IENICA

Interactive European Network for Industrial Crops and their Applications

INFO*RRM*-IENICA is a project funded under the Fifth Framework Programme by DG XII of the European Commission

REPORT FROM THE STATE OF SWEDEN

Update Report

February 2004

Prepared by PhD Mikael Kjellin
YKI, Institute for Surface Chemistry
Box 5607, 114 86 Stockholm, Sweden
Sweden
mikael.kjellin@surfchem.kth.se

CONTENTS

ACKNOWLEDGEMENT

This work was funded under the IENICA workstream of the IENICA-INFO*RRM* project. IENICA is the Interactive European Network for Industrial Crops and Applications. The overall project is funded by the Fifth Framework Programme of the European Commission under the Quality of Life Programme. This project is a development of the FAIR Programme (FP4)-funded IENICA project.

METHODOLOGY

This report has been prepared by Dr. Mikael Kjellin, who has been the Swedish co-ordinator for the IENICA project since August 2002. The work started with a survey to all the Swedish contact persons listed on the IENICA website. The answers received have been included in the report. Sweden Statistics and the library at the Swedish University of Agricultural Sciences (SLU) have also aided in the work on finding out relevant statistics for Sweden. Interviews and communication with the persons below have been helpful when writing the report.

Literature and persons that have contributed to the report:

- Statistics Sweden (www.scb.se)
- Yearbook of Agricultural Statistics, Statistics Sweden. 2003: Örebro
- Press information from Karlshamns 2004-01-27, Rapeseed oil for biodiesel
- Larsson, M., Crop and Forest Biotechnology for the Future, in Kungl. Skogs- och Lantbruksakademiens Tidskrift. 2003
- Finell, M., The Use of Reed Canary-Grass (Phalaris arundinacea) as a Short Fibre Raw Material for the Pulp and Paper Industry, in Unit of Biomass Technology and Chemistry. 2003, Swedish
- University of Agricultural Sciences: Umeå
- FAOSTAT Agricultural Data, (http://apps.fao.org/page/collections)
- IFP-SICOMP wepage (www.ifpsicomp.se)
- Chemical and plastic industry in Sweden, Facts & Figures. 2003

- Christer Martinsson, Karlshamns AB
- Kenneth Alness, Svenska Lantmännen ek.för.
- Martin Svensson, Svenska Lantmännen ek.för.
- Michael Finell, Swedish University of Agricultural Sciences (SLU).
- Olle Wikström, Lyckeby Stärkelsen. 2003.
- Pål Börjesson, Lund University.
- Ulf Hansson, Karlshamns AB
- Susanne Andersson, VINNOVA

EXECUTIVE SUMMARY

This report is an update to the original report from 1998 about the non-food uses of crops in Sweden. Much research on the subject has been going on since then but the industrial implementation is slow, so many possible applications are still in the experimental stage. The reader is referred to the original report available at the IENICA website (www.ienica.net) for advantages and disadvantages about the non-food use of renewable materials from crops. Most of the issues described in the original report are still valid today.

The demand for environmentally friendly materials made from renewable resources is increasing and this has been recognised by Swedish industry and many funding agencies. For example, the Swedish Agency for Innovation Systems (VINNOVA) has a special programme/growth area related to green renewable materials. Most materials produced from renewable resources in Sweden are obtained from the forest industry, however products from other renewable sources are getting increased attention. The major sources for the production of renewable materials from agriculture for non-food applications are potatoes (starch), rapeseed (fuel, technical oils) and wheat (ethanol production, gluten).

The production of rapeseed oil has been constant at around 95,000 tonnes between 1998-2001, whereas the production of linseed and hemp oils has decreased in the last couple of years due to the removal of Government subsidies.

The production of crop fibres for industrial use is very low in Sweden although the potential for industrial use is large. It is mainly uses of flax (replacement for glass fibre in composites) and reed canary grass (paper) that have been considered. Growing of industrial hemp has been allowed since 2003 so this crop will probably receive increased attention in the future.

