

IENICA

REPORT FROM THE STATE OF DENMARK

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Index of Contents

ACKNOWLEDGEMENT **I**

INDEX OF CONTENTS **II**

GENERAL **1**

AGRICULTURE/FARMERS	1
CONSUMERS AND GOVERNMENT	1
INDUSTRY	2
ECONOMICS OF AGRICULTURAL ENTERPRISES 1996/1997	2
ENSURING THE FARMERS A LARGER SHARE OF THE ADDED VALUE	2
FARM SCALE PROCESSING	3
MOLECULAR FARMING	3
PRE PROCESSING IN RURAL AREAS, WHOLE CROP UTILISATION, BIOREFINERIES	4
CASH CROPS	5
IMPACT OF AGENDA 2000	5

OIL CROPS **7**

1. OPPORTUNITIES	7
1.1 SCIENCE AND TECHNOLOGY	7
a. Breeding and primary production	7
b. Harvesting and storage	7
c. Research in processing and application	8
1.2 INDUSTRY	9
a. Needs for and uses of industrial crops	9
1.3 MARKETS	10
1.4 ENVIRONMENTAL	11
2. BARRIERS TO PROGRESS	11
2.1 – 2.2 SCIENTIFIC AND TECHNICAL ISSUES	11
2.3 – 2.4 ENVIRONMENTAL AND LEGISLATIVE ISSUES	11
2.5 ECONOMIC ISSUES	12

FIBRE CROPS **13**

1. MISCANTHUS **13**

1. OPPORTUNITIES	13
1.1 SCIENCE AND TECHNOLOGY	13
a. Breeding and primary production	13
b. Harvesting and storage	14
c. Research in processing and application	14
1.2 – 1.3. INDUSTRY AND MARKETS	15
1.4 ENVIRONMENTAL ISSUES	15

2. BARRIERS TO PROGRESS	15
2.1 –2.2 SCIENTIFIC AND TECHNICAL ISSUES	15
2.3 –2.4 LEGISLATIVE AND ENVIRONMENTAL ISSUES	15
2.5 ECONOMIC ISSUES	15
2. FLAX (LINUM USITATISSIMUM MILLER)	15
<hr/>	
INTRODUCTION	15
1. OPPORTUNITIES	16
1.1 SCIENCE AND TECHNOLOGY	16
a. Research in processing and application	16
1.2 PRESENT INDUSTRY AND NEW INDUSTRIES UNDER CONSIDERATIONS	16
1.3 MARKETS	16
1.4 ENVIRONMENTAL	17
2. BARRIERS TO PROGRESS	17
2.1 – 2.2 SCIENTIFIC AND TECHNICAL ISSUES	17
2.3 ENVIRONMENTAL	17
2.4 –2.5 ECONOMIC AND LEGISLATIVE ISSUE	18
3. HEMP	18
<hr/>	
GENERAL	18
1. OPPORTUNITIES	18
1.1 SCIENCE AND TECHNOLOGY	18
a. Breeding and primary production	18
b. Harvesting, retting and storage	18
c. Reseach in processing and applications	19
1.2. PRESENT AND POTENTIAL MARKETS	19
2. BARRIERS TO PROGRESS	19
2.1 - 2.2 SCIENTIFIC AND TECHNICAL ISSUES	19
2.3 ENVIRONMENTAL ISSUES	20
2.4 LEGISLATIVE ISSUES	20
2.5 ECONOMIC ISSUES	20
CARBOHYDRATE CROPS	21
<hr/>	
1. CEREALS	21
<hr/>	
INTRODUCTION	21
1. OPPORTUNITIES	21
1.1 SCIENCE AND TECHNOLOGY	21
a. Breeding and primary production	21
b. Harvesting and storage	22
c. Research in processing and applications	22
1.2 INDUSTRY	24
1.3 MARKET	25
2. BARRIERS TO PROGRESS	26
2.1 - 2.3 SCIENTIFIC, TECHNICAL AND ENVIRONMENTAL ISSUES	26
2.4 - 2.5 LEGISLATIVE AND ECONOMIC ISSUES	27
2. POTATOES	27
<hr/>	

INTRODUCTION	27
1. OPPORTUNITIES	27
1.1 SCIENCE AND TECHNOLOGY	27
a. Breeding and primary production	27
b. Harvesting and storage	28
1.2 INDUSTRY	28
1.3 MARKETS	29
1.4 ENVIRONMENTAL CONSIDERATIONS	30
2. BARRIERS TO PROGRESS	31
2.1 – 2.2 SCIENTIFIC AND TECHNICAL ISSUES	31
2.3 – 2.4 ENVIRONMENTAL ISSUES AND LEGISLATIVE ISSUES	31
2.5 ECONOMIC ISSUES	31
3. SUGARBEET	32
<hr/>	
INTRODUCTION	32
OPPORTUNITIES	32
1.1 SCIENCE AND TECHNOLOGY	32
a. Breeding and primary production	32
b. Harvesting and storage	32
1.2 INDUSTRY	32
1.3 MARKETS	32
1.4 ENVIRONMENTAL ISSUES	33
2 BARRIERS TO PROGRESS	33
2.1 – 2.2 SCIENTIFIC AND TECHNICAL ISSUES	33
2.3 ENVIRONMENTAL ISSUES	33
2.4 LEGISLATIVE ISSUES	34
2.5 ECONOMIC ISSUES	34
CROPS WITH SPECIALIST USES	35
<hr/>	
INTRODUCTION	35
ECHINACEA PURPUREA L., COMPOSITAE	35
ANTIRRHINUM MAJUS L., SCROPHULARIACEAE	35
SCUTELLARIA ALBIDA, LABIATAE	35
LUPINUS LUTEUS L.	35
ANNEX	36
<hr/>	

METHODOLOGY

This report is based on statistical informations, literature surveys and interviews with industries, research centres and universities in Denmark.

We would like to thank all contributors for their valuable informations.

Summary

The main crops in Denmark are cereals, rape seed and sugar beet making up for more than 87% of the total plant production (excl. grass).

5 potato starch factories and 4 vegetable oil mills produce products for both food and non food use.

In addition a number of, mainly small, companies import plant based raw materials that are transformed into a large number of non-food products – cosmetics, detergents, paints and varnishes etc.

Currently Denmark has no cereal based non food production, however, the potential is large for e.g. production of plant based packaging materials, films, foams, adhesives, cosmetics etc.

There is a revival of interest for flax and hemp growing. The production, however, is still very small.

In summary Denmark has experienced a growing consumer interest in products from renewable raw-materials, and consumers have shown that they are willing to pay a "green premium" for environmentally friendly products.

However, the production is still modest compared with synthetic products mainly due to higher production costs and thus prices.

The gap in production costs is slowly being reduced for some commodities, and if this could be combined with an internalizing and quantification of environmental and macroeconomic externalities such as product safety, "clean production" biodegradability, job creation, trade balance etc., then products based on renewables might become a very viable alternative to many traditional synthetic products.

In this context, it is important for the decision makers in industry that there is a long term political consistency between the stakeholders – agriculture, producers, users and government. Including long term regulations and rules.

Denmark

Industrial Crops and their applications

General

Agriculture/farmers

Like in most EU countries the Danish agricultural plant production is dominated by a few major crops. The three main crops in Denmark: cereals, rape seed, and sugar beet, make up for more than 87 % of the total plant production (exclusive grass). Furthermore for the grain production accounting for 79 % of the total production (exclusive grass), the value-added through processing is limited to a few product-groups like dairy products, meat, poultry, and pork, the price of which is subdued to frequent fluctuations.

Danish agriculture is therefore vulnerable to factors outside the control of Denmark. Low pork prices for instance have a negative effect on the whole agricultural sector including the support industries.

On the other hand the specialisation into a few cultures and product groups of course have made the Danish farmers efficient and competitive. Some concern is however expressed about the future competitiveness, as it is foreseen that e.g. the farmers in the former Eastern-Europe will improve their efficiency and productivity in the coming years. This boost in production will presumably also be within areas, where Danish agriculture today has its strength.

The ideal situation for Danish agriculture might be a more, diversified and thus flexible agriculture allowing for a production closely reflecting the consumption pattern of the EU and major markets outside Europe. It might be so that the apparent contradiction, competitive agri-production versus diversified/balanced sustainable agri-production actually was only apparent; it is thinkable that the introduction of new specialty crops and the stretching out of the plant season via a broad range of crops could improve the production capacity utilisation to a degree that outweighed the benefits of monoculture specialisation.

One might therefore assume that there will be a need for new crops and income possibilities, and this combined with a consumer demand for environmentally friendly products could lead to an increase in Danish non-food production.

Consumers and government

Denmark is presently experiencing a shift in consumption patterns. Consumers are increasingly including intangible aspects in their decisions about which products to buy. The groundwork for this shift was laid in the eightieth when consumers first began to express concerns about the hazards of industrialised production methods by demanding products that were produced with due care for the environment. Furthermore some Danish consumers have proven that they are willing to pay a “green” premium for environmentally friendly products (food and non-food).

Today the demand for organic food has increased considerably, and a state controlled “organic food” label (a red label) was introduced some 10 years ago. A similar label (green) for organically produced non-food products (paints, varnishes, textiles, Christmas trees, insulation materials, cosmetics etc.) will be introduced next year.

Also EU and national regulations will add to the trend towards biobased environmentally friendly products (phosphate free detergents, restrictions on the use of synthetic dyes and aromas, restrictions concerning solid waste disposal, use of synthetic pesticides, organic solvents etc.).

The Danish government has also in other ways shown its interest in promoting agricultural based non-food products. So far two research programmes solely devoted to this area have been launched, plus other national programmes including support of “industrial crop” research.

The government has recently introduced a “green” purchasing policy, which obliges the governmental institutions to buy environmentally friendly products, whenever possible. This will naturally give biobased products a comparative advantage, as such products generally are environmentally friendly. One result of this policy is that all state owned forests are using vegetable oil based chain-saw oils.

An interministerial non-food agency was established in 1994. This agency has the objective to co-ordinate non-food research both within Denmark and with research centres in other countries.

Industry

Danish agriculture is traditionally centred around food production. Moreover Denmark has no major non-food industries. Thus there is no “locomotive” in the form of a multinational companies like Henkel, Eridania Beghin Say, Unilever, ICI or Monsanto that can stimulate the development. The major Danish agricultural raw material consuming companies are all focused on food.

The Danish packaging companies, detergent producers, cosmetic producers, paint and varnish industries, pesticide producers etc. that are potential consumers to biobased raw-materials have little or no experience in the use of biobased raw-materials. In general they are not even raw-material processors. They import semiprocessed materials for formulation into final products.

Immediately this might be considered as a constraint. It could however turn out to become an advantage, as it presumably will be easier to introduce a new paradigm or raw-material base, when there is no basic industry that tend to preserve the traditional raw-material base. There will thus be no need to adapt a current manufacturing process to accept the renewable feed stocks.

Denmark does however have a number of small innovative companies with an interest in non-food production, and they do make valuable contributions to the development of new non-food products. In addition 5 potato starch factories and 4 vegetable oil mills are producing commodities for both food and non food purposes.

The Danish industry has expressed a cautious interest in new non-food productions. Some industries - packaging industries and industries for production of building and insulation materials - have clearly stressed their intention to start up biobased productions, as soon as they are convinced that there is a market for their products.

Economics of Agricultural Enterprises 1996/1997

Ensuring the farmers a larger share of the added value

The traditional Danish farmers share of the added value in the agro-industrial sector has diminished during a number of years. During the period 1980-84 the share was 35 ore per DDK sales value, while today it is as low as 26 ore.

The debate concerning introduction of new crops and new uses of traditional crops has mainly been focused on the actual production and the end use, while the possibilities of altering the distribution of the created added value between farmers and industry so far has drawn little attention.

There will always be room for specialised productions catering goods to a very limited market. Such productions can become an important income source for individual farmers with the skill to produce a given specialty crop, but will only have a small impact on the agricultural situation in general.

However even in niche productions the added value is often created by the (pharmaceutical, cosmetic, paint etc.) industry and not by the farmer.

Farm scale processing

In an effort for farmers getting a higher share of the added value a small innovation company, H. C. Biosystemer ApS has established a joint venture with a Danish farmer. On farm is being developed a full-automatic oil press for production of vegetable oils. The oils are used both for food and non-food products. Production started in 1997 with a capacity of 80 -120 kg oilseed pr hour. Biosystems is convinced that they can develop competitive farm-scale units by exploitation of the following advantages:

- by modern monitoring and control technology it is possible to operate the plant continuously 7 days a week and 24 hours a day,
- the plant is operated by the farmer himself, who naturally is highly motivated. He lives close to the plant and is therefore able to supervise the production round the clock.

The capacity of the production unit at Grønnegård will be doubled in 1998, and a semi automatic bottling machine will be installed (see also page 7).

Another farm (Nykilde) has for the last 8 years produced linseed oil on a very small oil mill. The oil is used for wood protection and paints and sold to local users such as municipalities and local painters. The farmer has 30 ha of land, all of which is used for growing of oil flax.

Quite a few farmers have shown interest in a commercial production of herbal products for nutraceutical and pharmaceutical uses. For example, a farmer on the island of Langeland, Erik Hansen, established in 1997 a plantation of dog roses on 100 ha of land. The mature hib are dried, finely ground and sold as a herbal pharmaceutical. The trade name is "Hyben Vital"

The above described may be a (modest) beginning to a new era, where a number of innovative and inventive farmers create alliances with specialty product industries.

