugar refining and distilleries

Industrial conversion of by-products to saleable products is a recent concern. Diversification of applications for markets other than those traditionally targeted (animal feed) has become a strategic goal in the setting up of biofuel ethanol production facilities, to lower costs and enable the product to compete with fossil fuels. This predilection for creating high added-value products from processing by-products has spread to exploitation of starch and sugar processing by-products, as summarised in the following table:

Grain	By-products %	By-products tonnage
Maize 1.76 MT	• Draff and solubles 20% • Oil 3% • Filtercake 4% • Proteins 5%	352 000 T 52 800 T 70 400 T 88 000 T
Wheat 1.02 MT	• Leavings 20% • Solubles 10% • Gluten 8%	204 000 T 102 000 T 81 600 T
Beet	• Pulp 8% • Vinasse 0.002%	1 630 000 T

<u>Non food uses of flours</u>

Upstream of production of industrial byproducts, certain direct applications of grain flours are already in use, or close to it. Some examples are given below:
In partnership with IVG in eastern Germany, the ROVERCH factory in France produces POLYNAT, a bioplastic with characteristics close to those of polyethylene or polypropylene made from rye flour by gelling and plastifying with natural alcohols (31). This product sells for 15 to 20 FF/kg, and projected production capacity is 5,000 T. The product can be injected into heated canal moulds and can be reinforced with flax, hemp or wood fibre. It can be used to make plates and flatware for "biologically compatible" restaurants and picnic use, packaging separators for technical parts, camera film containers, etc.

The ARD company is working with the CORA chain of hypermarkets to produce packing boats from wheat flour. Although some problems persist with the sturdiness of the finished product, research focusing on formulation with cellulose, glycerol, etc. should lead this project to a successful conclusion.

Non food uses of by-products

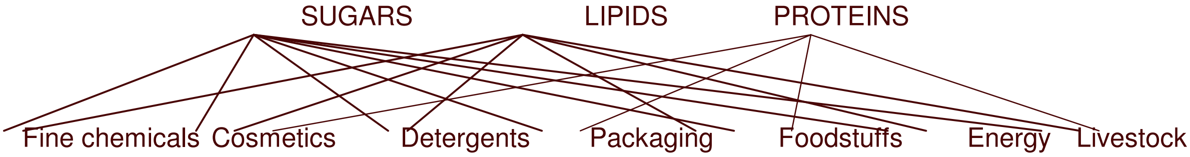
A number of research teams, in particular at INRA and the CNRS, are working on potential applications for starch by-products. Few industrial-scale projects have been completed to date, but researchers are pursuing their efforts to improve industrial processes, lower production costs and enhance final product performance, and these applications could be developed in the medium term.

Because few higher-value products are extracted from these by-products, feedstock costs are low:

- gluten, which sold for around 15 FF/kg a few years ago, now sells for a competitive price of 4 to 7 FF/kg (ethylene: 4-5 FF/kg), wheat bran sells for 0.50 FF/kg.

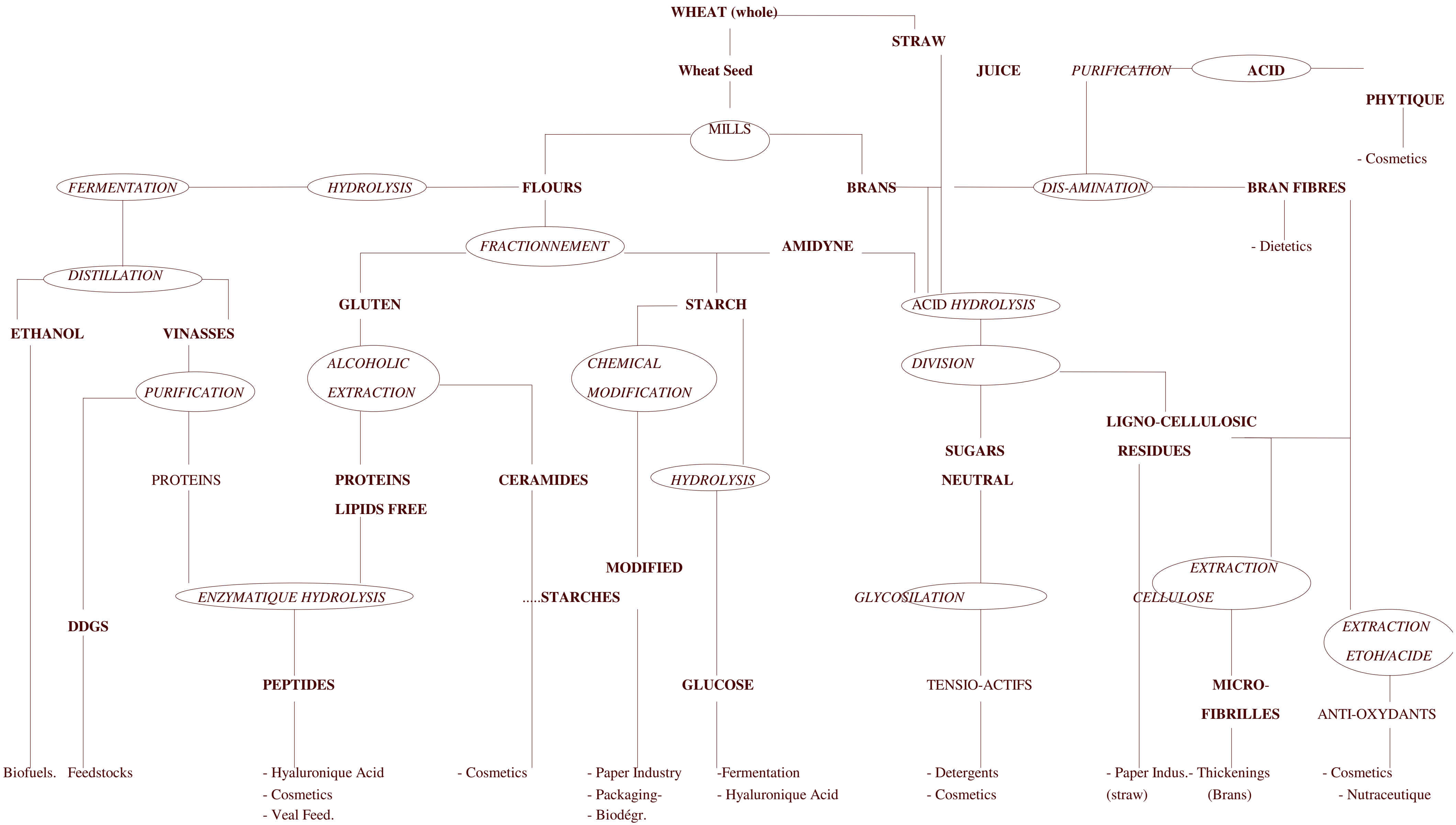
The different processes presented basically aim to make industrial processing profitable by creating value from all components of the feedstock, by targeting high added-value sectors such as cosmetics, where the demand is low in volume but very strong for so-called "green" products.

The types of added value projected for products obtained after fractionation of the plant substance are outlined in the diagram below:



To simplify the illustration of the potential for obtaining valuable products from wheat by-products, the process for the full conversion of wheat developed by ARD can be taken as an example. This process aims to transform all wheat by-products, by optimising fractionation processes and creating high added value.

WHEAT PROGRAMME OF ARD 1996



This company is working on conversion of beet pulp in the same manner. By way of an example, the following production volumes are obtained from 1 tonne of pressed pulp:

- neutral surfactants 340 kg (added value: 15 FF/kg)[3]
- anionic surfactants 110 kg (added value: 20 FF/kg)
- microfibrillae 125 kg (added value: 20 FF/kg
- ferulic acid 0.75 kg (added value: 450 FF/kg)

ARD subsidiary SOLIANCE markets various products derived from vegetable feedstocks, primarily for applications in cosmetology: DHA (40 T/yr), hyaluronic acid, enzymatic hydrolysates of atomised wheat gluten, and quite recently doubly natural surfactants made from copra, palm or palm-nut oil and a C16-18 hydrophilic head obtained from wheat bran or beet pulp, selling at between 80 and 100 FF/kg. The projected market is 1,000 T/yr.

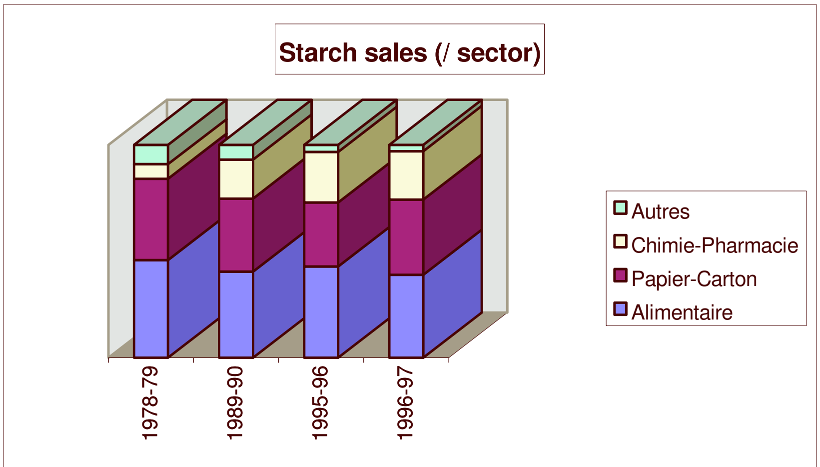
This product could find applications as a pesticide emulsifier, with larger scale production that would bring the price down to 20-30 FF/kg for short-chain surfactants and to 80-100 FF/kg for long chains.

Wheat germ could be exploited for its oils. In France BERTIN extracts these oils by cold pressing (4,000 bars in sunflower oil as solvent). After fractionation of the two oils, around 11 kg of wheat germ oil is obtained, called HELIOGERME. BERTIN markets 10 T/yr of this oil at a price ranging between 60 and 80 FF/kg. This oil is used mainly in cosmetology.

1.3 Markets for starch products

Where available, market figures have been quoted in the preceding sections. However it is important to underscore the market trends in chemicals and pharmaceuticals over the last few years. These trends show that use of starch solely for foodstuffs and papermaking is a thing of the past, and that industrial users are very interested in this feedstock, even if actual applications are still shaky and more progress must be made.

The progression of sales in industrial sectors is presented in the following graph:



The outlook for the European Union in the year 2000 follows this trend (19):

	2000	Progression since 1993
Paper industry	1 300 000 T	x 1.3
Plastics, detergents	1 100 000 T	**x 11**
Fermentation	1 200 000 T	x 1.64
Total Starch	**3 600 000 T**	x 1.96
of which grains used	5 500 000	x 2.11

The implementation of the new common agricultural policy, Agenda 2000, which calls for lower prices for feedstocks, will give a boost to efforts to conquer new industrial markets.

1.4 Environment

see annex 2.

2. BARRIERS

Constraints and outlets for the development of non-food uses for sugar-yielding crops in France

Constraints	Focus	Proposals

[3] 1 ECU = 6.60 FF

Scientific / Technical	• Feedstocks • Industry	• Enhance grain quality while ensuring availability in large supply and consistency of composition. • Optimise fractionation processes for grains, products and by-products.
Environmental	• Biodegradability and ecotoxicity	• Ascertain and control biodegradability of starch-based products
Legislative	• French legislation • European legislation	• Institute taxation of fossil carbon, non-biodegradable packaging • Ensure ongoing rebate mechanisms for starch production and use • Make isoglucose production more competitive with US competitors (↗ isoglucose quota in Europe)
Economic	• Crops • Industry	• Lower cost of extraction/purification by improving cultivation conditions and plant qualities, to meet the specific needs of industrial users. • Optimise industrial processes and encourage conversion of byproducts to saleable products.

III PRIORITIES: Strengths and weaknesses

Starch processors in France are large, and few in number. This makes it hard to establish contacts between research centres, technical institutes, and these processors. Industrial starch processors are waiting to know what action will be taken in their sector with implementation of the new common agricultural policy.
Nonetheless, starch processing is a dynamic sector of agro-industry, with a very broad range of market outlets in foodstuffs and non-food uses, and perspectives for growth. It is an industry with high technical performance, and steady growth.
Problems are encountered at the global scale, for world competitive is fierce. Europe must arm itself with a consistent policy aimed at the development of all non-food uses for agricultural products. Agenda 2000 calls for supplying European industry at prices closer to world prices; this will not suffice without consolidation of the rebate mechanisms for starch use, which should be transparent, predictable and based on the world price for maize.

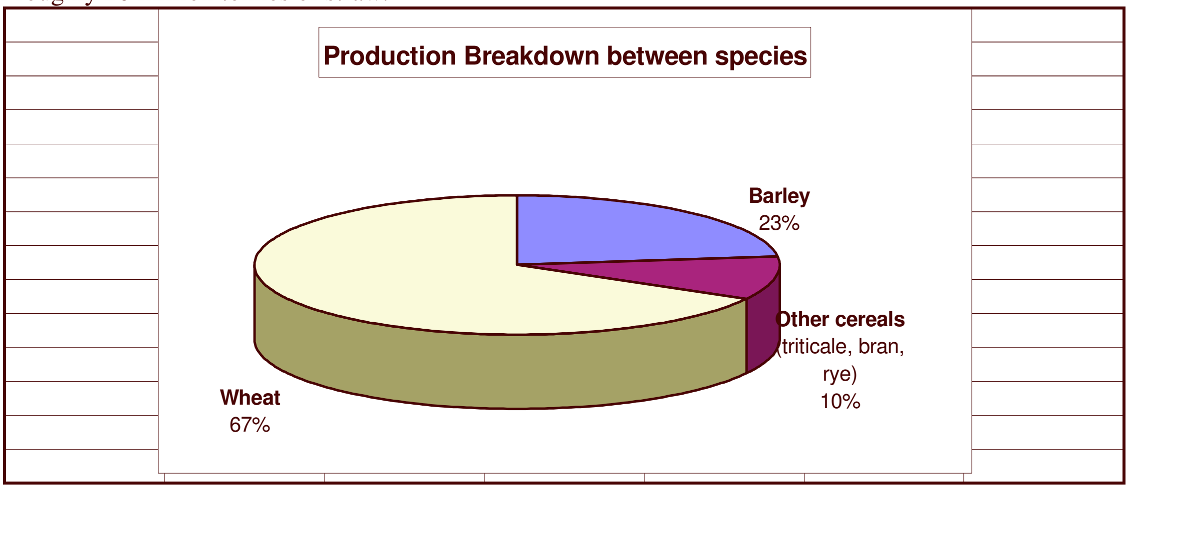
PART III
Fibrous Plants

I. OPPORTUNITIES

1.1 Production and composition of ligneous plants and residues (mainland France)

Three types of production are considered here for the study of non-food uses of fibre production other than forestry wood, i.e.
1. **Dry residues** (by-products), for example grain STRAW.
2. **Annual lignocellulosic plants**, for example HEMP, SORGHUM, textile FLAX.
3. **Perennial lignocellulosic plants**, for example SRC (short rotation crops) poplar, eucalyptus.

Grain straw :
The straw which remains after threshing of grain is a very plentiful renewable resource. Assuming an average yield of 3.5 t of straw per hectare of grain, the 6.5 million hectares of grain crops in France generate a production of roughly 20 million tonnes of straw.