Molecular farming

There is an emerging interest in molecular farming in Denmark. However still primarily amongst scientists and biotech industries. Workshops have been organised to measure the interest and discuss the benefits for Danish agriculture and society. The outcome of these workshops was very positive, and it is now discussed how to proceed.

It is generally agreed that Denmark would be well suited for molecular farming. Our farmers are skilled and well educated, we have a good functioning extension service, and our control system is well organised. Furthermore Danish farmers have access to a number of vital information systems such as "Geographical Information System" (GIS), Global Position System" (GPS), and vision technology. In addition, Danish biotech companies have the necessary expertise and equipment to purify and process plant biomolecules.

In principle the value added is created not only in industry (as is generally the case) but also to some extent already at the primary production level. Therefore one might assume that the farmers could achieve a larger share of the value added, especially if the post harvest treatment, storage and first separation steps take place in the rural area, perhaps even at farm level.

Pre processing in rural areas, whole crop utilisation, biorefineries

In the mid eightieth was in Denmark introduced a new concept for organisation of agricultural production, the biorefinery concept. The objective of a biorefinery is to minimise production costs for plant-derived products through an optimal utilisation of all components in a given crop.

A biorefinery should be located in the centre of a rural area ensuring that transport distances for the normally voluminous crops are minimised. The local refinery produces “made-to-measure” intermediates for relevant industries, including food industries. The part to be used for feed will be transported back to the farmers, while the “energy part”, i.e. the part that cannot be used for either food, feed and industrial purposes, remains at the biorefinery and is used for production of heat/electricity. The local farmers should be involved in the production in order to receive a share of the added value.

The refinery is thus a link between primary production and industry. It will aim at ensuring a stable supply of homogenous pre-processed raw-materials for individual industrial purposes. Hopefully the introduction of such refineries can thus help to overcome two of the main obstacles for industrial exploitation of plant raw-materials namely the uneven quality of plant-materials and the limited supply-security.

A demonstration biorefinery was established on the island of Bornholm in the beginning of the ninetieth. It was financed by the EU Commission (ECLAIR), the Danish government, farmers and industry. It has been operating for 8 years and is now developing a production system to homogenise and improve the quality of Danish grown wheat for production of bread flour and starch (page 23). Another project deals with development of a process to separate rape seed in all its constituents (page 8). Furthermore is done research on the further processing and derivation of individual components (page 8).

Since the introduction the biorefinery concept has attained much interest from most European countries, USA and developing countries like India, China and the Philippines. So far no commercial production has been initiated.

In a co-operation between South Danish University, Aalborg University, and the local agro-industry in Jutland a new concept for integrated usage of "green" crops such as grass, clover, alfalfa, potatoes for production and feed pellets, starch and different fermentation products has been developed.

A development company: Danish Biomass A/S, owned by South Danish University and the local agro-industries has been established and a pilot plant for fermentation of different residues from the involved agro-industries has been build.

The technology for production of organic acids and amino acid, developed in the co-operation between the universities and the agro-industries, will be transferred to industrial commercialisation by Danish and Dutch companies in the very near future.

All the scientific activities in the above area of biotechnological utilisation of biomass and agricultural residues are being put together in a new scientific centre in Esbjerg named: “Centre for Agro-Industrial Biotechnology”.

Cash crops

Of the 4,308,000 ha, which present the total area of Denmark, 62 percent (2,679,000 ha) are cultivated. The cultivated area had its maximum in the 1930'ties with 3,268,000 h or 76 percent of the total land area. To day forests and plantations account 13 percent, wetland 1 percent and cities, roads and uncultivated areas etc. 24 percent of the total land area, respectively.

During the period 1970 to 1998 the agricultural area has decreased with 300,000 ha giving a yearly reduction rate of 0.4 percent. Most of the transformed land area has been used to development of cities and creative objectives.

The EU common agricultural policy was modified in 1992. The prices for cereals, rape, linseed and peas was reduced and hectare subsidies introduced. In 1998 about 144,000 ha. was set aside and 10.000 ha was cultivated with non-food rape.

As a result of the 1992-reform the area cultivated with cereals decreased to 1,404,000 ha in 1994. Since that year the cereal area has increased due to the lower set aside percentage and a reduction in the oilseed area. In 1998 the total cereal area was 1,519,000 ha.

After a fall in the rape seed area in 1997 to 104,000 ha, it has increased to 118,000 ha in 1998. Just before the 1992-reform the rape area was 280,000 ha.

Table 1. Economics (average per ha) for 1996/97.

	Cereals						Other cash crops				
	spring barley	winter barley	wheat	ray	96/97	95/96	pea	rape	grass-seeds	potatoes	sugar beet
Crop yield, hkg	52.3	56.1	71.3	50.2	61.3	63.3	36.3	24.9	11.6	313	459
Labour input, hours per ha	14.7	16.7	17.2	15.3	16.1	16.6	14.9	13.9	16.6	45.8	41.4
Enterprise output, DDK	7920	8023	9586	7447	8669	9126	7117	7739	9217	20917	18230
Subsidies, DKK	2164	2174	2187	2170	2176	2176	3150	3637	2763	34	24
Subsidies in % of prod v	27.3	27.1	22.8	29.1	25.1	23.8	44.3	47.0	30.0	0.0	0.0
Labour income per hour											
1996/97	134	81	143	118	132	-	143	137	237	157	180
1995/96	153	134	197	111	-	168	115	64	231	194	163

Source: SJFI 1998

As seen in table 1 the labour income per hour in 1996/97 is highest for grass seeds followed by sugar beet and potatoes. Table 2 shows the farm income in DKK per hours for full-time holdings based on main sectors. Pig holdings show an increasing per hour income. However in 1998 the pig price was drastically reduced causing substantial problems in the sector.

Table 2. Farm income in DKK per hour for full-time holdings based on main sectors

	91/92	92/93	93/94	94/95	95/96	96/97
Cash crops	82	50	105	133	163	143
Cattle	81	78	94	88	81	76
Pigs	167	136	60	114	134	188
Full-time holdings in total	101	83	90	104	113	120

Source: SJFI 1998

Impact of Agenda 2000

Danish Institute of Agricultural and Fisheries Economics assumes (note of 29 may 1998) that the overall income in Danish agriculture will be moderately reduced after the introduction of Agenda 2000.

Cereals will gain a competitive advantage over oilseeds and protein crops.

In 1997 about 159 000 ha of land was set aside of which 75,000 ha was voluntarily set aside. The latter will presumably continue to be laid idle, while 84,000 ha will be taken back into production.

In summary it is foreseen that cereal production will increase while production of oil seed will be significantly reduced and production of protein_moderately reduced. Production of potatoes, sugar and fibre crops will only be moderately influenced.

The Danish Forest and Landscape Research Institute has in 1998 analysed the potential development 1995 – 2025 in land use. The analysis is based on political statements given in strategies, action plans and land planning statements (see table 3).

Table 3. Development of land use in Denmark 1995 – 2025.

Landscape	Change in area in ha
Agricultural area food and fodder crops	- 430,000 – 610,000
Agricultural area with non-food crops	+ 250,000 – 270,000
Agricultural area as set aside	- 200,000
Agricultural area out of rotation	+ 250,000 – 350,000
Forest	+ 130,000 – 150,000
Hedges, ditches, and tracks	+ 0 – 20,000
Heath, dunes, and bogs	+ 0 – 10,000
Lakes and rivers	+ 0 – 30,000
Buildings in the land zone	+ 0 – 5,000
Cities, roads, and summer houses	+ 10,000 – 36,560

Source: Groth et al. 1998.

As shown in table 3 the agricultural area grown with non-food crops is forecasted to increase with between 250,000 – 270,000 ha in 2025.

Oil Crops

1. Opportunities

1.1 Science and technology

a. Breeding and primary production

Only two major oil crops are grown in Denmark, rape and linseed. Rape (*Brassica napus* L.) is grown both as a spring crop and as a winter crop. A good yield in Denmark is between 2-3 tonnes per ha of standard quality depending on the water availability during the growing season. Average yield from 1987-96 was 2.08 tonnes per ha with a yearly variation between 1.58 and 2.58 tonnes per ha.

Table 4 shows the area grown with rape seed in 1996 and 1997. In 1996 rape seed was grown on 5.8 percent of the agricultural land area (excl. grass). Of the total rape seed production in 1996 non-food rape constituted 24 percent. Set-aside percentage decreased from 10 in 1996 to 5 percent 1997 causing a decline in non-food rape of 58 percent from 1996 to 1997.

Most of the non-food rape is bought up by fodder companies and sold at the stock market in Rotterdam. A minor amount is manufactured inside Denmark to e.g. chainsaw oil.

Linseed (*Linum usitatissimum* Miller) was grown on 3,000-3,500 ha in 1998. Most of the area is grown with contracts to seed companies. If farmers can achieve the quality required by the seed companies, an additional EU premium of 169,55 DDK per 100 kg (1998 prices) will be received. If seed quality doesn't meet the requirements the crop will most likely be sold to varnish and paint companies.

The average yield for the years 1987-96 was 1,144 tonnes per ha. The yearly variation were between 0.54 and 1.75 tonnes per ha.

Breeding is carried out at a.o. DANISCO SEED. For industrial uses the objective is to improve the oxidation stability of rape seed oil. Changed fatty acid composition usually causes decline in yield.

Table 4. Area with rape seed grown in Denmark in 1996 and 1997.

	1996	1997
Winter rape, excl. non food	54 298	67 490
Winter rape, non-food	13 871	5 727
Spring rape, excl. non food	25 711	25 884
Spring rape, non-food	11 412	4 413
Other seeds for industrial use	3 538	3 513
Seeds for industrial use total	108 831	107 027

Source: Statistics Denmark

b. Harvesting and storage

Normally linseed ripeness in September. It is beneficial that the crop is standing on root as long as possible. The seeds should be brown and loose in the pods. Harvested seeds should immediately be dried to 9 percent water content.

Linseed oil is used in paints and varnish-like products for indoor painting and to protect wood floors and furniture. Several small companies produce paints and varnishes based on linseed oil like TRIP TRAP, Damson Paint Int. A/S, P. C. Vinduer, DANOLA A/S, Nykilde.

The company TRIP TRAP is manufacturing the wood protecting product Tripolin®, which is based on virgin linseed oil, tungoil and aromatic pine oils.

A small window manufacturing company, P. C. Vinduer, specialising in windows in old designed wood frames with thermo glass, is now developing linseed oil based paintings for spraying (oil in water emulsion).

At Nykilde a farmer has installed a rather old fashioned oil press and is producing cold pressed linseed oil for wood preservation under the trade name Nykilde.

The farm-scale production unit at Groennegaard described on page 2 is producing chain saw oil from cold pressed rape seed oil. The required viscosity is achieved in such a way that 100% biodegradability is achieved. Moreover the farm produces cold pressed and clarified linseed oil for wood preservation and cold pressed rape seed oil for food uses.

Test quantities of oil from hemp seed, poppy seed, parsley seed and Evening Primrose have been produced for use in cosmetic and pharmaceutical industries etc.

c. Research in processing and application

Under the non-food research programme (1998-2001) with a total budget of 40 mill. DDK three vegetable oil projects have been supported with a total budget of 6.5 mill DDK. These are:

1. Development of biological hydraulic oils based on rape oil

The objective of the project is to improve biological hydraulic oils based on rape seed oil by adding different sources of minor used vegetable oils

2. Development of cutting fluids and metal working oils from vegetable oil

The aim of the project is to develop up to four products which will be able to cover a considerable part of the market for pure oil products used for metal working at least in the most frequently used types of machines and metals. Simultaneously, cultivation experiments with limnanthes will be carried out under Danish climatic conditions.

3. Assessment of Natural Plant Protection Agents from Oilseed Crops (NaPPA)

The project comprises preparation of biocides from glucosinolates prepared ad formulations based on water, emulsions and rape seed oil. Subsequent biocide test will be performed against economically important pests, pathogenic fungi and weeds common in Danish crops.

Potential plant species that are not yet commercial crops

A research project entitled "special chemicals and pharmaceuticals from plants" supported by the Danish Research Council is investigating the following plant species:

Dimorphotheca pluvialis, Compositae

Experimental plants gave in 1997 a seed yield of about 800 kg per ha in a combined sowing rate and N experiment. The hydroxy fatty acid can be used for cosmetics and several technical purposes. Seed loss is a major obstacle and further experiments are planned with suitable harvesting methods.

Crepis alpina, Compositae

Crepis alpina (Alpine Hawk's-beard) is not grown for commercial production yet. Together with the Swedish University of Agricultural Sciences, (Sten Stymne) research is conducted to increase the production of acetylenic fatty acids in the seeds of *Crepis alpina*. High amount of acetylenic fatty acid could probably be used in biobased paints, inks and coatings due to its highly reactive structure.

Limnanthes douglasii

Limnanthes douglasii seeds contain an oil where nearly 90 percent of the fatty acids has a chain length above 18 carbons. The dominating long chain fatty acid is the unusual eicosa-5-enoic acid (20:1D5). Both the long chain length and the position of the double bond makes the oil interesting for industrial purposes especially in the pharmaceutical industry.