The amount of straw actually available for industrial non-food uses is greatly reduced, however, due to :
- New harvesting techniques (harvesting/threshing/mulching combines, and 20-cm cutting heights)
- A drop in straw yields caused by the introduction of dwarfism genes (reducing risks of crop lodging)
- Traditional use of straw as organic amendments for crops, and as animal feed and litter.

This heavily damaged straw is not always of sufficient quality to meet the specifications required of industrial raw materials. This brings available quantities down to 3 to 4 million tonnes.

Annual lignocellulosic plants
Highly diversified, there are many usable species: hemp, fibre sorghum, kenaf, etc. But for reasons that vary from species to species, crop acreage of these plants is low, and their extension is hampered (insufficient productivity, limited markets, or markets that remain to be developed, applications that are still experimental, an inappropriate regulatory framework).
Hemp: 11,000 ha planted in France in 1997; estimation for 1998, 10,000 ha. [14]
Fibre sorghum, at an experimental stage, with fewer than 20 ha planted in 1998.

Perennial lignocellulosic plants
There are two types of crops in this category: shrub-like (SRC) and grassy (Miscanthus).
Short-rotation poplar and eucalyptus were planted on around 1,000 ha in France in 1996.

i. Production method

The most intensively studied lignocellulosic crops in France are hemp and sorghum. Today these two crops attain sufficiently high yield targets. Hemp: 7 to 9 t/ha of stalks. Fibre sorghum, whole plant: 15 to 25 t dry matter/ha on small plots, 10-15 t dry matter/ha in mass planting (highest yields south of the Loire River and in Alsace). Short-rotation crops yield 7 to 10 t of wood per year.

Special features of these crops :
As a general rule lignocellulosic crops require very few inputs; this is particularly true for perennial crops.
The only requirement of hemp is 110-140 units of nitrogen. Hemp can be grown exclusively for industrial applications, and is restricted to varieties with a THC (tetra hydrocannabinol) content lower than 0.3%.
Fibre sorghum makes efficient use of water (irrigation 0-1,000 m^3/ha) and of nitrogen (50-100 units/ha).

Kenaf (gambo fibre) yields 10 to 15 tonnes of dry matter a year. With water and warmth needs similar to those of fibre sorghum, cultivation is limited to the geographical zones of south-western France.
Cultivation of SRC is established for 20 years, with three harvests 7 to 10 years apart. After planting this crop requires no inputs.
Miscanthus is susceptible to water stress in summer periods; the crop is harvested in winter, with an average yield of 12.5 t of fibre/year over a period of at least 15 years. Planting costs are high (a delicate phase) and crop production will start only 2-3 years after planting.

ii. Crop products

The principal value of these crops is their high fibre content. The composition of these crops is given in the table below (in % of dry matter).

Crop	**Cellulose**	**Hemicellulose**	**Lignin**
Wheat straw	40-50	25-30	15-20
Hemp	48	27	21
Fibre sorghum	37	28	8
SRC poplar	31-33	15-22	23-27

NB: Three products are obtained from hemp straw fibre: peeled hemp (60%), tow (30%) and "fines" (10%).

Market outlets may be found for two basic raw materials: lignocelluloses and sugars.

iii. New technologies and their impact on production

New technologies have had a negative effect on straw production, because the resulting by-product is of little value, not readily converted into a saleable product.
Inversely, research on sorghum and hemp cultivation practices has revealed overall increases in production yields.
Concerning fibre sorghum for example, under the EU programme EUROSORGHO instituted in 1991 research carried out from 1992 to 1997 led to the introduction of agricultural production techniques, in particular a harvest prototype for the straw pathway, and the creation of the first high-performance European hybrids, with a potential yield of 15-20 t dry matter per year in mass plantings.
For hemp, new varieties without THC (tetra hydrocannabinol, a psychotropic substance classed as a narcotic) will make it possible to avoid a total ban on this crop.

1.2 Industry and markets

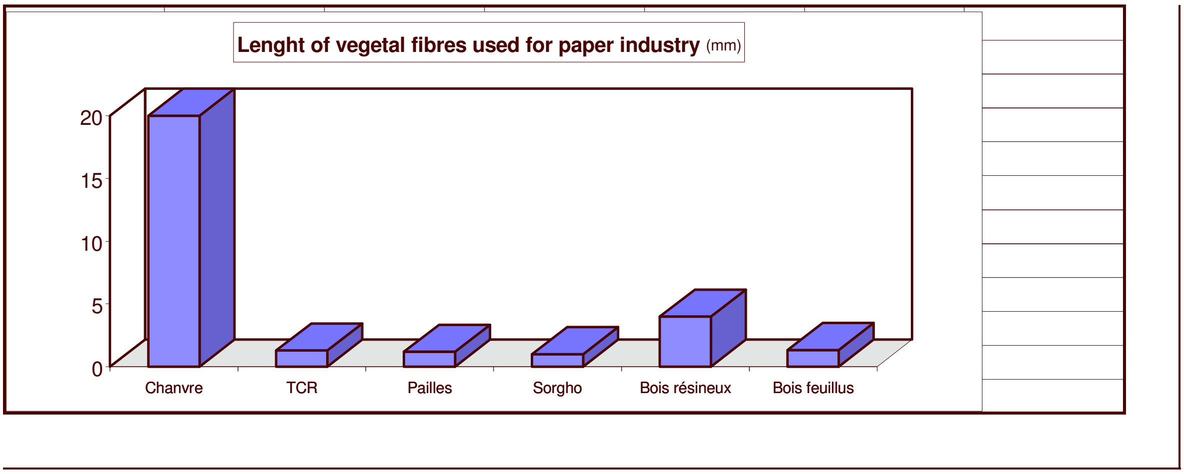
The use of fibres for industrial applications has many advantages: [36]

- renewable feedstock
- biodegradability
- neutral CO_2 balance
- large quantities available (straw)
- independent supply
- favourable legislation (industrial set-aside lands, special treatment for hemp, flax)
- low selling prices
- low-cost industrial process
- preservation of the socio-economic landscape

Therefore producers, inter-professional bodies and industrialists are interested in the development of fibre production turned towards new applications.

i. Industrial feedstock needs

Traditionally used for energy purposes, the industry which now uses the most fibre is the paper industry. The type of application depends on the quality of the fibre (length, thickness). Long fibres are used for papers with very high added value, while short fibres (comparable to those of deciduous woods) are used in a wider range of pulps and papers (graph [5:32]).



Grain straw

In the European Economic Community, straw consumption for paper making is on the order of 200,000 to 250,000 tonnes, roughly 1% of total pulp production.

Hemp stalks [14]

Byproducts	**Tow**	**Peeled hemp**	**"Fines"**
Main sector of use	• Paper making • Rope and string	• Animal litter	• Animal feed • Industrial absorbents
Average tonnage exploited	17,000	21,000	4,000

Short rotation crops supply approximately 8,000 t of wood to French paper mills.
Fibre sorghum: Use of this fibre in paper making is in the predevelopment phase, but the needs have not yet been ascertained.

ii. Industrial outlets and processes

Market outlets for fibrous crops fall into two categories, depending on the level of hydrolysis of the feedstock which determines the added value of the finished product:

- low or medium added value for the use of fibres
- medium to high added value for polymer applications, by direct use of plant polymers or by conversion of basic sugars.

Fibre applications

Traditionally straw and hemp (like flax) have been used in paper making.
In 1993 the E MC2 co-operative in Lorraine created a subsidiary, E MC2 DEVELOPPEMENT, which worked on conversion of lignocellulosic materials by steam cracking (pulp yield: 60%). This project reportedly involved 100,000 t of straw, and generated by-products suitable for conversion to saleable products [7:159] (cf. use of polymers).
More recently, a high-yield manufacturing process for unbleached pulp (pulp yield 85%), using a twin-screw extrusion process, has emerged from research carried out under the European programmes ECLAIR (straw) and EUROSORGHO, and national programmes (AGRICE). This process, now in a pilot stage, can also be applied to straw, as well as fibre sorghum silage, kenaf and grain straw.
Qualification tests of sorghum and kenaf for making packaging paper, flat and corrugated cardboard have been successfully conducted by French industrial paper companies (Papeteries de Gascogne, SAPSO, EMIN LEYDIER). Nonetheless there is a need for greater improvement in the technical characteristics of the papers and optimisation of the different phases in the pulp and paper production processes.