Crambe abyssinica

Crambe abyssinica has given a seed yield of 2000-3000 kg per ha in experiments. *Crambe* contains 58 percent of erucic acid in the oil.

Calendula officinalis

Calendula officinalis has in experiments given seed yield between 7001-1200 kg per ha. Only Danish varieties have been examined. *Calendula* contains the important fatty acid calendic acid used for cosmetic and medicinal purposes (ref).

Coriandrum sativum

Coriandrum sativum contains petroselenic acid, which can be transformed to lauric acid (used for cosmetics, shampoo and soap) and adipinic acid, which can be used in production of nylon. With a seed yield of about 2000 kg per ha *Coriandrum* seems to have a potential for industrial use.

During the last 15 years, field and laboratory research with False flax or gold of pleasure (*Camelia sativa* L.) has been carried out at the experimental station of the Royal Veterinary and Agricultural University, Denmark. The yield from summer varieties amounted to 2.6 tonnes DM per ha with an average oil content of 45 % oil and yield from winter varieties up to 3.3 tonnes per ha with average oil content of 42 %. Oil production is about 1.2 tonnes per ha.

Camelina oil is characterised by a high content of unsaturated fatty acids (about 90%). The content of alfa-linolenic acid (18:3n - 3), amounting to about 35% of the total fatty acids, predominates. The content of linoleic acid (18:2n-6) is about 15% and gondoic acid (20:1n-9) about 15%. The content of erucic acid is about 3.0%.

Camelina oil was earlier used for lighting due to its outstanding purity. Industrially, the oil has been exploited for production of soap and varnishes. The specific polyunsaturated fatty acid profile may make camelina oil suitable for cosmetic applications, such as cosmetic oils, skin creams and lotions (J. Zubr 1997).

1.2 Industry

a. Needs for and uses of industrial crops

Aarhus Olie A/S manufactures vegetable oils and speciality fats for the food as well as speciality fats and oleochemicals for cosmetics and pharmaceutical industries. The company was founded in 1871 and is now represented in more than 60 countries worldwide.

Scanola - The National Association for Farm Supply Crops owns a little over 50 percent of the shares in Scanola - which was split into Scanola Holdings A/S and the operating company *Protein-og Oliefabrikken Scanola A/S* as of 1 August 1997. At the same date a three-year partnership with the company Deutsche Conti was introduced. Deutsche Conti has acquired Scanola's entire production capacity of 180-200 000 tonnes per year. Conti has invested DKK 30 million in a sunflower seed dehulling plant meaning that Scanola now processes both rape seed and sunflower seed. During 1998 Scanola Holding will decide whether to invest in a refinery for the further processing of the crude sunflower and rape oil. The planned oil refinery will be based upon a new technology, so that a "green" edible oil can be produced without the use of chemicals.

Emmelev Mølle and Dan-raps, the latter owned by DLG-Vensyssel, are pressing rape seed oil. According to the technical directors of the two companies all the pressed rape is food rape which is sold mainly to Danish food industries.

Grindsted products is an international company with headquarters in DK, and subsidiaries in UK, D, AU, F, NL, B SCH, ESP, USA, C, Brazil, Mexico and Japan. The company is part of Danisco A/S. The factory complex at Grindsted is still the largest production unit however production facilities also exists in other countries. The stabilisers, Grindsted offers, are produced in Mexico, where Grindsted owns a modern pectin plant, in France where Grindsted's alginate plant, Sobalg S A is situated, and in Spain where locust bean gum and guar gum are produced (Cemar S A).

The company headquarter at Brabrand, near Aarhus, Denmark is the centre for research and development, marketing and administrative activities. For list of products see appendix table 20.

Urtekram is a company offering 800 organic food and non-food staples. The company has its own surfactant mixing plant producing environmental friendly cleaning product including soaps detergents and personal care products.

1.3 Markets

A small amount of Passionflower seed oil is bought in South America. The oil is used in cosmetic formulations.

Vegetable chainsaw oils is used in Denmark. The marked potential for Scandinavien and Germany is about 15,200 tonnes per year.

Also vegetable graphic cleaning products are formulated and sold in Denmark. Metylester based cleaning products are used in metal cleaning and is especially preferred when fat and oils need to be removed. However if the metal is going to have an after treatment, it is needed to after wash with water. In these cases other cleaning products are used in order to save working time.

Table 5. Import and export of vegetable oils (non food uses) (1997).

	Import		Export	
	tonnes	1.000 DDK	tonnes	1.000 DDK
Rape seed oil, technical uses				
- raw	4 153	15 944	60 039	201 062
- purified or refined	78	784		
Coconut oil, technical uses, raw	1 390	6 252	114	578
Coconut oil, - , solid fractions	152	1 481		
Palm kernel and babassu, technical uses, raw	16 806	89 132	778	4 842
Solid fractions	-	-	222	4 819
Soya oil, technical uses, raw	5 350	18 666	-	-
purified	1 448	5 981	-	-
Peanut oil, technical uses, raw	67.5	575		
Linseed oil, raw	391.9	1 761	57,1	311
Linseed oil, purified or refined. Technical uses	974.1	4 622	55.2	509
Ricinus oil for production of aminoundecansyre, kemofibres or plastic	634,2	6 165	3.5	49
Ricinus oil, hard (opal wax)	23.2	429		
Sesam oil, raw, for technical uses	0.4	10	-	-
Jojoba oil, raw	0.1	4	-	-
Purified or refined	1.1	106	0,1	13
Tobacco seed oil, purified or refined, technical uses	1.2	92	-	-
Other plant oils for technical uses, raw	0.4	35	2.2	138
Other plant oils for technical uses, purified or refined	18.0	597		
Rape oil, linseed oil and other similar oils and fats for technical industry	256,6	1 618	9.3	84
Non-food blends of vegetable fats and oils	210,2	2 088	26,1	131
Glycerol	844.7	7 121	15.7	272
Vegetable wax, raw	23.4	1 653	1.1	123
Vegetable wax, not raw, also formed	2,7	162		

Source: Statistics Denmark

1.4 Environmental

There is no major environmental problem in growing rape or linseed in Denmark.

2. Barriers to progress

2.1 – 2.2 Scientific and technical issues

Under dry condition linseed has a poor competition capacity for weeds. Late maturity of seeds can be a problem in wet summers.

2.3 – 2.4 Environmental and legislative issues

Both vaseline (petroleum jelly) and paraffin are based on mineral oils and can be substituted by vegetable oil formula. The barrier for fully market penetrations of the renewable substitutes is:

- Suspicion on health problems in using vaseline and paraffin has not yet been confirmed (especially in paper coatings, where the paper is used for food wrapping).
- Low mineral oil prices. Vegetable substitutes is sold for about 10 DDK per kg where as paraffin can be bought for 5-7 DDK per kg.

2.5 Economic issues

It is assumed that if the Agenda 2000 is launched in its present form then it might become economically unfavourable for farmers to grow linseed for oil production in Denmark, and rape seed production will probably be less profitable than at present.

Fibre crops

The production of fibre crops is very limited in Denmark. However the interest from farmers and industry is increasing, and an increase in production is expected in the future.

In order to strengthen the plant fibre research in Denmark the Centre for Plant Fibre Technology was established in 1996. The centre includes the following 5 independent research institutions:

- The Technical University of Denmark,
- The Royal Veterinary and Agricultural University,
- Risoe National Research Centre,
- Danish Institute of Agricultural Sciences (DIAS), and
- Novo Nordisk A/S,

It is worth noticing that the participants are from universities, research centres, and industry. Together they possess scientific knowledge about all steps in the production chain. The centre will mainly deal with fibre crops that can be grown in Denmark.

The main crops are beech, spruce, wheat, rye, flax and miscanthus.

Hemp growing was not allowed in Denmark until this year, therefore there are only a few hectares with hemp for the time being. Canary reed is currently being tested in small experimental plots.

It should be stressed, that although Denmark has a very limited primary fibre crop production, it has a large secondary fibre production from the production of cereals. The annual production is about 7 mil. tonnes dry matter lignocellulose from straw and 1 mil. tonnes wood fibres. The overall aim of Centre for Plant Fibre Technology is to enhance the industrial use of this large plant fibre resource for the production of environmentally friendly materials and products.

1. Miscanthus

1. Opportunities

1.1 Science and technology

a. Breeding and primary production

Danish Institute of Agricultural Sciences (DIAS) has since 1983 carried out production trials with miscanthus.

Miscanthus is due its C₄-photosynthesis a potentially high yielding crop, and it has a low demand for fertilisers and pesticides. The productivity of miscanthus is sensitive to low temperatures and the crop benefits from good shelter.

Harvest normally takes place in April at which time mainly the stem, which has the best quality for fibre purposes, is left. Under experimental conditions on sandy soil, yield in April has varied between 8 and 14 tonnes of dry matter per ha. However, after several dry summers yields as low as 4-5 tonnes per ha were harvested. Mean spring yields by farmers seems to be about 8 tonnes per ha of dry matter. Total biomass in autumn, before shedding of leaves and top during winter, is almost double of what is harvested in spring.

Establishing costs are high, when plantlets raised in greenhouse are used. Furthermore, plantlets of the most common species, *M. 'Giganteus'* have very low survival during the first winter in Denmark. Experiments performed at DIAS have shown that it is possible to disintegrate a mother culture with a rotary cultivator, pick up the rhizomes with a stone picker and simply spread the rhizomes on the new field, followed by ploughing. Recently a planting machine has been developed in corporation with the company Hvidsted Energy Forest. The machine plants the rhizomes in rows and in pre-selected depths. Preliminary tests have shown good practical performance and good plant emergence.

It is expected that this method can reduce the establishment costs by a factor of five. Furthermore, first winter survival is significantly improved compared to that of plantlets.

M. 'Giganteus' is triploid and does not produce seeds in Denmark, while new selections of *M. sinensis* does in good summers. A FAIR breeding project aims to create the basis for a breeding programme in miscanthus with the aim of creating clones adapted to different European climatic zones and to optimise industrial quality characteristics.

b. Harvesting and storage

Harvesting and storage is not considered to present major problems.

c. Research in processing and application

Miscanthus is an efficient producer of biomass and therefore considered to be a good energy crop. However it is also a fibre crop with a higher cellulose content than e.g. birch and pinewood (44 % versus 41 %) (ATV, 1995).

In 1987-88 a number of experiments were carried out at Fredericia Cellulosefactory (see page 22), both in laboratory scale and pilot plant scale. The results were promising. The quality of the produced paper samples was good, and it was concluded that the quality of miscanthus fibres were between the quality of straw fibres and fibres from softwood (ATV, 1988). There were no technical difficulties in using miscanthus instead of straw.

In Denmark many houses are thatched. Reed is normally used as thatching material, partly grown in Denmark and partly imported. The yield of reed is declining and the demand is increasing. Therefore it was decided to investigate whether miscanthus could be used as thatching material. Only miscanthus varieties with a slim stem like *Miscanthus sinensis* can be used. Thatching with miscanthus has proven workable and the durability appears good (DIAS).

Scaling up of the selections for thatching is expensive, but the first full hectare will be harvested in the winter 1998-99. Economic calculations indicate that when larger mother cultures are available it can be an economically attractive production for farmers, which may in the longer run ensure lower prices on thatching material.

DIAS is involved in a FAIR-project on the optimisation of the production chain of 'Light Natural Sandwich materials' (LNS). Stems of Miscanthus, grain crops, *Arundo donax* or bamboo can be used in LNS. A German company currently manufacturing sandwich materials from pvc and aluminium is a partner of the project and intends to include the biological material in its product range when the main problems are solved.

The fibres of Miscanthus have shown to be suitable for composting into a renewable growing media to substitute peat moss, and this is investigated in a basic national study on composting processes and on the growth of potted plants in renewable growing media.

1.2 – 1.3. Industry and markets

As previously mentioned no industry in Denmark is presently using Miscanthus as raw material. Miscanthus may in the future be used for production of sandwich boards for insulation purposes, and for thatching of roofs. Other areas of applications could be as growth media and compost.

Theoretically miscanthus stems can be used for production of paper, but it is most unlikely that a miscanthus based pulp factory will be established in Denmark due to high installation costs. A remote possibility is to reopen the Fredericia Cellulose factory.

1.4 Environmental issues

Miscanthus has a low demand for fertilizers and pesticides. It is thus considered to be an "environmentally friendly" crop.

2. Barriers to progress

2.1 –2.2 Scientific and Technical issues

The existing varieties are not well adapted to the Danish climate. More cold tolerant varieties are needed and the yield must be improved. More research is needed to reduce establishment costs, and better post harvest handling systems must be developed.

2.3 –2.4 Legislative and environmental issues

No specific problems.

2.5 Economic issues

Today miscanthus is not competitive, and it will not be able to compete with most other crops before the yield is improved considerably, and the production costs are reduced. Calculations have thus shown that when larger mother cultures are available, it can become an economically attractive production for farmers for use e.g. as thatching material.

2. Flax (*Linum usitatissimum* Miller)

Introduction

Flax is one of the oldest industrial crops in Denmark. It has been grown from the "iron-age" up to the middle of the last century, when it was ousted by cheap and more versatile cotton fibres. Up to the Second World war the production was very limited, however, mainly due to lack of linseed oil, a small production of oil flax was started up in 1940. At its height in 1948, 18 000 ha of land was used to produce both linseed oil and textile flax. At that time there were 10 flax factories in Denmark. After the war the interest for flax production faded out, and the last flax-factory was closed down in 1970. The Danish produced flax textiles could not compete with state subsidised flax yarn from some West European countries and very cheap raw-materials e.g. from the former Soviet Union and Poland.