This new low-pollution modular process can also be applied to kenaf.

A pilot twin-screw facility installed in Pontcharra for production of unbleached paper pulp can produce unbleached pulp batches from annual plants in quantities from 300 kg to 10-15 tonnes, ready for direct use in industrial paper production. The pilot plant is also equipped to do work on bleaching annual plant pulp in the twin-screw process.

These tests have shown that:

- Fibre sorghum and kenaf pulp have good "machining" qualities in industrial processes.
- Annual plant pulp can be substituted for some standard pulps (post-consumer paper in making paper for corrugated cardboard, foliaceous pulp in making packaging paper).
- The loss of quality in post-consumer paper can be slowed by adding virgin fibres from annual plants, for example 25 to 30% of sorghum pulp (this has traditionally been achieved by using various agents, including starch, with ever greater difficulty in meeting product specifications).

Approximately 70 tonnes of finished products (cardboard boxes) have been sold; these products meet market standards, and even surpass them for certain characteristics (better "bulk" for packaging paper, higher compression resistance for foliaceous pulp).
Further R&D work has been planned for 1998-1999, with the goals of improving the cost/performance ratio, investigating other feedstocks and areas of application (bleached hemp or flax pulp using continuous twin-screw processes), and validating technical and economic data that would warrant setting up a demonstration twin-screw pulp plant (high-yield unbleached or "chemically" bleached) using annual plants, around the year 2000.
More broadly speaking, with paper and cardboard consumption rising at a pace of 2.5 to 3% annually, some specialists expect 24 million tonnes of non-wood pulp to be used in the world in 2000.
Other fibre applications are found primarily in the buildings sector [14].
In France the hemp plantation in the Aube department (95% of the hemp market in France) has been particularly active in research and proof-of-concept work to define new outlets for hemp in buildings.
Current methods for processing the stalks for fibre make it possible to improve yields and quality of peeled hemp chips.
Peeled hemp is sold as a construction material and an insulating product. The products elaborated and sold by the Aube facility are the following [13]:

• Trade name • Date first manufactured	**Nature**	**Main uses, in bulk, without binder**	**Main uses, in concrete form, with binder**
- **Méhabit** 1962	peeled hemp coated with natural bitumen	Underlayer in floating pad	
- **Canobiose** 1986-87	Peeled hemp treated by silication	Filler between struts or under-roof insulation	Filler for wood-frame walls, non-load-bearing pads and masonry
- **Isochanvre construction** - **Isochanvre isolation** 1989	Petrified peeled hemp	Insulation: attics, partition walls, flooring	Construction: tiling on earth foundations, filling for wood-frame walls, non-load-bearing masonry
- **Canosmose** 1994	Raw peeled hemp, sorted and dedusted		Filling between struts, under-roof insulation, filling for wood-frame walls, non-load-bearing pads and masonry

Other lignocellulosic feedstocks can also be used for these applications.

Other applications for hemp exploit the absorbency of peeled hemp chips [36]:

- animal bedding and litter
- active carbon
- retention of heavy metals
- oil absorption (petroleum)

or are found in textiles. This sector is overwhelmingly dominated by cotton and synthetic fibres. But buoyed by the current trend toward ecological textiles, hemp could be developed to produce fibres at competitive prices.
Technical textile materials should also make a breakthrough in the automobile industry, as substitutes for glass fibres (brake pads, sturdy and recyclable dashboards), and many auto makers are already expanding their use of this lignocellulosic raw material (Citroën, Mercedes, Fiat).

Likewise, these fibre-polymer composite materials can be made using SRC fibres, after fibrillation and/or preprocessing (pressed particle panels).

One of the remaining problems in all cases, however, is the dispersion of a hydrophilic phase in a hydrophobic matrix: surface treatment of the fibre is often required to render the two components compatible [5:75].

Application in the field of polymers

After solubilisation (NMMO solvent) and regeneration, films, fibres or foams can be obtained from polymer cellulose. Chemical modification by organo-soluble thermoplastic derivatives or by hydrosoluble polymers facilitate processing of polymers derived from lignocellulosic materials. These transformations could ultimately produce compounds that could compete with synthetic polymers used as thickeners or complexing agents. If reticulated they could generate super-absorbent substances [5:71-72].

Starting with basic sugars, different kinds of applications are envisioned:

- Modification (furfural) = competitor for synthetic polymers
- Carbon source for fermentation = gelling agents, kelating agents, emulsifiers, surfactants)
- Copolymerisation of lignin = adhesives, foams

Examples of applications:

The ARD company has set up production of surfactants derived from wheat straw (70% carbohydrate content), recovering lignocellulosic residues for use in paper pulp or combustion. (Pulp: 558 kg of paper pulp at 2 F/kg. One tonne of straw (dry matter) yields an added value of 6,500 F/t feedstock. Combustion: 620 kg at 0.1 F/kg; added value = 5,500 F/t feedstock). On average 370 kg of surfactants (15 F/kg) are obtained from one tonne of straw dry matter (value 350 F).

E MC2 DEVELOPPEMENT had considered the possibility of recovering the by-products of steam cracking of lignocellulose for paper making applications [7]:

Feedstocks	**Fractions obtained by steam cracking**		**Characteristics**	**Markets and uses**
Lignocellulose dry matter 100,000 t/yr (equivalent 120 Kt of rough straw)	Pentose hydrolysates (xylose, arabinose) 19,000 t/an	• xylitol (3,000 t)	➢Substitute sugars	➢Worldwide: 10,000 t/yr (35-55 F/kg
		• crystallised xylose (1,000 t)	➢Hemicellulose sugars	➢Specific fermentation substrate: production of enzymes, cellulases, xylanases
		• furfurylic alcohol (6,500 t)	➢in composition in heat-resistant resins	➢Worldwide: (total pulp) 180,000 t/yr
➢40,000 ha of grain harvested	Fibres, cellulose, lignin 60,000 t/yr	• Paper pulp for cartons (60,000 t)	➢Manufacture of packaging, paper and cardboard	➢France: 3,470,000 t/yr (imports 670,000 t)
➢or 8,500 Ha of fibre sorghum on set-aside lands	Lignin	• Polymers and plastics	➢Plastic films, biopolymers et photodegradables	
	Hexose fractions		➢Foodstuff sugars	

1.3 Environment **(Annex 2)**

Cultivation

- Improve sustainable management of forest resources in ecological and economic terms (complementary nature of wood/annual plants)
- Contribute to long-term socioeconomic development of farmlands by organising the structure of local industrial and commercial market outlets.
- Introduce new crops to diversify plantings.

- Many lignocellulosic plant crops (hemp, sorghum, SRC) have low or very low input requirements, reducing the risks of pollution, and in the case of perennial crops with efficient use of soil resources, pollutant leaching is limited.
- Renewable resources that are easily adjusted because annual in nature.

Life-cycle analyses (LCA) can be used to measure inputs and outputs for each stage in the production process, then to assess environmental impacts, and lastly to make adjustments for optimal operations, as required by outside constraints or user priorities.
For fibre plants the findings of the first step in this analysis are as follows:

Fibrous products —— production —— destruction of wastes

absorption of CO_2
local production
renewable resource

production:
less pollution
biodegradable waste
upkeep of landscape
farm employment
biodiversity

destruction of wastes:
less pollution

Negative aspects: production chain to be organised, major investment requirements.
Positive aspects: Neutral CO_2 emission/absorption balance, lower energy needs.

Industry

Generally speaking, substitution of lignocellulosic materials derived from plants for fossil products (depletable, toxic, non-biodegradable and subject to ecotaxation) provides a way to control pollution and greenhouse effects. More specifically, in the case of uses in paper making: lignocellulosics could reduce pollution caused by effluents, by limiting the use of starches and other additives, facilitating the development of modular processes adapted to the scale of an agricultural production zone, and enabling high-yield production of unbleached pulp, and perhaps bleached pulp in the near future if R&D efforts are maintained to devise low-pollution techniques (soda, sodium bicarbonate reagents, rather than polluting sulphur compounds; bleaching with hydrogen peroxide rather than chlorine compounds).

II. LIMITING FACTORS

Constraints and issues regarding development of non-food uses of fibre crops in France

Constraints	Issues	Proposals
Scientific / Technical	• Feedstocks	• Optimise practices for lignocellulosic crops (ex. fibre sorghum harvesting) • Improve logistics in the straw market (harvesting, storage, preparation, transport) • Incentives for the development of farm co-operatives centred around pilot crops
	• Industry, process	• Upstream research: correlation of chemical and macromolecular structure / suitability for paper making, suitability for bleaching • Optimisation of conversion processes • Obtain materials with specified and replicable properties • Adjust preparation of feedstocks to the specific requirements of different applications (ex. sorghum, kenaf for paper making) • Broaden approaches to new feedstocks and applications (ex. continuous processing of bleached hemp pulp)
Environmental	• Biodegradability and ecotoxicity	• Measure and control biodegradability of plant-derived lignocellulose
	• Overall assessment of the production stream	• Take into account the diversification of plantings in France • Preserve soil fertility
Legislative	• European laws	• Draw up a regulatory framework adapted to non-food crops in order to guarantee economic and agricultural profitability, stability and security of supply • Maintain production subsidies for fibre plants (ex. hemp), and even extend them to other crops • Develop synergy within the EU and with international programmes
Economic	• Crops	• Set up a market system favourable to lignocellulosics • Pursue optimal farming practices to lower the cost of feedstocks, making them competitive with fossil feedstocks and forestry resources • Cut the costs of gathering feedstocks (50% of cost price at delivery) and optimise logistics
	• Industry	• Improve cost/output ratio in processing (ex. unbleached pulp from annual plants) • Validate all technical and economic data before starting up production
	• Internalising costs	• Internalise macroeconomic impacts in a global fashion (greenhouse effects, job creation)
Information	• Marketing	• Encourage creation of prototype projects demonstrating the relevance and effectiveness of plant lignocellulosics in their various applications

III. PRIORITIES: Strengths and weaknesses

Agricultural fibres have been used successfully for the manufacture of a range of materials and composites. Certain new applications are headed for further development (lignocellulosic/thermoplastics).
Fibrous agricultural residues are **available in large quantities** to meet the needs of fibre industries, and constitute an attractive feedstock because they are lightweight, economic and renewable.

They are advantageous for the environment because of their neutral greenhouse gas balance and their renewability (unlike fossil-derived products).
Environmental constraints thus weigh in favour of recourse to alternative feedstocks and help remove the obstacles that have blocked their development hitherto. Internalisation of external costs (infrastructure, networks, environmental impacts) and institution of an environmental tax on carbon dioxide emissions should push the balance in favour of use of agricultural residues.

In addition, conversion of this agricultural resource should **maintain jobs** in rural areas, by stimulating economic activity. Indeed, this type of crop is well suited to areas with mediocre or low crop-growing potential, where wheat and beets are not feasible.

However, the **economic activity chain** for this production remains to be **organised** and **optimised:** geographic availability and the significant acreage occupied may make exploitation of these crops costly.

The seasonal nature of the harvest has non-negligible consequences for the regularity of supply of annual fibres, and many stages are sometimes required for the processing of fibres: harvesting, separation of the fibrous part, drying, pressing, storage, cleaning, handling, transport (sorghum, miscanthus). All these stages are, as yet, costly, for they are not carried out on a large scale, given the slow development of industrial markets, in inverse proportion to the quantities of fossil products processed.

These weaknesses in the fibre production chain should not obscure its many advantages. In order to protect our environment, **the development of industrial markets for plant lignocellulosic materials** is now a necessity. This implies above all **a favourable policy framework** and implementation of prototype projects that demonstrate all the advantages of products derived from plant fibre, in terms of performance and bio-compatibility.
Technological intelligence and awareness in this domain must be reinforced, as well as technico-economic evaluation of the plants with the most potential. Demand for fibre plants which is weak today will grow stronger over the next 10 to 20 years, due to the inevitable depletion of forestry wood, traditionally used in the energy and paper making industries.

PART IV
Plants for Specific Uses: Medicinal Plants and Perfume Plants

I. OPPORTUNITIES

1.1 Production of Medicinal and Perfume Plants in Mainland France

Medicinal, aromatic and perfume plants form a sector that is particularly complex. Five factors explain this complexity [32]:

1. A great **many species** are involved, necessitating the development of specific cultivation techniques.

~~3.~~2. A **multitude of elaboration and transformation processes** in the production stage (plants are sold fresh, dried, frozen, as essential oils).

~~4.~~3. A **diverse user sector** (agro-food, flavouring industry, perfumes, cosmetics, pharmaceuticals) that subject agricultural production to the constraints of industrial feedstock production.

~~5.~~4. A **highly competitive international market**, all the more so that this sector is not governed by EU mechanisms, and production occurs in many countries around the world.

~~6.~~5. The **major impact of technological advances and consumer trends.**

Plant material must thus meet industrial criteria, accounting for particular specifications (stable and sure supply, standards, active principle content, etc.). This first challenge is made more difficult by technical production requirements (harvesting, processing) that call for considerable and specialised investment, and impose specific types of steps and organisation related to the intended industrial use.

There are three factors, however, that ensure the status of these crops:

- The substances derived from these plants for industrial uses cannot always be made synthetically.
- If and when a competing synthetic substance is brought to market, its cost price may be higher than that of the same molecule obtained from plants.
- "Natural" origins secure a strong marketing advantage that is sometimes crucial for product sales (cosmetics).

Thus despite the complex and competitive international context, France can point to diversified and effective activity in this sector.
France ranks first among European countries for acreage planted (≈28,000 ha), ahead of Spain (see breakdown of figures, 1.1.i).

i. Plant species

(Given the complex synthesis of a range of data, these figures are orders of magnitude.)

Two types of crops represent the most valuable production in France:

- Crops with low unit value, but extensively planted (lavandin, poppy).
- Crops that are picked or gathered in small quantities, with relatively high unit value (gentian, wild blueberries).

Planted acreage of medicinal, aromatic and perfume plants in mainland France
(1995, [32]) :

CROP SPECIES PLANTED ON > 10,000 ha		
	Lavandin (13,300 ha)	
CROP SPECIES PLANTED ON > 5,000 et < 10,000 ha		
	Oil poppy (5,000 à 6,000 ha)	
CROP SPECIES PLANTED ON > 1,000 et < 5,000 ha		
Lavender (2,500 ha)		Clary (1,000 ha)
CROP SPECIES PLANTED ON > 100 et < 1,000 ha		
Tarragon	Thyme	Parsley
Bitter fennel	Hyssop	Psyllium
Ginkgo Biloba		
CROP SPECIES PLANTED ON > 10 et < 100ha		
Wormwood	Chervil	Peppermint
Dill	Chives	Passiflora
Angelica	Coriander	Woad
Green anise	Ergot	Horseradish
Artichoke	Sweet fennel	Rosemary
Burdock	Fenugreek	May rose
Basil	Gentian	Savory
Borage	Lovage	Officinal sage
Wild camomile	Melilot	Verbena
Roman camomile	Melissa	
Blackcurrant	Mint	
CROP SPECIES PLANTED ON < 10ha		
Artemisia	Hamamelis (witch hazel)	Meadowsweet
Bluet	Jasmine	Saffron
Calendula	Marjoram	Santolina
Cistus	Mallow	Saponaria (soapwort)
Escholtzia	Bitter orange	Valerian
Ginseng	Origanum (oregano)	Red creeper
Grindelia	Mouse-ear (hawkweed)	Violet
Marsh mallow	Dandelion	Others

ii. Production methods

Due to the diversity of crops and the range of plant parts used (bark, aerial parts, roots, seeds, flowers), it is hard to spell out in detail the cultivation methods used. It should be added, however, that because of their specific uses, cultivation of plants other than mass-grown crops is often costly.
Furthermore, many medicinal, aromatic and perfume plants are not grown, but are picked in the wild.