There is now a revival of interest both for fibre flax and oil flax, the acreage with flax is however still very modest, approximately 3,500 ha.

1. Opportunities

1.1 Science and technology

The flax plant grows well in wet and temperate climates like in Denmark, and the quality of Danish grown flax fibres is excellent.

Flax can produce 2 tonnes of seeds per ha, while fibre flax produces 1 ton of textile fibres per ha in Denmark.

a. Research in processing and application

The Danish “Centre for Plant Fibre Technology” (page 12) has recently together with a Danish flax factory, The Danish Agricultural Advisory Centre, and The Danish Force Institute started up an extensive plant fibre research project, “Plant Fibre Composites- From Plants to Products”. This project includes research on flax from growing to end product. One of the main issues addressed is the retting and defibration process. It is crucial for the use of flax fibres in modern productions that the flax can be transformed into a homogenous raw-material. A main problem today is the great variation in qualities which makes it very difficult to produce end products with specific quality characteristics.

The objective is to produce high performance products, car parts and insulation mats. Another important issue is to investigate the effect of mixing long and short fibres using the “air laid technique”.

During the last 4 years The Department of Plant Production at The Danish Agricultural Advisory Centre has been involved in a project, developing new processing methods for flax handling from field to final products. The research programme is called “production of flax fibres for industrial purposes”.

The objective has been to work out simple and profitable systems to handle the flax fibres from the field to final industrial end-uses. Also trials with hemp fibres have been a part of the research work.

1.2 Present industry and new industries under considerations

Currently one factory, Danflax, is using by-products from fibre flax production for production of tow for mattresses etc and moulded products for use in the car industry. The raw-materials are imported.

The production is modest. The factory is situated in the northern part of Jutland. The production has momentarily stopped due to lack of good quality raw materials and economy.

A group of investors, including a local municipality, local industries and farmers, are presently considering to build a small factory for production of insulation boards based on flax or a flax/waste paper mixtures. The plant will be located in the southern part of Denmark in an area with a high unemployment rate (Lolland).

The flax straw will not be scutched but used as a whole, which should reduce production costs significantly compared to other insulation boards based on plant fibres. The technology is a.o. based on results from the above project “Flax fibres for industrial purposes”.

The production will be very small to begin with. Approximately 3,000 tonnes per year (1 million m²), which is ca 5 % of the total market for insulation materials in Denmark.

1.3 Markets

Relatively recently, new products have emerged with the manufacture of moulded fibre composites for the automotive industry, such as inner panels, parts of seats etc. With the

appearance of moulded bio-based composites new markets have opened up within the building, transportation, furniture, and packaging industry. In addition bio-fibres seem promising for the production of filters as their absorption capacity is very large, especially after chemical modification which may be selective for the removal of desired contaminants.

The main advantages of bio-fibres in relation to plastic are, that they are cheap, the specific strength is high and the insulation properties as to heat and noise are high. The main disadvantage is that plant fibres are hygroscopic.

Research has documented the possibilities for making both cheap bulk products and high performance products. The main question is the market potential. It seems to be impossible at this stage of development to forecast the market share in say 10 or 20 years time. New insulation mats for houses based on bio-fibres have recently been introduced to the European market and a factory is as mentioned under consideration in Denmark. The main argument for believing in a huge future market for bio-based products is the great increase in world production which is expected to take place. For example, the Bruntland Report estimates that the world production of goods will 5-10 double over the next 50 years. Such a great increase in the use of raw material seems only possible if a large proportion of the products are based on renewable resources and the process techniques are less environmentally harmful than today.

1.4 Environmental

Products made from flax fibres are biodegradable and thus environmentally friendly.

2. Barriers to progress

2.1 – 2.2 Scientific and technical issues

All in all the product potential seems very promising the main draw back at the moment being the lack of know how. Although research into the industrial use of plant fibres has increased over the last years it is insignificant compared to the research done with other materials such as plastic, concrete, steel etc. Thus, before a major industrial break through may take place much more research is needed. The processing techniques are numerous and so are the product properties. For the production of products with specific properties as to environmental impact, strength, surface characteristics, weather resistance, degradability, and economy we need to know much more about species properties, time of harvesting, retting, defibration, chemical modification, new bonding systems, enzyme treatments, mat forming, surface treatments, and finishing to mention the most important factors of research. As these factors interact, only make the problems more complicated.

One main barrier is the large variation in fibre quality, which makes it very difficult to produce end products with homogeneous and well defined quality characteristics. It is vital for the whole flax industry to overcome those problems, and research must be initiated both on plant improvement, agronomic, and post harvest treatment. Also research on end use is needed to make optimal use of the excellent fibre strength. With to days production and processing methods the strength is reduced considerably during treatment.

2.3 Environmental

Growing of flax does not present any major environmental problems. Some organic farmers are to a very limited extend growing flax. It could thus be a candidate crop for a "green label" (page 1) so that its environmental friendliness could be capitalised.

2.4 –2.5 Economic and legislative issue

Today flax fibres can compete with other fibres of similar quality due to the prevailing generous EU subvention. However with the foreseen future reduction in subvention, Danish grown flax will only become competitive, if the production methods are improved considerably.

3. Hemp

General

Together with flax, hemp is the oldest industrial crop in Denmark. Hemp was produced by Danish farmers already in the Middle Ages. Around 1600 it was even included in the Danish law (Frederik the Fifth's Danish law of 1622) that Danish farmers were obliged to produce hemp. The hemp fibres were mainly used by the Danish navy and for clothing. In the eighteenth century hemp was grown on approximately 3,500 ha.

In recent history a revival of interest was recorded during the First and the Second World War. Thus, in 1942 hemp was grown on 2,000 ha of land. After the war it was decided to forbid the production of hemp due to its content of psychoactive components.

The Danish government announced in April 1998 that it again is allowed to grow hemp for industrial purposes, provided that only varieties with a low content of psychoactive components are used. This has created a revival of interest both amongst farmers and a number of small industries.

1. Opportunities

1.1 Science and technology

a. Breeding and primary production

Due to the cool climate hemp ripens very late in Denmark and the production of seeds is thus limited. However the fibre yield seems to be in the same range as in other countries.

Danish plant scientists have since 1861 carried out controlled growing experiments on hemp. This year Danish Institute of Agricultural Sciences (Flakkebjerg, Rønhave) and Grønt Center (Holeby) have established about 60 ha with French, German and Hungarian varieties, and a few farmers have started their own test productions. So far there has been no systematic hemp breeding programmes in Denmark.

Experiences from the late fifties show that the yield of dry biomass is about 10 tonnes per ha, yielding 1.5 tonnes of long fibres and 600 kg of tow. The oil yield is very low. The demand for fertiliser and pesticides is very limited making hemp a good candidate for sustainable production of non-food products.

The seeds are sown in April/May and the plant harvested in September.

b. Harvesting, retting and storage

The Danish experience with harvesting and retting of hemp is very limited and considerable experimental work needs to be done before these processes are ready for commercial use.

c. Research in processing and applications

Currently there are no hemp processing industries in Denmark, however, a number of small industries are considering to include hemp in their raw-material portfolio. The incentive seems to be the growing consumer interest in environmentally sound and natural products.

The company Randers Rebslageri A/S is selling sisal, hemp and manila rope, all from imported raw materials.

The “Centre for Plant Fibre Technology” (page 12) is doing research on the use of hemp fibres for production of insulation mats composites and high performance fibres.

Two small firms (“D.S. Striber” and “Egen Vinding og Datter”) produce/use paints based on hemp oil. The paint is a o used for industrial painting of prefabricated window frames. The production volume is unknown, but presumably very small.

A producer of high quality carpets (sisal fibres) is considering the possibility of using hemp fibres in some of their products (SKANKO).

A few Danish textile designer firms (“Tinta”, ”301 Textile Design” and “The Hemp Company”) use hemp textiles in their collection.

The international retailer chain “The Body Shop” and a national company “Urtekram” use hemp oil in some of their cosmetics, and a small shop, “Hemp House”, is selling a large variety of imported products based on hemp.

1.2. Present and potential markets

In spite of the considerable interest and many activities, it is realistic to assume that the potential is modest, about 2,000-3,000 ha.

There is obviously a consumer interest in hemp products, however whether the products will be imported or produced from Danish grown hemp will naturally depend on the Danish production costs and farmer interests.

Table 6. Import and Export of plant fibres 1997.

	Import		Export	
	tonnes	1,000 DKK	tonnes	1,000 DKK
Hemp (not raw or rettet, not spun, incl. waste)	97.2	445	-	-
Flax (raw or winded, not spun)	30.4	318	0.1	3
Flax (not rettet, broken or scutched, not spun)	189.6	4,168	72.5	2,618
Flax (waste)	11.8	365	42.5	970

Source: Statistics Denmark

2. Barriers to progress

2.1 - 2.2 Scientific and technical issues

The scientific knowledge in processing and application of hemp fibres and oil is very limited in Denmark. Know how on hemp growing and the processing of hemp for production of short fibres is however being built up through ongoing projects.

There is an obvious need for plant breeding to produce varieties that are better suited for the Danish climate. Furthermore the retting process must be improved (e.g. through water retting and/or use of enzymes), and the existing harvesting equipment must be adapted to hemp, before a viable production becomes possible. Also the existing equipment for desintegration

and defiberisation (built for processing of flax fibres) must be modified and adapted to the hemp fibres.

2.3 Environmental issues

Hemp (with a low content of psychoactive components) is considered to be an environmentally friendly crop with very little demand for fertilisers and pesticides. It is thus a candidate raw-material for production of non-food products with a "green label".

2.4 Legislative issues

As mentioned on page 17 hemp growing was forbidden in Denmark until April this year. Today there seems to be no legislative obstacles.

2.5 Economic issues

With today's varieties at hand and today's technology it is questionable whether a Danish hemp production is competitive. One serious obstacle today is the fact that the seeds are very expensive. This is presumably partly due to a lack of seeds from high-yielding varieties and partly due to a monopolistic situation with a limited number of seed producers.

There seems to be plenty of scope for improvements. Preliminary calculations indicate that (after necessary technical improvements) a future Danish hemp production could become economical feasible provided that the present EU subvention prevails.

However the EU Commission has announced its intentions to reduce the subvention level considerably, which might have the effect that Danish grown hemp becomes too expensive, unless its sustainability (environmental friendliness) could be capitalised.

Carbohydrate crops

1. Cereals

Introduction

Cereals are the dominating crops in Denmark. Yearly is produced 8-9 million tonnes. The main varieties are wheat and barley, while oats and rye are produced in small amounts. Recently there has been a revival of interest for triticale for feed and energy. More than half of the grain produced is used as feed. Only approximately 8 % is processed, 5 % is used for food, and 3 % for other industrial uses. There are no starch factories based on cereals in Denmark, but we are importing approximately 28.000 tonnes each year. See table 8.

Table 7. Import and export of starches (both food and non food uses) (1996).

	Import		Export	
	tonnes	1.000 DDK	tonnes	1.000 DDK
Wheat starch	7 941.0	22 692	147.4	507
Maize starch	19 685.6	65 078	999.5	4 059
Potato starch	6 199.0	21 974	84 007.9	271 411
Manioc starch	43.7	273	-	-
Rice starch	1 184.8	9 891	188.6	2 542
Other starches	2 194.0	8 746	4.3	141
Sum	13 948.1	128 654	85 347.7	278 660

1. Opportunities

1.1 Science and technology

a. Breeding and primary production

Cereals are well suited for the Danish climate. The Danish farmers are skilled in growing and handling it, and the Danish research capacity in breeding is excellent. Therefore Danish cereal production is very efficient, and Danish cereal growers stand a good chance to be able to remain competitive also after the Agenda 2000 has come into effect.

There are many potential industrial applications for cereals, but variation in “industrial quality” is not yet fully explored. There is very little interrelated systems information on the yields of chemical components such as starch and cellulose from modern varieties. An investigation into the variability of cereals grown in Northern Europe /Carlsberg Research Centre, 1986) revealed that the starch and cellulose contents varied considerably between species and also between varieties of the same species. Some varieties had high contents of both starch and cellulose, and others had high yields of both grain and straw. These findings lead to the conclusion that it should be possible to breed an industrial cereal with high yields of starch and cellulose; the two most industry relevant components. Furthermore, it is technically possible to separate both the kernel and the straw into a number of fractions, each of which may be used for specific purposes. For example, leaves have a much higher fodder value than the rest of the straw, and inter nodes have a high cellulose content that can be used for chipboard, paper and pulp, or simply for energy purposes. The main component in the grain is starch, but cereals also contain a number of industrially interesting components in minor quantities, for example B-glucans, pentosans and esters of fatty acids.