Some examples of perfume plants that are picked or gathered:

- Mimosa: 100 t/yr
- Labdaniferous cistus: 800 t/yr
- Narcissus: 400 t/yr
- Cypress: ~ 10 t/essential oils
- Blackcurrant buds: 35 t/yr
- Tree mosses: 2,000 – 2,500 t/yr

iii. New technologies and their impact on production

Despite the narrowly focused market outlets that often make it difficult to earn a return on research, work is currently underway in France aimed at improving yields and introducing new crops.

ONIPPAM in particular and to varying degrees, is participating in efforts to improve cultivation techniques, either through financing, or under joint national/regional programmes. This work is often conducted in partnership with ITEPMAI, CRIEPPAM, or other research groups such as INRA units (Dijon, Colmar) or laboratories in universities, specialised faculties (INPT, ENSIAM) and industry.

This research work has given a range of results:

- adaptation of existing equipment (machines for harvesting forage, root plants etc.)
- construction of prototypes (lavender, camomile harvesting machines)
- improvement of dehydration and freezing methods (chives, tarragon, parsley)
- modernisation of distilleries (essential oils of lavandin, lavender, sage, cypress).

This work has thus been devoted to classical agricultural subjects (selection, reproduction, cultural practices, harvesting), but has been extended to cover initial processing operations (cutting, distillation, drying, etc.), endowing it with an original imprint.

1.2 Industry

i. Feedstock requirements

Feedstock needs vary widely with the industrial sector, and often depend on international procurement. User industries have adopted three procurement strategies:

1. **Acquisition of bulk raw materials on the international market**. Laboratories buy their supplies from traders and brokers when plants are traditionally brought to herbal plant markets, and have no procurement problems.

~~3.~~2. **Controlling production in developing countries.** Laboratories may sign sales agreements with local producers, or may choose to invest in extraction facilities for processing plants at the production sites.

~~4.~~3. **Transfer of production**. When the above two supply pathways are deemed insufficiently secure, and when it is technically possible, laboratories introduce cultivation in industrialised countries. In addition to transferred production comes **exploitation of plants that are naturally present in temperate climates**, either by picking or by raising crops.

ii. Industrial users

<u>Medicinal sectors</u>

- **Conventional allopathic remedies:** exploitation of molecules containing highly complex active principles, or ones that cannot be made synthetically. These molecules are subject to the regulatory constraints governing medicines.
  Grown in France: poppy, ergot, digitalus (foxglove), or picked in the wild (colchicum, holly…)
  Imported: jaborandi, orec nut, rauwolfia…
  Used by pharmaceutical firms: (Boiron, Alban Muller, Gifrer & Barbezat, Indena, Hoecht, Marion Roussel, Roche)

- **Herbal medicine:** use of medicinal properties of plants without isolating any one molecule, exploiting the synergy of multiple plant characteristics. This sector is maintained by the persistence of traditional herbal remedies and the revival of plant therapeutics.
  A broad range of plants are raised for this market, most often on small plots. A streamlined market authorisation process is recommended for 112 plants.

- **Aromatherapy:** this is a form of treatment that makes use of essential oils. Aromatherapy is defined in France as the ingestion of essential oils or their use in external applications (the definition is broader in Anglo-Saxon countries).

- **Homeopathic medicine:** uses many elements found in the animal and vegetable orders. This sector uses small quantities of each plant, and relies on a limited number of gatherers.

- **Veterinary plant therapeutics:** therapeutic plants used by manufacturers of conventional veterinary preparations. This market is limited in terms of retail prices, and therefore could interest suppliers who can furnish raw materials under mass cultivation conditions.

Aromatics

Many industrial applications for aromatic plants are intended for foodstuffs (spices, savoury plants, herb teas). There are however also may non-food applications: tobaccos, toothpastes containing essences of mint, cloves or sage, etc. Aromatic plants are attractive for a range of industrial sectors, by virtue of four basic properties: as antioxidants, dyes, insecticides and active molecules for fine chemicals. This sector has strong potential to develop towards non-food uses.

Perfumes

A great number of plants, mass or speciality crops, picked or gathered, are used in perfumes for their olfactory properties. In most instances the scent is obtained by a complex mixture of natural and synthetic products (90% of perfume feedstocks).

- **Industrial scents** (detergents): Cost price is the determining factor in this sector, and in France only the only usable substances are those that are cost-competitive with imported or synthetic products. This is the case for lavandin.

- **"Down-market" cosmetics and perfumes**: This sector comprises essentially body care products. The major cosmetics firms possess their own formulation facilities (synthetic – essential oils), but many have recourse to perfume companies for their compositions.

- **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 drop in producer prices. The French industry has performed well in export markets, however.

Other sectors

Among these other sectors, natural colouring dyes can be mentioned (pastels, for example).
Other new applications also appear potentially interesting. INPT research has demonstrated the possible applications for a number of plant extracts (essential oils and aromatic extracts) obtained from plants some but not all of which are grown for their phytosanitary properties (fungus and bacterial control, insect repellents,

nematicides, herbicides, anti-oxidant protective agents). Of these, 24 essential oils emerge as particularly attractive in terms of industrial processing.

1.3 Markets

It is difficult to evaluate the total markets for medicinal, aromatic and perfume plants, given the diversity of plants and applications, and the ongoing changes in producer countries. **World production** figures for 1995 give an idea of the market size:

	Essential oils	Aromatic plants	Medicinal plants
World tonnage	45,000	50,000	*

* : Data not available.

Price formation and market dynamics are influenced by different parameters:

- total market size
- French and European production share in international markets
- nature of competition.

Prices are frequently subject to wide fluctuation. In addition, price formation is linked to the nature of commercial relations, and notably to the share of contractual operations.

With the harvest period running for May to October, the year is divided into two segments:

- First semester = end of preceding season. Prices = users needs / available stock.
- Second semester = after harvest. Prices = function of harvest quality and quantity.

Overall the market for medicinal, aromatic and perfume plants is growing. But the broadening geographic distribution of producer countries is heightening competition with European production. Industrialised countries nonetheless maintain their superior position:

- by profiting from intensive and mechanised cultivation
- by rationally exploiting species that are abundantly available in the wild
- by fostering local production of plants and essences that are minor crops in terms of volume, but which represent a sizeable advantage in terms of quality.

II. LIMITING FACTORS

Constraints and development issues for non-food uses of medicinal, aromatic and essential oils crops in France

Constraints	Issues	Proposals
Scientific / Technical	• Feedstocks • Industry, process	• Optimise cultivation techniques, adapt equipment, improve processing operations. • Find and develop new opportunities (for example: antioxidant essential oils, new active medicinal molecules)
Environmental	• Overall evaluation of product stream	• Take biodiversity of farmlands into account. • Regulate picking and gathering to avoid depletion of natural plant resources
Legislative	• European laws	• Set up an EU protection mechanism to confront international competition • Institute support measures for European research programmes – joint action – demonstration projects – other
Economic	• Crops	• Optimise productivity gains (selection, harvesting and distillation techniques) to

		make natural molecules more competitive with synthetic ones
Information	• Marketing	• Inform the general public of the advantages of natural molecules.

III. PRIORITIES: Strengths and Weaknesses

In a complex and competitive international environment, France possesses a diversified and effective range of activities– industrial, trading and production. France ranks second among industrialised countries on the medicinal/aromatic/perfume plants market, behind the United States.
It should be noted that an association of 15 producer groups was set up in 1995-1996 and recognised by the Ministry of Agriculture, Fisheries and Foodstuffs. Through this association price fluctuations have come under control, production is negotiated with buyers, and a producer framework instituted for crops where technical improvements may prove to be crucial.
At the European Union level, the member states must show a uniform desire for harmonisation, in order to ensure that the single market works smoothly via implementation of regulations to protect European production that is subject to strong outside competition. The creation of EUROPAM in 1994, the proliferation of European research programmes, and organisation of trade and industry on a European scale, can only consolidate EU production and markets, by fostering the emergence of a recognised and competitive professional activity stream.
To build an effective long-term market framework, however, a coherent and ongoing dialogue must be instituted between farmers and industrialists, who are the main actors in this branch of activity. Talks should focus on three aspects:

⇒ techniques
⇒ timing and sizing of the project (timetable)
⇒ technical specifications.

Farmers will have to be able to satisfy specific industrial user demands, notably by making clear commitments guaranteeing a minimum production of stable quantity and quality. In return, industrialists will have a sure supply of high-quality natural products over the long term. In the absence of this dialogue, the industrial trend of replacing natural molecules with synthetic products will only grow stronger (95% of substances used in perfume products are synthetic).

ANNEXES

Annex 1

Cropping patterns for agriculture products

		1975	1980	1985	1990	1995	1996	1997
				CEREALES				
WHEAT								
Surfaces	(Kha)	3592.7	4465.9	4666.0	4799.0	4515.8	4770.1	4843.7
Average yield	(q/ha)	39.5	52.1	61.1	66.1	66.1	72.7	68.1
Production	(KT)	14199.3	23256.0	28503.0	31743.0	29852.5	34695.0	32970.8
MAIZE								
Surfaces	(Kha)	1960.0	1756.9	1888.7	1545.0	1650.3	1733.4	1857.6
Average Yield	(q/ha)	41.8	53.3	65.9	58.2	77.2	83.8	90.6
Production	(KT)	8201.8	9358.0	12441.0	8996.0	12735.9	14529.7	16832.5
BARLEY								
Surfaces	(Kha)	2769.6	2649.9	2248.0	1761.0	1386.8	1534.3	1690.3
Average Yield	(q/ha)	33.7	44.0	51.0	57.2	55.4	61.9	59.9
Production	(KT)	9343.5	11715.6	11470.0	10067.0	7685.6	9496.9	10126.3
OATS								
Surfaces	(Kha)	655.3	533.8	432.8	218.0	148.6	139.5	133.4
Average Yield	(q/ha)	29.7	36.2	40.9	38.8	40.4	44.6	42.5
Production	(KT)	1947.9	1930.7	1770	846.0	600.6	621.9	567.2
RYE								
Surfaces	(Kha)	110.1	129.5	87.3	64.5	46.3	48.6	45.1
Average Yield	(q/ha)	26.5	31.5	34.0	36.6	41.0	45.4	43.6
Production	(KT)	291.7	407.5	296.8	236.2	190.3	220.8	196.9
SORGHO								
Surfaces	(Kha)	81.6	147.4	44.0	66.6	45.8	54.8	68.7
Average Yield	(q/ha)	33.0	47.4	46.8	39.7	56.5	62.6	66.2
Production	(KT)	269.2	349.2	206.2	264.4	258.5	343.2	454.2
				OIL CROPS				
RAPE								
Surfaces	(Kha)	281.7	780.5	473.7	677.4	838.8	870.0	974.9
Average Yield	(q/ha)	18.0	28.0	29.9	29.1	32.3	33.2	35.4
Production	(KT)	507.3	2181.6	1418.6	1973.1	2706.7	2885.2	3449.2
SUNFLOWER								
Surfaces	(Kha)	75.7	102.8	638.5	1116.3	976.8	913.4	894.9
Average Yield	(q/ha)	14.9	23.8	23.7	20.7	20.6	22.4	22.8
Production	(KT)	113.3	244.8	1513.3	2312.1	2015.5	2044.9	2041.1
SOJA								
Surfaces	(Kha)	1.6	7.8	27.4	118.2	101.8	85.9	97.9
Average Yield	(q/ha)	19.7	21.2	21	22	26	27	27
Production	(KT)	3.3	16.5	56.4	255.6	261.3	229.6	268.6
OIL FLAX								
Surfaces	(Kha)	20.8	3.0	/	2.2	15.3	8.4	5.4
Average Yield	(q/ha)	13.4	19.6	/	19.0	18.0	18.0	18.0
Production	(KT)	27.8	5.9	/	4.2	27.2	14.9	9.9
				AUTRES				
SUGAR BEET								
Surfaces	(Kha)	598.1	548.8	490.9	474.7	458.2	456.7	461.7
Average Yield	(q/ha)	395.5	480.4	610.8	668.5	667.1	677.4	743.2
Production	(KT)	23655.7	26368.4	29990.7	31734.6	30571	30943.5	34311.4
HEMP								
Surfaces	(Kha)	7.5	6.6	6.1	3.3	6.0	7.6	10.6
Average Yield	(q/ha)	58.5	68.3	60.5	63.7	62.0	51.0	71.0
Production	(KT)	44.1	45.1	37.0	20.9	37.0	38.9	75.2
TEXTIL FLAX								
Surfaces	(Kha)	43.2	46.3	58.8	58.7	54.0	44.1	45.0
Average Yield	(q/ha)	56.1	63.6	68.2	62.2	61.0	64.0	69.0
Production	(KT)	242.4	294.6	401.8	365.1	327.5	283.9	312.6
SPECIALTY USES CROPS	(Kha)	32.1	29.5	/	21.9	26.8	27.9	29.1
(cf, part. IV)								
LAVANDIN								
Surfaces	(Kha)	19.6	16.9	12.6	12.4	14.2	14.1	14.3
Average Yield	(q/ha)	/	/	60.7	66.3	77.0	79.0	79.0
Production	(KT)	/	/	76.6	82.7	109.2	112.4	113.4

Annex 1

Main crops for non food purposes

Crops	Surface (1000 ha)	Set Aside surface	Average Yield	Production
OIL SEED CROPS [22]				
Rape	970	162 where : RME 149 Erucic 4,1 Chimical 8,1	3.5	3,400
Sunflower	895	41 dont : Oléic 2,6	2.3	2,100
Soja	97		2.9	280
Oil Flax	5		1.8	9
SUGAR CROPS [30]				
Wheat	5,000	10.4	7	33,055
Maize	1,700		9	15,451
Barley	1,500			10,146
Others	400			
Sugar beet	461	12.4	11 (T sucre/ha)	32,773
Potatoes				1,240
FIBRES CROPS (estimate)				
Wheat Straw			3.5	13400 T straw
Barley straw			3.5	4600 T straw
Other straws			3.5	2000 T straw
Hemp	11		7 à 9	90 T fibres
SRC poplar, eucalyptus	1		7 à 10	8,5 T wood