A major issue in Denmark is sustainable agriculture and currently a number of plant breeding projects are aimed at improving pest and disease resistance in cereals

In the “cereal package” (a cereal research programme including plant breeding and processing) are 4 projects on reduction of inputs of pesticides:

- Improved resistance towards leaf diseases in barley and wheat
- Haploid in wheat
- Trans genetic barley with improved disease resistance (mildew)
- Breeding of barley and wheat varieties with improved competitive power towards weeds
- Use of markers to develop barley varieties with high malting quality and resistance towards diseases

b. Harvesting and storage

Denmark has a long tradition for using not only the grain but also the straw part. Today the straw/grain separation is usually done in the field with a combine harvester. The efficiency of the separation depends on the harvesting conditions, and especially on the ripeness of the kernel and the moisture content of the crop. The combine harvester was developed for the dry climate in the mid west in the USA and it is not optimal for the wet climate in Denmark. The combine separation often leads to losses of kernels in the field or in the straw fraction. The straw fraction is left in the field and the quality is deteriorating rapidly. Normally the grain has to be dried after harvest.

Over the years attempts have been made to find alternative harvesting systems. For cereals for industrial use the most promising is from a technical and quality point of view a whole crop harvester, combined with a stationary separator and drier. This system is weather independent and leads to higher quality and yield of both grain and straw. The system is not economical feasible unless the straw can be used for industrial purposes. Experiments in pilot plant scale have shown that straw harvested in this way is excellent for e.g. paper production and for particle board production.

Another principle is stripper harvesting. The upper part of the plant containing the ear and kernels is stripped off by the harvester, while the stem remains on the root. It is easy afterwards to plough under the straw, if there is no use for it, or to harvest it with e.g. a field chopper or a bale pressing machine. Stripper harvesting, originating from UK, is currently being tested in field trials in Denmark.

The Danish climate with frequent wet weather during harvest, makes it necessary to dry the grain before storage in most years. Efficient drying systems have been developed, so that grain can be stored and transported cheaply in bulk. Therefore wheat processing plants can be large and can operate continuously throughout the year.

c. Research in processing and applications

From an industrial point of view a cereal plant is a fascinating raw material, containing the building blocks for a wide variety of commodities of major importance for our daily life.

However, the crop as a whole is an inhomogeneous raw material. The various botanical constituents have different physical and chemical properties applicable for different purposes. Therefore, an optimal total utilisation will imply a number of processes to divide the crop into its main constituents.

Efficient dry milling techniques have been developed for wheat and maize for separation of bran (pericarp and aleurone), germ, and endosperm. The endosperm can be further separated into starch, protein, and fibre (United Milling Systems).

The Royal Veterinary and Agricultural University in Copenhagen is project leader in a project (Cascade refinery) that has as aim to separate wheat kernels into food grade grain for the milling industry and industrial grade grain for production of starch. Danish wheat is like North European wheat in general not well suited for bread production mainly because of a low gluten content. The main objective of the project is to separate ordinary Danish wheat into a gluten rich bread wheat and a starch rich industrial wheat. The industry wheat is milled and further purified in a dry process into a starch rich fraction.

According to the programme description, it is possible to produce a very cheap dry processed starch. It is not as pure as wet processed starch, but it is assumed that it is applicable for many purposes such as in the paper industry, as binder, in the paint and varnish industry etc.

Straw

Denmark has a long tradition for application of straw for industrial purposes. Up to two decades ago straw was used for production of building boards (10 000 tonnes/year - STRAMIT) and pulp and paper (100,000 tonnes/year - Fredericia Cellulosefabrik) and corrugating board (10,000 tonnes/year- Holeby). At periods with high grain prices grain substitutes for cattle was produced industrially (alkaline treatment, pelleting) from cereal straw. At its peak the production of feed pellets was 500,000 tonnes/year. Furthermore an organisation - DANSTRAW (fourteen Danish industries) - was established (1974) with the aim to export Danish know how and equipment to the world market. As a result a number of straw-processing plants were established mainly for animal feed production and mainly in Eastern Europe.

Two Danish companies - Nykøbing Sukkerfabrik (beet sugar) and Suhrs fabrikker (packaging) together with a research institute, Biotechnical Institute carried out in the beginning of the seventieths pilot plant experiments on straw particle board production. The work included market tests. The results were good and an industrial scale plant was planned in details. Even the necessary financing was established, but the plant was not built partly due to obstruction from the existing particle board industry.

In 1980 a pilot plant for sulphuric acid hydrolysis of straw was built by the two Danish companies De Danske Sukkerfabrikker and De Danske Spritfabrikker. These two factories are now merged into one company - DANISCO. The objective was to produce bioethanol and furfural for industrial applications.

After three years of experiments in the pilot plant an industrial scale plant was projected. The aim was a capacity of 270,000 tonnes of straw per year. The companies claimed to have solved all technical problems, but the factory was never built presumably due to high raw-material costs and problems with a guarantee for a year round supply of raw materials in sufficient quantities.

A new process for production of moulded pulp for packaging materials (egg trays, fruit trays, etc.) was developed at the Biotechnical Institute in the beginning of the eightieth. This process is less energy consuming and less polluting than traditional processes, but the interests from industry was rather limited, and a planned factory was never built.

Today all these activities are closed down, however straw is still used in large quantities; not for production of particle boards and paper etc. but for production of electricity and heat. This is the result of a government decision from 1990 to reduce CO² emission by 20 % (of the

1988 level) by the year 2000 and further by 50 % before 2030. Today is used approximately half a million tonnes of straw for energy, and the target is 1.2 million tonnes by the year 2005.

In order to fulfil these ambitious goals, the Danish power plants have set up extensive research programmes including research on straw handling, transportation plus large scale trials with combined use of straw and coal and burning of straw alone.

There is still an interest in using straw for other industrial purposes, and there have e.g. been many attempts to reopen the Fredericia Cellulosefactory, which used to be one of the largest and most efficient straw pulp factories in Europe. Furthermore a number of research projects have been financed in order to improve the industrial value of straw.

Thus, the biorefinery project (1988 - 92) included research on separation of straw into its botanical constituents - leaves, nodes and inter nodes. The inter nodes are the best suited part for particle board and paper pulp production, while the leaves have the highest fodder value. Prior to the biorefinery project an industrial separator was developed and the inter node fraction was used for production of particle boards in industrial scale (Baltic board - a chipboard factory based on wood as raw material). The production was a success from a technical point of view, but the suppliers of wood chips reduced their price so much that the straw inter nodes could not compete.

A number of research projects at the "Centre for Plant Fibre Technology" include straw fibres for production of new materials and products based on agro fibres. For example, while long fibres offer high performance, short fibres can be produced more cost effective. Therefore there is a sizeable potential market for composites containing both short and long fibres.

This includes both fibre composites and mixtures of fibres and plastics. In addition the "Centre" is involved in research on extraction of higher added value fractions from wheat and rye straw.

Two companies, Lars Schou Holding ApS (DK) and S. A. Louis Dreyfus & Cie (F) have recently jointly established a production company called "BioCore" based on utilisation of agricultural by products for production of particle boards. As a first activity was in 1998 built a demonstration plant for production of light (moulded) particle boards from cereal straw. The plant is situated near the town Skærbæk in Jutland. The capacity is 25- 30,000 m³ per year, which is rather modest compared with today's standard, but the plant is fully automatic, so that the labour demand is limited to three workers per shift.

The plant will be used both as a demonstration unit and for test of new processing principles and equipment. The boards will be used in production of doors, inner panels etc.

In 1997 were built two "straw bale houses" in Denmark, one in Copenhagen and one on the island of Falster (Green Centre). An American expert, Joe Matesi, New Mexico, who also helped with the construction work, designed the houses. The main purpose is to test the durability and insulation ability of such houses in the wet and cold Danish climate. In the dry New Mexico climate straw bale houses can last for more than 100 years.

1.2 Industry

Currently there are no wheat starch factories in Denmark. In 1987 was built a small wheat starch plant on the site of a potato starch factory. The idea was to make use of the synergy between the two productions and allow the factory to operate all year round. However, the wheat starch production was closed down in 1991 due to a considerable drop in the market price of vital gluten, which made the production unprofitable. The capacity was only 7,000 tonnes of starch per year.

1.3 Market

As cereals contain a number of main components such as starch, protein and cellulose that are potential raw-materials for many non-food products, it is reasonable to believe that cereals could become a major raw-material for a future Danish industry based on renewables.

Today, however, the non-food use of cereals in Denmark is almost non-existing (apart from the straw fraction). The total production and consumption are shown in table 8.

Table 8. Utilisation of Danish and imported cereals (1 000 tonnes)

	1994/95	1995/96	1996/97
Crop production	7 566	8 876	8 942
Imports	363	443	314
Stocks, beginning	1 893	1 274	1209
Total available	9 822	10 593	10 465
Exports	2 137	2 665	1791
Used for sowing	261	289	292
Grinding into flour and groats	569	511	554
Industrial uses	202	335	335
Used for feeding	5 379	5 433	6 097

Source: Statistics Denmark

It is seen that industrial processing (grinding into flour and hulled grain plus industrial uses) is very modest - approximately 10% of the total production. Most of the industrial use is for flour and groats production. Only approximately 4 percent are used for other industrial purposes (mainly malting).

Table 9 shows the cereal crop production in 1995, 1996 and 1997.

Table 9. Cereal crop production in Denmark 1996 to 1998.

	Land use of cereals in 1 000 ha			Cereal crop production / tonnes/ha			Total yield in 1 000 tonnes		
	1995	1996	1997	1995	1996	1997	1995	1996	1997
Winter wheat		669	671	7.6	7.0	7.2	4,565	4,729	4,902
Spring wheat		5	13	5.2	5.0	5.4	33	28	63
Rye		75	88	5.1	4.8	5.4	495	343	453
Winter barley		198	176	6.1	5.4	6.0	1,131	1,068	1,047
Spring barley		566	563	5.2	5.4	5.2	2,768	2,885	2,840
Oats and mixed grain		26	30	5.1	5.1	5.2	158	164	155

Source: Statistics Denmark

Wheat and barley are by far the most dominating crops - 90% total production.

Grain

As previously mentioned Danish produced cereal grains is not or only to a limited extend used for non-food application.

The straw part however is extensively used for energy, bedding etc.

Denmark imports 8,000 tonnes wheat starch and wheat starch derivatives, part of this amount is used for food purposes and part for non-food. The distribution is not known.

For the time being there are no specific plans for new non-food uses of cereal grains. Two years ago it was seriously considered to start up a production of bioethanol from grain (100,000 tonnes/year, ALFAX). The economy was based on the assumption that the government would grant a tax reduction on bioethanol. That was however not the case, and the plans were dropped.

Technical and scientific break-through could however change the present situation. If e.g. the objectives in the “cascade project” (page 22) are achieved, resulting in a very cheap wheat starch process, then there will no doubt be an interest in building a wheat starch factory in Denmark.

Denmark is a large producer and net exporter of food. The demand for food packaging is high and today packaging materials are imported. There is an interest in a Danish production of biodegradable films and coatings that could be made from starch - such products are on the market today, but the price cannot yet compete with synthetic polymers.

The Agenda 2000 reform will reduce cereal prices and probably also starch prices. That in combination with a positive outcome of the Cascade project might result in a situation where biopolymers can be produced at competitive prices.

The potential demand in DK for biodegradable polymers is high. To this can be added new markets for starch in coatings, agricultural mulches etc.

An optimistic guess would be that there would be basis for one or two wheat starch factories in Denmark with a total demand of 2-300,000 tonnes of wheat per year.

Straw

As mentioned straw is extensively used for production of heat and electricity, and in addition to that large amounts are used on the farm for bedding.

However the production is very large (up to 8 million tonnes per year), and there is still room for industrial applications.

2. Barriers to progress

2.1 - 2.3 Scientific, technical and environmental issues

As mentioned earlier there are many good reasons for a cereal based industry in Denmark, and one might wonder why the industrial use of cereals is so modest.

One reason is obviously the traditional agricultural production pattern in Denmark with main emphasis on food and feed (pig, milk and poultry). This has of course also influenced the way in which public research money is being spent.

However there has for many years remained an industrial interest in new untraditional productions based on cereals, and many attempts have been made to start up productions in industrial scale.

An analysis of the many failed cereal based projects in Denmark throughout the years, shows that there are almost as many reasons for their lack of success as there are projects, but there might be a few common denominators for all projects, namely:

- Fluctuation in raw material prices and often resistance from already established competing industries.
- The two general factors such as cost of capital and labour.
- Doubts about market acceptance seems not to be a major issue.

Lack of scientific knowledge on growing and handling of cereals is not seen to be a major obstacle either. A considerable knowledge concerning plant breeding and cereal production has been accumulated during the years. A general problem though is that the knowledge is spread between a number of institutions, geographically separated. Knowledge on the transformation of cereals into non-food end products is limited compared to countries with well-established cereal-based non-food industries.

As an attempt to overcome these problems has recently been initiated a comprehensive research program on biopackaging including starch and fibres as raw materials. In the project all major Danish players in this field are participating.

2.4 - 2.5 Legislative and economic issues

The Agenda 2000 will reduce the price of cereal grain and thus the production costs for the main component - starch. A further reduction in non-food starch prices may be foreseen due to technological developments. This will render starch much more competitive towards non-renewable raw materials and open up for new applications. Wheat starch will become a stronger competitor to maize and potato starch especially in bulk productions, and second grade starch might become cheap enough for use in the fermentation industry for production of bulk chemicals such as lactic acid (for polylactic plastics).

There is a strong interest in Denmark for production of biobased packaging materials either from native starch, starch derivatives or for example from lactic acid.

New legislative initiatives such as a directive on packaging materials will contribute in making cereal grain more interesting as a non-food raw material for the industry, however it is important for the decision makers in industry that there is a long term political consistency between the stakeholders - agriculture, producers, user, and government.

It is equally important to have stable long term regulations/tax rules. It might be necessary with subsidies during introduction of a new product, but not in the long term.

2. Potatoes

Introduction

In 1995/96 Denmark was produced 1,3 million tonnes potatoes on 40,000 ha. 300,000 tonnes are used for direct human consumption, while 1 million tonnes is used for starch production, snack products or seed potatoes. Approximately 50 % of the starch is used within the non-food sector in more than 500 different products making potatoes the largest non-food crop in Denmark.

1. Opportunities

1.1 Science and technology

a. Breeding and primary production

The average potato yield is 35 tonnes per ha. This figure represents a huge variation. Some growers produce 50 – 60 tonnes per ha while others have lower yield. The Danish potato growers have their own breeding centre - Landbrugets Kartoffelfond, Forædlingsstation Vandel- where the breeders for many years have aimed at improving the quality of potatoes both for human consumption and industrial application. At Vandel the yield of potatoes have reached 90 tonnes per ha and is now aiming at 100 tonnes per ha. The research work at Vandel includes both traditional breeding techniques and modern biotechnology. Much work is devoted to the improvement of disease resistancy and yield improvement, but some projects are aiming at the improvement of the “industrial quality” of the crop, e.g. increase of phosphor and starch content.

Native potato starch is preferred to corn and wheat starch in many non-food applications. This is due to the fact that potato starch consists of very large granules resulting in a very pure starch only containing trace amounts of protein, pigments and lipids. The molecules of

amylose and amylopectin are exceptionally large and the level of phosphorylation is high. The degree of phosphorylation significantly affects the physical/chemical properties of starch, e.g. viscosity gel strength, gel clarity, solubility and water binding capacity. A high phosphorylation degree is a significant advantage in many applications. This is why research efforts have been initiated to increase the level of phosphorylation in wheat and maize starches. If this work leads to maize and wheat varieties with the same level of phosphorylation as in potatoes, it might severely reduce the quality advantage that potato starch has today over its main competitors.

Two Danish research centres, Danish Institute of Agricultural Sciences and the Royal Veterinary and Agricultural University, have initiated work to improve the degree and phosphorylation in potatoes via genetic improvement. It is possible to improve the degree of phosphorylation chemically, however this process is rather unspecified and it reduces the chain length and the crystallinity of the starch molecules. Therefore the chemically modified product is inferior in quality.

The Danish Institute of Agricultural Sciences and Aarhus University are running a project on development of potatoes with natural resistance to late blight, spraing and common scab,

The in vitro increase in potato starch phosphorylation will be based on two synergistic approaches, a breeding strategy based on the use of DNA markers linked to starch phosphorylation and genetic modulation of the phosphorylation process in potatoes.

A Danish seed company is doing research aiming at improving the starch content in potatoes. Also breeding for improving either the amylose or the amylopectin content is being performed.

It is assumed that in the long run potatoes could become a host plant in “molecular farming”. Potatoes are well suited for gene manipulation, the potato cells could be manipulated to function as mini factories producing complicated molecules for e.g. pharmaceutical applications.

b. Harvesting and storage

Potatoes are in Denmark harvested in the period from August to October but is stored until the ending of the starch processing season in December and January.. Some of the harvested potatoes are stored in ventilated storage houses, where they can be kept at a low temperature.

Biotechnical Institute in Kolding has for many years done experimental work on potato storage including potatoes for industrial use.

A concept for a cheap storage for industrial potatoes has been developed in order to stretch out the season for potato starch production.

1.2 Industry

There are 5 potato starch plants in Denmark, four of which are linked together in a co-operative called KMC (Kartoffelmelscentralen). These factories are jointly owned by a total of 2.100 potato growers.

KMC is responsible for sales of native potato starch, quality control, research, and development and sales of seed potatoes. The co-operative has a turnover of DKK 500 million per year (70 million ECU/year) and an average production of 140,000 tonnes of starch per year (8 % of total starch production in the EU). KMC exports its products to more than 40 countries around the World. The sales to the non-food industry is approximately 45 % of the total sales. One of the factories, AKM Brande, processes in the season from August to December 180,000 tonnes potatoes resulting in 38,000 tonnes potato starch. From the fruit

juice is produced approx. 2,000 tonnes potato protein. The protein is mainly sold for fermentation purposes.

The fifth factory - AKV Langholt - is also a co-operative owned by 375 potato growers. Close to the starch plant is established a “modification plant” for production of starch derivatives (mainly cationic starches). The modification plant is jointly owned by AKV and CERESTAR (CERESTAR-AKV I/S).

Table 10. Modified potato starch product produced by KMC and Cerestar in Denmark.

KMC		Cerestar	
Type	Description	Application	Type
Oxidised starches	Oxidised by natriumhypo-chlorit	Surface gluing of paper Binder pap	Oxidised starch
Cationic and etheries starches			Etherified starch
Cationic starches with nitrogen		Surface treatment of paper	Esterified starch
Oxidised and acetylised starches		gummed paper tape	Thermally modified starches Cationic starch Sorbitol

Source: Company information

AKV processes in the season from August to December 180,000 tonnes potatoes resulting in 38,000 tonnes potato starch. From the fruit juice is produced 1,300 - 1,400 tonnes protein. The residual juice is spread on the nearby fields and used as fertiliser. The protein is sold as feed for piglets and fur animals. As by-product is produced 17,000 tonnes potato pulp that is sold to local farmers and used as cattle feed.

The main part of the starch is further processed in the modification unit and sold by CERESTAR Denmark mainly to paper factories throughout the World. The native starch is primarily used in the food industry. More than 80 % of the total production is exported.

Table 10 shows the different potato starch types produced by KMC and Cerestar, respectively. For KMC the oxidised starches are the largest commodity based on weight.

The International Starch institute is a private centre for research, development and engineering. The centre operates world-wide and serves industries that manufacture or use starch and starch products. The range of services covers all aspects of starch processing and use. Further description of their services can be seen on their homepage: www.starch.dk.

1.3 Markets

As previously mentioned, potatoes are the second most commonly grown and the main non-food crop in Denmark. The average yearly production is 1,3 million tonnes. Historically Denmark has exported large amounts of seed potatoes, however this export has declined somewhat during recent years. The human consumption of fresh potatoes and the use as feed have remained almost constant for many years and quotas limit the industrial production. Up to one million tonnes is used for production of starch.

Table 11. Production and utilisation of potatoes (million kg).

	1993/94	1994/95	1995/96	1996/97
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Crops in agriculture	1 740	1 359	1 441	1 617
Crops less waste	1 566	1 223	1 297	1 455
Imports of potatoes	131	161	184	249
<i>Utilisation</i>				
Export	79	98	111	116
Seed potatoes	116	97	106	108
Potato flour manufacturing	944	670	727	880
Other manufacturing	17	18	16	16
Human consumption	296	297	299	300
Consumption for feeding	245	204	221	275

Source: Statistics Denmark

Table 12. Value of agricultural sales of potatoes (from 1 July - 30 June).

	1993/94			1994/95			1995/96		
	Quantity tonnes	Average price	Value	Quantity	Average price	Value	Quantity	Average price	Value
	Mil. kg	DDK per ton	Mil. DDK	Mil. kg	DDK per ton	Mil. DDK	Mil. kg	DDK per ton	Mil. DDK
Sales to:	239.8	1029.8	247.0	227.3	2223.0	505.4	237.9	1631.0	388.0
Human consumption	944.1	407.3	384.5	669.9	450.8	302.0	727.5	458.7	333.7
Potato flour manufacturing	17.3	509.6	8.8	18.3	598.3	11.0	15.7	640.9	10.1
Other manufacturing	62.2	1204.3	93.7	81.0	1363.3	138.1	83.9	1625.7	136.4
Sales total	1 263.4	581.0	734.0	996.6	959.7	956.4	1 065.0	815.2	868.1

Source: Statistics Denmark

Table 13. Production and consumption of potato starch.

	Crop year			Calendar year		
	1993/94	1994/95	1995/96	1994	1995	1996
Production ¹	171.8	150.7	116.3	175.1	115.2	125.6
Import	6.8	1.6	4.2	4.0	9.4	6.2
Export	105.6	98.3	71.6	118.2	63.7	84.0
Domestic use, total	73.0	54.0	48.9	60.9	60.9	47.8
of which human consumption ²	4.6	4.6	4.6	4.6	4.6	4.6

1 Sold from potato starch factories

2 Estimated use

Source: Statistics Denmark

All in all, there seems to be little scope for any considerable increase in Danish potato production, whatever it is for food or non-food application, unless the quota system is abandoned or extended for potatoes.

As mentioned, the potato starch factories use yearly up to one million tonnes of potatoes for production of up to 180,000 tonnes of starch. This amount is equal to the Danish quota for potato starch (178 460 tonnes).

1.4 Environmental considerations

There are no specific environmental problems in potato growing. During processing is generated huge amount of waste water. Different projects are now aiming to solve the problems like watering at willow plantation or concentrate the fruit juice by evaporation after filtration.

2. Barriers to progress

The Danish potato starch production is faced with at least four inter linked problems that limit the profit and possibilities for expansion:

1. limitations on production due to the quota system,
2. increasing competition from cereal starches due to quality improvements,
3. seasonal production and thus poor utilisation of processing equipment, and
4. environmental problems.

2.1 – 2.2 Scientific and technical issues

It is necessary for the long term expansion/survival of the Danish potato industry that the work on improvement of the starch quality is continued and that production costs for the starch are minimised. The latter might be achieved via complementary productions during the off-season periods and by an optimal utilisation of all components in the potato plant (as for rape seed page 7). One of the Danish factories is as mentioned above today extracting the protein for use as feed. One of the factories is developing a process to extract the potato protein in such a way that it can be used in the food industry with different properties.

As a matter of fact a potato crop is a main producer of protein. Only Soya and alfalfa produce more protein per ha than potatoes. Potato protein is neutral in taste and has a biological value that can be compared with or are better than meat and milk protein. The functional properties of potato protein are excellent. Potato protein might also be used for non-food purposes such as glues, adhesives, edible coatings and plastic films. The Biorefinery has developed a protein purification unit for rape seed-protein that might be applicable also for potato protein.

Apart from starch and protein, potatoes also contain a pectin rich fibre component that has many potential applications in food and non-food industries. Different projects are now aiming to make better use of the fibres than than it's use as cattle feed.

The residue from the protein extraction (fruit water) or the fruit juice is today spread in the fields. This is an excellent fertiliser and can even be used for organic farming. The Green Biorefinery in Ølgod has plans to develop a process for fermentation of the fruit water for production of e.g. acetic acid and lactic acid, but so far it is not economical reasonable.

2.3 – 2.4 Environmental issues and legislative issues

EU potato starch production is subventioned, which makes potato starch competitive with other starches. However in order to control the budget costs and avoid overproduction is as frequently mentioned in the above, introduced a quota system for the potato starch producing countries in EU. The Danish quota is at present 178,460 tonnes/year, and is utilised to the limit. Without the subvention potato starch production would not be profitable.

2.5 Economic issues

The Danish potato starch factories are rather small compared with to days European standard, and thus they do not have the economic advantage of scale. They cannot individually increase production due to the quota system, so the only solution is to merge factories and close the most inefficient production lines. As a matter of fact this happened recently when two of the factories announced that they have decided to merge.

3. Sugarbeet

Introduction

Sugar beets demand special soil conditions and are therefore only produced in certain areas of Denmark (especially Lolland/Falster). The main part is used for production of sugar for human consumption. Part of the by product molasses is used as fermentation substrate for production of e.g. pharmaceuticals.

Currently sugar beets are produced on 68,000 ha of land. The total yield is 3,3 mill. tonnes, which is transformed into 0,5 million tonnes of sugar.

Opportunities

1.1 Science and technology

a. Breeding and primary production

The private company - DANISCO- has its own plant breeding centre (DANISCO Seeds) that for many years has worked on the improvement of sugar beets. Lately has been developed a sugar beet that is resistant against a specific herbicide, Roundup. The beet is currently tested in field trials.

Sugar beets are an efficient producer of carbohydrates. Under Danish conditions they produce more carbohydrates per ha than any other crop (8 – 8.5 tonnes of sugar per ha).

The nitrogen demand is limited compared to other crops. As a matter of fact, too much nitrogen gives lower yields and a poorer quality. The nitrogen leaching from a sugar field is thus less than from most other industrial crops.

b. Harvesting and storage

1.2 Industry

There are in Denmark 4 sugar factories. The number has been reduced drastically during the last decade. One factory (Gorlev) will be closed down by the end of 1999. The total Danish production will however remain constant, as the three remaining factories will increase production accordingly.

The sugar industry is one of the old industries in Denmark. The production process has undergone considerable improvements throughout many years and it is today very efficient. Therefore no considerable break-through in sugar production are expected in any foreseeable future. However, only 17 % of the sugar beet is refined to sugar, the rest is by-products that might be utilised in a more optimal way. Those by-products are molasses and sugar beet pulp.

Today sugar beet pulp is mainly sold as fodder while molasses, apart from use as feed, to some extent is also used as feedstock in the fermentation industries including non-food industries (pharmaceutical industry).