SPECIFIC USE CROPS (Medical, Aromatic, essential Oils : see Chap. VI

production of raw material for industrial uses in France

	Industrial product	Tons (1000 T)	By-Products	Tons (1000 T)
Rape	Oil	340	Cakes	436
Sunflower	Oil	585	Cakes	235
Soja	Oil	92	Cakes	3,344
Wheat	Starches	1,020	Issues Solubles Gluten	204 102 81.6
Maize	Starches	1,760	Drêches et solubles Oils Cakes Proteins	352 52.8 70.4 88
Potatoes	Starches	270		
Sugar Beet	Sugars		Pulps	1,630

Annex 2

Supply / Environmental Impact	Irrigation	Nitrogen supply	Phosphate supply	Potassium supply	Fertilisers supply	Phytosanitary products	Total/ Crop
WHEAT	~	**	*	*	~	*	
	0	*1*	*1*	*1*	*0*	*1*	*4*
MAIZE	**	***	**	**	~	*	
	2	*2*	*1*	*1*	*0*	*1*	*7*
RAPE	~	****	***	***	Sulphur	*	
	0	*3*	*2*	*2*	*1*	*1*	*9*
SUNFLOWER	~	***	**	**	Bore	*	
	0	*2*	*1*	*1*	*1*	*1*	*6*
SRC	_	_	_	_	_	_	
	0	*0*	*0*	*0*	*0*	*0*	*0*
SORGHO	~	**	_	_	_	~	
	0	*1*	*0*	*0*	*0*	*0*	*1*
HEMP	_	**	_	_	_	~	
	0	*1*	*0*	*0*	*0*	*0*	*1*

Key :

Crops management	_ :	Negligeable supply
	~ :	Possible supply
	* :	Supply
		(* : low, ** : middle, *** : high, **** : very high)

Environnemental impact	0, 1, 2, 3 :	Impact
		(2 et 3 : environmental impacts predicted to be injurious at middle term)

Annex 3

Contacts List

NAME	ADDRESS	PHONE/FAX (+33 ....)	CONTACT	SECTOR
Coordinator /. IENICA Network				
ADEME Agence de l'Environnement Et de la Maîtrise De l'Energie	27, rue Louis Vicat 75 737 PARIS cx 15	01.47.65.22.26 / 21 58 / 01.46.45.52.36	LABROUSSE S/ GAOUYER J.P ROY C.	
INRA UR 253 Institut National de la Recherche Agronomique	Unité de Bioclimatologie 78 850 THIVERVAL-GRIGNON	01.30.81.55.22 / 01.30.81.55.63	GOSSE Ghislain	
Professionals				
ORGANISATIONS PROFESSIONNELLES ET CENTRES TECHNIQUES				
AGPB Association Générale des Producteurs de Blé	8, Av. d Président Wilson 75 116 PARIS	01.44.31.10.00	GATEL Pierre	Cereals
AGPM Association Générale des Producteurs de Maïs	Route de Pau 64 121 MONTARDON	05.49.45.40.28	GAULTIER	Cereals
CEMAGREF Centre du Machinisme Agricole, Génie Rural, Eaux et Forêts	Parc Tourvoie 92 160 ANTONY	01.40.96.61.21		
CETIOM Centre Technique Interprofessionnel des Oléagineux Métropolitains	174, Av. Victor Hugo 75 116 PARIS	01 44 34 72 00	MESSEAN Antoine	Oil seed Crops
CGPB Confédération Générale des Planteurs de Betterave	43, rue de Naples 75 008 PARIS	01.44.69.39.00		Sugar Beet
Chanvrière de l'Aube	rue du Général de Gaule 10 200 BAR SUR AUBE	03.25.92.31.95	BOYEUX Bernard	Fibres
CPB Coopérative des Planteurs de Betterave	43-45, rue de Naples 75 008 PARIS	01.44.69.41.28	CREDOZ Paul	Sugar beet
CTP Centre Technique du Papier	Domaine Universitaire BP 251 38 044 GRENOBLE cx	04.76.44.82.36	PERRIN	Paper industry
ITCF Institut Technique des Céréales et des Fourrages	ENSMIC 16, rue N. Fourtin 75 013 PARIS	01.42.16.72.50	LEYGUES Jean-Philippe	Cereals
ITEIPMAI Institut Technique des PAM et PAP	ZI des 3 routes 49 120 CHEMILLE	02.41.30.30.79	BOUVERAT- BERNIER	Plants with specialist uses

ITL Institut Technique du Lin	5, rue Cardinal Mercier 75 009 PARIS	01.42.80.40.56	SULTANA	Fibres
ONIC Office National Interprofessionnel des Céréales	21, Av. Bosquet 75 007 PARIS	01.44.18.20.00		Cereals
ONIDOL Organisation Interprofessionnelle des Oléagineux	12, Av. GeorgesV 75 008 PARIS	01.40.69.48.00	CLAUDE Sylvain	Oil Seed Crops
ONIPPAM Office National Interprofessionnel des PAM et PAP	25, rue du Maréchal Foch BP 8 04 130 VOLX	04.92.79.34.46	GARNON	Plants with specialist uses
SIDO Société Interprofessionnelle des Oléagineux, protéagineux	174, Av. Victor Hugo 75 116 PARIS	01.40.69.49.50	LABALETTE Françoise	Oil, seed crops
UNIGRAIN Union financière pour l'économie et le développement	8, Av. Du président Wilson 75 016 PARIS	01.44.31.10.00	MARCHAND Daniel-Eric	Cereals
USIPA Union des Syndicats des Produits Amylacés	4, Place d'Orves 75 009 PARIS	01.48.78.51.00	PELLETIER	Starches

INDUSTRIES				
AGRIPACK	17 240 PLASSAC	05.46.49.72.75	MORILLON	Starches
BIODECAP	Bureau AIP aviation d'affaires 93 350 LE BOURGET	01.48.35.92.90	DOUMEIZEL Jacques	Starches
ELF ATOCHEM (CECA)	95, rue Danton 92 300 LEVALLOIS-PERRET	01.47.59.12.96	BERNARD	Oil Petroleum
LIMAGRAIN	rue de Limagrain BP 1 63 720 CHAPPES	04.73.63.42.88	BARON Michel	Cereals
NOVANCE RHÔNE-POULENC	Chemin de l'usine 60 280 VENETTE	03.44.90.70.00	BROWNING Peter	Oil / Chemical
POLYNAT Groupe ROVERC'H	44, rue des entrepreneurs 91 560 CROSNE	01.69.49.67.66		Cereals
ROQUETTE	4, rue Patou 59 022 LILLE cx	03.20.13.28.00		Starches
SOLIANCE Filiale ARD	Route de Bazaincourt 51 110 POMACLE	03.26.05.42.80	de BAYNAST Régis	Starches / By-products

RESEARCH INSTITUTES, UNIVERSITY,				
ARD Agro-industrie , Recherche et Développement	Route de Bazaincourt 51 110 POMACLE	03.26.05.42.80	de BAYNAST Régis	Starches / By-products
CATAR-CRITT	ENSCT 118, Route de Narbonne 31 077 TOULOUSE cx4	05.61.17.57.25	CARUEL Hervé	
CNRS-CERMAV	Domaine Universitaire 601, rue de la chimie 38 400 St MARTIN D'HERES	04.76.03.76.03	PEREZ Serge	
Faculté de pharmacie	ANGERS	02.41.22.66.00	M. BRUNETON	Plants with specialist uses
Faculté de pharmacie Centre de recherche sur les biopolymères	GRENOBLE	04.67.41.82.60	M. VERT	Cereals
INPT Institut National Polytechnique de Toulouse	TOULOUSE	05.61.17.57.35	M. LE BIGAUD Antoine GASET	PAM et PAP
INRA UR 725	NANTES	02.40.67.50.61	COLONNA Paul	Céréales
INRA UR 869	COLMAR	03.89.22.49.40	POUTARAU Anne	Plants with specialist uses
VALAGRO	40, Av. Du recteur Pineau 86 022 POITIERS cx	05.49.45.40.28	MARECHAL	

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