1.3 Markets

Only a very small part of the Danish produced sugar is used for non-food purposes. The potential market is large. Sugar (sucrose) is an excellent fermentation feedstock, which is of specific interest for Denmark with our large fermentation industry (including a number of non-food industries -pharmaceutical industries). The industrially produced sucrose is a very pure carbohydrate source and it has a very low microbial count. It is however doubtful

whether Danish produced sugar will be able (for economical reasons) to compete with imported alternative feed stocks such as cane-sugar, corn syrup, maize steep liquor etc.

The presence of eight hydroxyl groups in the sucrose molecule provides a theoretical possibility of a very large number of sucrose derivatives. Sucrose derivatives are used by Danish industries in production of detergents, emulsifiers (sucrose + fatty acids) and adhesives (sucrose octa acetate). These products are relatively expensive and can not compete with the commonly used detergents in major household and industrial detergent formulations. Therefore they are used in specialist applications such as cosmetics. The sucrose derivate, sorbitol, is used in e.g. production of polyurethan foams.

Denmark has no sugar derivative industry, therefore the above mentioned products are all imported.

1.4 Environmental issues

There are no specific environmental problems in growing sugar beet in Denmark.

2 Barriers to progress

2.1 – 2.2 Scientific and technical issues

As mentioned earlier sugar beets are the most efficient carbohydrate producer measured in tonnes per ha, however the main carbohydrate competitor, starch, has the advantage that the long chain polymeric nature of starch imparts properties that are not matched by sucrose, leading to a substantially higher usage of starch. Both products are readily hydrolysed, starch to glucose and sucrose to glucose and fructose. Both compete with each other for use in a large range of fermentation reactions. Sucrose, tonne for tonne, has 5 % higher carbon content than glucose, however the price difference is often not in favour of use of sucrose instead of glucose (starch).

As the by-product molasses is price-competitive it is used as feedstock in the Danish fermentation industry, however molasses contains other compounds than fermentable carbohydrates, which makes the final purification more costly.

Sugar beets cannot be stored for a significant period of time without biological spoilage. The sugar-factories are therefore situated close to the growing areas and are relatively restricted in size by crop transport considerations. They are, as potatoes, restricted to campaign type operation during the harvest period, a further important cost factor, though this has been improved by modern techniques of thick juice storage, which allows some extension of sugar production periods. For long term storage to meet the needs of industry for a regular supply it is the higher value added product, sugar, which has to be stored.

2.3 Environmental issues

As previously mentioned sugar beets has a moderate N demand (about 100 kg N/ha) and thus a low leaching of nitrogen to the soil.

Sugar-beets, especially young plants, have difficulties in competing with weeds, therefor it is necessary to use herbicides or mechanical, labour intensive and thus expensive, weed removal methods.

DANISCO has via genetic manipulation developed a beet variety that is resistant towards a very efficient weed killer ROUND UP. ROUND UP is normally considered to be less harmful to the environment than other herbicides. Besides the dosage of herbicides may be reduced considerably.

2.4 Legislative issues

The quota system for sugar limits the production size.

According to the EU marked regulation for sugar beet the sugar factories has to pay the farmers a certain minimum prices determined from the intervention prices of sugar. The fixed prices are related to specific amount of quota A and quota B sugar beets respectively. The quota A for Denmark is 328,000 tonnes per year and the quota B is 96,629,3 tonnes per year. Production exceeding the quota for A plus B is not included in the price guaranty but can be sold to world market price.

2.5 Economic issues

The Danish factories are very efficient and with competitive production costs.

Table 14. Land areas grown with root crops in Denmark 1996 and 1997 in ha.

	1996	1997
Seed potatoes	6 645	5 426
Potatoes for manufacturing	24 876	23 794
Potatoes human consumption	11 690	10 096
Sugar beets for sugar production	69 732	69 495
Fodder beets	41 347	37 414
Total	154 289	146 225

Source: Statistics Denmark

Crops for special uses

Introduction

The research centre "Green Centre" is currently following the market for herbal products for pharmaceuticals, and making appraisals of the feasibility of growing and production of specific pharmaceutical plants in Denmark. "Green Centre" established a few years ago a test production of ginseng on its research fields. The results so far have been promising.

In the mid nineties Danish scientists were involved in a EC-BIOTECH project evaluating Sesbania wood for biopackaging material. In Denmark this nitrogen-fixing legume reach 2 m per year, biannuals are not possible under field conditions as Sesbania are not frost resistant. The project did not continue to commercialisation due to lack of market penetration.

Artemis is a small company with 7 employees producing vegetable based wax, paints and pens (all coloured) for e.g. artists and children (kinder gardens). All ingredients are totally safe and environmentally friendly. The waxes are based on bees wax, and the colours used are all pure plant colours. The following plants are used:

- Madder root (*Rubia tinctorum*)
- Indigo (*Indigofera tinctoria*)
- Buckthorn berries (*Rhamnus cathartica*)
- Reseda (*Reseda luteola*)
- *Coreopsis tinctoria* (flowers)
- Catechu (*Acacia catechu*).

Echinacea purpurea L., Compositae

Preparation of the purple coneflower is used and sold as treatment for common colds and similar symptoms. Documentation from clinical trials has led to registration of more herbal remedies containing Echinacea in Denmark. Two groups of compounds - alkamides and caffeic acid derivatives, e.g. cichoric acid, are considered to influence the therapeutic effect. The plant is endemic to the eastern part of USA and is now cultivated in USA, Switzerland and southern Germany. For some years initial cultivation have taken place in Denmark.

***Antirrhinum majus* L., Scrophulariaceae**

Antirrhinum majus (Snapdragon) is not used commercially yet, but is tested in a research project for its content of antirrhinosides. Isolation procedures are identified and possibilities to convert iridoids to chiral building blocks for new pharmaceutical drug e.g. anti-HIV drugs such as carbovir and BCA.

Scutellaria albida, Labiatae

Same use as for *Antirrhinum*!

Lupinus luteus L.

Subspecies (*L. luteus*, *L. angustifolius* and *L. albus*) is examined for yield potential in a research programme. Several varieties are examined for yield and quality parameters as well as fermentation characteristics in co-operation the enzyme industry.

ANNEX

Table 15. Land use (in ha).

	1970	1975	1980	1985	1990	1995	1996	1997
Cereals, total	1 738 944	1 720 314	1 816 318	1 600 599	1 566 562	1 447 494	1 545 175	1 555 265
Pulses, total	23 389	4 164	4 441	126 836	114 354	74 178	69 158	95 256
Root crops, total	289 197	297 570	240 542	227 926	208 044	163 055	154 289	146 225
Seeds for industrial use total	20 608	75 833	103 633	220 287	272 285	154 200	108 831	107 027
seeds for sowing total	52 972	61 723	46 031	47 042	51 743	61 556	60 964	61 212
Grass and green fodder in rotation	500 714	464 313	414 420	356 582	326 400	401 938	370 274	386 863
Horticultural products, total	13 989	11 082	25 427	31 047	27 792	24 719	22 808	20 689
Other crops	2 045	2 608	2 117	3 217	3 860	1 308	982	477
Permanent grassland	299 458	277 378	251 817	220 564	217 235	397 601	383 552	314 999
Utilised agricultural area	2 941 316	2 914 985	2 904 745	2 834 100	2 788 276	2 726 048	2 716 034	2 688 014
Utilised agricultural area in percent of total land area	68.3	67.6	67.4	65.8	64.7	63.3	63.1	62.4

Source: Statistics Denmark

Table 16. Non-food on set aside areas in Denmark 1993-1997 (in ha)

Year	1993	1994	1995	1996	1997
With contracts					
Rape, winter			30 396	12 956	5 753
Rape, spring			12 177	11 575	4 468
Total	16 848	47 588	42 573	24 530	10 221
Cereals					
Triticale			348	230	
Wheat	4		126	80	
Barley		24 6	3	2	
Ray			71	69	68
Bitter lupin	15	22	9		
Peas		4	3		
Borage	87	118			
White mustard	5	9			
Clover					5
Without contract					
Willow	not known	208	362	493	526
Poplar	not known	1	1	3	3
Alder	not known		1	1	1
Lime	not known				6
Mixed forest and set aside	-				42
Miscanthus	not known	28	21	208	25
Red Canary grass	-		2	1	2
Solhat (?)	-		2	2	
Total	16 959	48 001	43 522	25 430	10 899
Set aside in percent	15	15	12	10	5

Source: Danish Market Management and Intervention Board

Table 17. Production of seeds for manufacturing and of seeds for sowing (in tonnes)

	1994	1995	1996
Winter rape	240 173	237 510	172 985
Spring rape	130 489	74 927	78 428
Mustard	8	157	118
Oil flax	313	1 219	2 027
Poppy	184	162	-
Caraway	180	674	68
Seeds for manuct , total	371 346	314 649	253 626
Root crops			
Red clover, semi late	170	347	200
White clover	1 935	2 001	1 279
Black medic	119	72	48
Perennial rye grass	24 674	34 731	35 637
Italian rye grass	4 159	3 873	2 593
Hybrid rye grass	632	821	550
Timothy	215	567	393
Cock's food grass	1 687	1 996	2 148
Meadow fescue	1 692	2 273	1 624
Red fescue	20 512	19 415	13 298
Common meadow grass	910	884	455
Smooth meadow grass	564	477	344
Smooth meadow grass	10 060	10 590	5 699
Seeds of other grass crops	148	159	215
Seeds for sowing, total	67 477	78 209	64 483

Table 18. Selected bodycare products produced by Aarhus Oil A/S

Chemical description	CTFA/INCI name	APPLICATIONS								
		Milks and Lotions	Creams and Soft Creams	Message Oils	Waterless Formulations	Lipsticks and Lip-care Sticks	Suppositories	Deosticks	Hair and Body Shampoo	Hair Conditioner
NATURAL FATTY ALCOHOLS										
Cetyl Alcohol, 1-Hexadecanol	Cetyl Alcohol	1-2	1-4	○	●	●		●	0-2	0-3
Cetyl-Stearyl Alcohol	Cetearyl Alcohol	1-2	1-4	○	●	●		●	0-2	0-4
Stearyl Alcohol, 1-Octadecanol	Stearyl Alcohol	1-2	1-3	○	●	●		●	0-2	
SPECIALITY OILS & FATS										
C16-C18 Triglycerides	Palm Glycerides	2-4	2-8	○	●	●			○	●
C16-C18 Triglycerides	Palm Kernel Glycerides	2-4	2-8	○	●	●	●		○	
C16-C18 Triglycerides	Palm Kernel Glycerides	2-4	2-8	○	●	●	●		○	
C16-C18 Triglycerides	Hydrogen Coconut Oil	4-10	4-10			1-4			○	
C16-C18 Triglycerides	Hydrogen Palm Kernel Oil	4-10	4-10			1-4			○	
C16-C18 Triglycerides	Hydrogen Soyabean Oil	4-10	4-10			1-4			○	
C16-C18 Triglycerides	Hydrogen Veg Oil	4-10	4-10	1-3		1-4	●		○	
C16-C18 Triglycerides	Vegetable Oil	2-10	2-10	10-90		10-80	●		○	
C16-C18 Triglycerides	Hydrogen Veg Oil	1-3	1-5	1-4		1-10	●	●	○	
C16-C18 Triglycerides	Hydrogen Veg Oil	1-3	1-3	○		1-5	●	●	○	
FRACTIONATED VEGETABLE GLYCERIDES										
C16-C18 Mono-, Di-, Triglycerides	Glyceryl Dioleate	8-12	6-15	○	○		○		○	1-4
C16-C18 Mono-, Di-, Triglycerides	Hydrogen Veg Glycerides	○	2-6	○	○		○		○	1-8
EXOTIC OILS & FATS										
C16-C18 Triglycerides	Palm Oil*	1-10	1-10	1-2		1-5	1-5	○	○	1-2
C16-C18 Triglycerides	Passionflower Oil	1-5	1-5	1-10		2-20	●		○	1-2
C16-C18 Triglycerides	Shorea stenoptera Butter	2-4	2-8			2-6	●		●	1-2

Legend:
* Applied for, but not adopted

Legend:
Recommended dosage in percent by weight
●. use is recommended
○. use is not recommended

Table 19. Selected oleochemical products produced by Aarhus Oil A/S

Description	Main field of application						
	Graphic cleaner	General cleaning	Lubricants	Mould release	Surface coating	Dust control	Penetrating oil
Vegetable oil + additive			x				
Methylester (RME)	x						
RME + emulsifier	x						
Mixture ester + emulsifier	x						
Vegetable oil ?emulsifier			x	x		x	x
Oxidative resistant oil + release agent			x				
Oxidative resistant veg oil			x				
Ester oil + emulsifier		x	x				
Ester + vegetable oil				x			
Esters + vegetable oil				x			
RME		x					
RME + emulsifiers		x					
RME + vegetable oil		x					
Vegetable fat					x		

Table 20. Grindsted Products for Non-food

Application area		Grindsted product	Description	
Adhesives		Dimodan PM	monoglyceryl stearate	
Bandage materials		Sobalg PH	alginates	
Cosmetics		Grindtek ML 90	monoglyceryl laurate	
		Grindtek MM 90	monoglyceryl myristate	
		Dimodan PM	monoglyceryl stearate	
		Dimodan LS	monoglyceryl linoleate	
		Emuldan HLT 40	mono-diglyceryl stearate	
		Emuldan HA 32/S6	mono-diglyceryl stearate S E:	
		Lactodan F 15	glyceryl palmitate lactate	
		Lactodan B 30	glyceryl stearate lactate	
		Promodan SP	propylene glycol stearate	
		Acidan N 12	hydrogenated tallow glycerides citrate	
		Artodan SP 55	sodium stearoyl lactylate	
		Homodan PT	polyglycerol-3-ester of dimerised soya bean oil	
		Famodan MS	sorbitan monostearate	
		Famodan TS	sorbitan tristearate	
		Sobalg FD	alginates	
	Cutting oil emulsions		Mexpectin	pectins
			Artodan SP 55	sodim stearoyl lactylate
		Emuldan PK 60	palm kernel glyceride	
		Dimodan	lard monoglyceride	
Dental impression powder		Sobalg FD	alginates	
Denture adhesives		Sobalg FD	alginates	
Emulsion explosives		Famodan SMO	sorbitan monooleate	
Fabric softener		Emuldan HLT40	mono-diglyceryl stearate	
		Grindsted ML 90	monoglyceryl laurate	
		Emuldan PK60	palm kernel glyceride	
Household toiletry		Famodan SMO	sorbitan monooleate	
		Dimodan S	lard monoglyceride	
		Dimodan LS	monoglyceryl linoleate	
Lubricants		Mexpectin	pectin	
Ostomyrings		Sobalg TC	alginates	
Papers	High quality papers, release papers			
Pharmaceutical preparations		Glyceroli	mono-diglyceryl sterate	
		Monostearas Ph Eur:		
		Grindtek ML 90	monoglyceryl laurate	
		Sobalg PH	alginates, alginic acid	
		Mexpectin	pectin	
Plastics	EPS		monoglyceryl stearate	
	PE, PP		mono-diglyceryl sterate	
	PVC		triglyceryl sterate	
	Thermoset resins			
Printing inks		Homodan PT	polyglyceryl-3-ester of dimerised soya bean oil	
		Famodan SMO	sorbitan monooleate	
Textiles and Textiles printing paste		Dimodan PM	monoglyceryl stearate	
		Sobalg TX	alginates	
Water purification		Guardan	guar gums	
Welding rods		Sobalg FD	alginates	
Wound dressing		Sobalg TC	alginates	
		Sobalg PH	alginates	
		Mexpectin	pectins	

Source: Grindsted Product Profile, Grindsted

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4.4 Lists of key contacts and addresses for industrial crops in Denmark

List of Danish organisations with affiliation to renewable rawmaterials

Company	Contactperson	Phone	Fax/E-mail/Website	Rawmaterial	Product	Remarks
1. Oil Crops						
1.1 Industri						
Danson Paint Int. A/S Grønlandsvej 9x DK-8700 Horsens		(+45)75625666	(+45)75622044	Linseed oil	Paints	Production
Aarhus Olie M.P. Bruunsgade 27 DK-8100 Aarhus	Jørgen Eriksen	(+45)87306000	(+45)87306036	Oilseeds	Vegetable oils and derivations	Oil mill
Horn ApS / PC Vinduer Staushedevejen 2 DK-Gesten	Charlotte Horn	(+45)75557277	(+45)75557504	Linseed oil	Windows painted with linseed oil based paints	Production
Nykilde Lundbækvej 11 Slotsbjergby DK-4200 Slagelse	Kjeld Kristensen	(+45)53584072	(+45)58585048 nykilde@get2net.dk	Linseed oil	Paints	Production
Artemis Farver Rudolg Steiner Allé 17 Snogbæk	Svend Pedersen		(+4575943712	Plant colours	Paints for decoration	Production
DS Striber DK-4660 Store Heddinge		(+45)56504311		Hemipoil	Paints	Testproduction
Egen Vinding og Datter Rønnedvej 18 DK-4100 Ringsted		(+45)57617701		Linseed and hemipoil paints	Windows painted with vegetable oil based paints	Industrial production
The Body Shop Søvangsvej 1-5 DK-2650 Hvidovre	Isabel Morgenstern	(+45)36775519		Hemipoil	Cosmetics	Retail

Danisco Seeds Højbygårdsvej 14 4960 Holeby	Morten Helt Poulsen	(+45)53906031	(+45)53906375	Oil crops	Seeds	Seed Company
Protein og Oliefabrikken Scanola A/S Viborgvej 128 DK-8210 Århus		(+45)86120300		Rape seed Sunflower	Vegetable oils	Oil mill
1.2 Retail						
Trip Trap Denmark A/S Havnen DK-9560 Hadsund		(+45)99525252	(+45)525299 www.triptrap.dk	Linseed oil	Vegetable oils for wood protection	Retail
1.3 Research organisation						
Danish Institute of Agricultural Sciences Forskningscenter Flakkebjerg DK- 4200 Slagelse	Poul Flengmark	(+45)58113300	(+45)58113301	Oil crops	Breeding	Governmental research centre
Chemistry Department Royal Veterinary- and Agricultural University Thorvaldsensvej 40 DK-1871 Frederiksberg C	Hilmer Sørensen	(+45)35282828	(+45)35282089	Vegetable oils	Research in oil chemistry	University
2. Fiber Crops						
2.1 Industry						
Bio Core Morsøgade 8 DK-6700 Esbjerg	Lars Schou	(+45)75451313	(+45)75451399	Cereal Straw	Composites	Industry
2.2 Retail						
THC The Hemp Company Vintapperstræde 43 DK-5000 Odense	Annette Schjødt	(+45)66194743	(+45)66194743	Textile fibres from hemp	Design of textile products	Retail

Hemp House Larsbjørnsstræde 22 DK-1454 København K		(+45)33914171	(+45)31571042 hempvol@post 5.tele.dk http://home5.inet.tele.dk/hempvol	Hempfibres and oil	Assortment of hemp products	Retail
Textile design Dampfærgevej 27 DK-2100 København Ø	Lykke Bloch Kjær	(+45)35264680		Cotton, flax, hemp fibres	Sustainable textiles	Design, retail
2.3 Research organisations						
Plant Vision Dampfærgevej 8 DK-2100 København Ø	Ulla Eikard Niels Peter Flint	(+45)35433528	(+45)35433598	Fibre crops	Products from Danish fibre crops	EU financed project (ADAPT Employment potentials in the use of Danish fibre crops)
Danish Institute of Agricultural Sciences Research Centre Foulum P.O. Box 23 DK-8830 Tjele	Uffe Jørgensen	(+45)89991900	(+45)89991619	Miscanthus and other fibre crops	Research on chip boards thatching materials, energy crops etc.	Governmental research centre
Research Centre Risø Kemi sektionen Dept. of Miljøteknik P.O. Box 49 DK-4000 Roskilde	Anette S. Schmidt	(+45)46774101	(+45)42371491	Lignocellulosics	Research hydrolysis separation	Governmental research centre
Research Centre Risø Dept. for Material Research P.O. Box 49 DK-4000 Roskilde	Hans Lilholt	(+45)46775700	(+45)46351173 materials@risoe.dk	Natural and syntetic fibres	Composites	Governmental research centre
FORCE Instituttet Niels Jernes Vej 2-4 DK-9220 Aalborg Ø	Knud Rasmussen	(+45)96350800	(+45)96350829	Natural and syntetic fibres	Research on composites and fibre enforcement	Research centr

Royal Veterinary & Agricultural University Unit of Forestry Agrovej 10 DK-2630 Taastrup	Per Ole Olsen	(+45)35282223	(+45)35282216	Fibre crops Wood	research on composites and other fibre based products	University
3. Carbohydrate Crops						
3.1 Industry						
KMC Nr. Lindvej 14 DK-7400 Herning	Ole Bandsholm	(+45)97122066	(+45)97122321	Potatoes	Starch and derivattives	Industry
AKV Langholt Gravsholtvej 92 DK-9310 Vodskov	John Chr. Aasted	(+45)98286233	(+45)98286503	Potatoes	Starch and derivatives	Industry
Danisco Seeds Højbygårdsvej 14 4960 Holeby	Morten Helt Poulsen	(+45)53906031	(+45)53906375	Sugarbeet	Seeds	Seed Company
Frede Andersens Fabrikker A/S Naurbjergvej 1 DK-4623 Ll. Skensved	Flemming Moch Jørgensen	(+45)56169015		Starch, protein etc.	Glues and adhesives	Industry
3.3 Research organisation						
Danish Institute of Agricultural Sciences Dep. of Crop Physiology and Soil Science Research Center Foulum P.O: Box 21 DK-8830 Tjele	Marianne Madsen	(+45)89991900	(+45)89991919	Potatoes	Know how and research on plant breeding and production	Governmental research centre
Danish Institute of Agricultural Sciences Dep. of Cereals Seeds and Ind. Crops Forskningscenter Flakkebjerg DK-4200 Slagelse	Johannes Ravn Jørgensen	(+45)58113300	(+45)58113301	Breeding and growing	Know how and research on cereals	Governmental research centre

Royal Veterinary and Agricultural University Food Technology Rolighedsvej 30 DK-1958 Frederiksberg C	Michael Schneider	(+45)35283564	(+45)35283245	Cereals Research	Research on starch production, application	University
Danish Institute of Technology Institute of Polymer Technology Århus	Nils Nilsson	(+45)89438260	(+45)89438282	Starch Fibres Protein	biopolymers Research	Research centr
The Royal Veterinary and Agricultural University Institute for Dairy and Food Rolighedsvej 30 DK-1958 Frederiksberg C	Grethe Bertelsen Grith Mortensen	(+45)35283212	(+45)35283210	Biopolymers	Research on foodpackaging	University
Danish Potato Breeding Foundation Grindstedvej 55 DK-7184 Vandel	Karl Tolstrup	(+45)75885533	(+45)75885615	Breeding potatoes		Fund
Ålborg University Biotechnologi Laboratory Sohngårdsholmsvej 57 DK-9000 Ålborg	W. Zimmermann	(+45)98142024	(+45)98142555	Starch	Research on biopolymers Enzyme technology	University
Institute of Plantbiology The Royal Veterinary and Agricultural University Thorvaldsensvej 40 DK-1871 Frederiksberg C	Birger Lindberg Møller	(+45)35283352	(+45)35283333	Starch Biotechnology	Research on starch synthesis in plants	University
International Starch Institute Science Park Aarhus Gustav Wieds Vej 10 DK-8000 Aarhus C	Jens Kirk Thomsen	(+45)86202000	(+45)862012122 www.starch.dk	Starch	Know how on starch production and application	Consultancy Company

4. General

Konceptor Gyndbjerg 23 DK-6091 Bjert	Torsten Reffstrup	(+45)75572452		Cereals	Know how in harvesting and post harvest treatment	Consultant
JRS Engineering Hellerupvej 8 2900 Hellerup	Jan Robert Schade	(+45)39625614		Cereals and fibre crops	Know how on fibre production, cereal processing	Consultant
Green Centre Råhavegård Maribovej 9 DK-4960 Holeby		(+45)53907000	(+45)53906905	Hemp oilcrops Medicinal plants	Know how and research	Regional research centre
Biosystemer ApS Odinshøjvej 116 DK-3140 Ålsgårde	Holm Christensen phone: fax: e-mail:	(+45)49709882	(+45)59709931 biosystemer@post4.tele.dk	Linseed Rapeseed	Know how	Consultancy Company
Urtekram A/S klostermarken 20 DK-9550 Mariager	Lisbeth Damsgaard	(+45)98542288	(+45)98542333		Detergents Cosmetics Soaps etc.	Production Retail
Biomasseinstituttet Industrivej 11 DK-6870 Ølgod	Pauli Kiel	(+45)56975556	pauli.kiel@danskbiomasse.dk	Organic byproducts	Fermentation products e.g. lysin Pilot plant facilities	Research centr
Bioraf Danmark Foundation Reasearch Centre P.O. Box 35 DK-3720 Åkirkeby	Christian Kjøller	(+45)56975556	(+45)56974707	Oilseeds Cereals Fiber crops	Know how Research Pilot plant facilities	Research centr
Danish Agricultural Advisory Centre Udkærvej 15 Skejby DK-8200 Århus N	Kjeld Vodder Nielsen	(+45)87405000	(+45)86109700	Post and pre- harvest processing	Know how and development	Extension servi centre Agricultural development
Danish Institute of Agricultural Sciences Dep. Cereals, Seeds & Ind. Crops Forskningscenter Flakkebjerg DK-42 Slagelse	Kim B. Itenov	(+45)58113300	(+45)58113301	Agricultural crops	Know how plant breeding and production	Governmental research centre

Danish Institute of Agricultural and Fisheries Economics Toftegårds Plads Gl. Køge Landevej 1-3 DK-2500 Valby	Morten Gylling	(+45)36442080	(+45)36441110	Agricultural production systems	Agricultural economics	Governmental institute
The Royal Veterinary and Agricultural University Food Technology Rolighedsvej 30 DK-1958 Frederiksberg C	Lars Munck	(+45)35282828	(+45)35283245	Agricultural products	Research Chemometry, control systems	University
Grindsted Products / Danisco Ingredients Edwin Rahrs Vej 38 DK-8220 Brabrand		(+45)89435000	(+45)86251077	Vegetable oil Starch Sugar	Intermediates for detergents tensides Adhesives Lubricants Printing inks etc.	Industry