The main non-food application in Sweden for modified potato starch is for wet end-application in the paper industry (130,000 tonnes). Other industrial applications in the mining industry, the chemical industry and the adhesive industry consume 20,000–30,000 tonnes. Relatively small volumes are used for the production of biodegradable materials such as plastics. Much research is going on in Sweden about using carbohydrates as renewable materials. This includes using carbohydrate as a raw material for surfactant synthesis, as functionalised polymers and for packaging material.

Regarding protein crops, much research is into the use of gluten as an oxygen barrier for packaging. Gluten is obtained for example as a by-product from the production of ethanol for wheat. By using the gluten for a high value application the cost for ethanol production can be reduced. Research on using proteins for surfactant synthesis has recently been initiated.

INTRODUCTION

The demand for environmentally friendly materials made from renewable resources is increasing. Sweden has a good research base in biotechnology and materials technology and has therefore a good opportunity to satisfy this demand. The importance of this area is demonstrated by the fact that the Swedish Agency for Innovation Systems (VINNOVA), has a special programme/growth area related to Green renewable materials. In particular, VINNOVA gives 80 MSEK (8.8 million Euros) to special "Demonstrator" projects, which are about the utilisation of renewable materials for products.

It is likely that the need for an efficient agriculture will increase in the future. Genetically modified crops could lead to a faster development towards renewable resources. One obstacle to the growth of companies developing genetically modified crops is scepticism among the general public about the products. This scepticism is especially pronounced in Sweden.

OIL CROPS

The most important crops in Sweden within this sector are rape (winter, spring), turnip rape (winter, spring), and oil flax. The production and yield of these crops are given in Table 1.

Table 1. Hectares, tonnes and yield of the largest oil crops in Sweden 1998-2002

		1998	1999	2000	2001	2002
Winter rape	***Hectares***	23,159	19,626	24,870	19,900	31,219
	Tonnes ('000)	69.3	56.2	80.9	61.7	90.9
	Yield, kg/ha	2,990	2,860	3,250	3,100	2,910
Spring rape	***Hectares***	16,705	31,273	12,112	13,591	21,943
	Tonnes ('000)	32.5	63.8	23.1	26.9	46.3
	Yield, kg/ha	1,950	2,040	2,010	1,980	2,110
Winter turnip rape	***Hectares***	1,470	1,206	1,395	857	1,899
	Tonnes ('000)	2.4	2.3	2.4	1.2	3.3
	Yield, kg/ha	1,630	1,880	1,750	1,460	1,760
Spring turnip rape	***Hectares***	13,238	23,784	9,791	10,425	12,408
	Tonnes ('000)	19.3	39.8	15.1	16.2	18.7
	Yield, kg/ha	1,460	1,670	1,550	1,550	1,510
Oil flax (Linseed)	***Hectares***	15,056	34,172	10,660	4,437	3,191
	Tonnes ('000)	6.4	**32.5**	7.9	**3.3**	5.2
	Yield, kg/ha	420	950	770	780	1,700

Source: [1, 2]

The production of rapeseed oil was around 95,000 tonnes during 1998-2001 whereas the production of linseed oils decreased dramatically from 14,267 tonnes (1999) to 736 tonnes (2001). The reason for this was the removal of the governmental subsidies. The production of hemp seed oil is very low and has decreased from 309 tonnes (1998) to 123 tonnes (2001).

Industrial Applications

It is worth mentioning that 1.4 million tonnes of rapeseed oil were used for biodiesel applications in the EU during 2003. It is believed that half the EU rapeseed harvest (or the equivalent of 2.3 million tonnes of rapeseed oil) will be used for fuel applications in 2004 which is even more that the farmers in EU can provide for this particular application [3]. The demand for rapeseed oil will increase even further in the future to fulfil the EU-directive regarding the use of renewable fuels for transport purposes.

The annual consumption of mineral oils in the chemical industry is about 220 million tonnes whereas the consumption of oil based on renewable resources is less about 10 million tonnes. Advantages with vegetable oils are their biodegradability, non-irritability to skin and lungs, and the fact that there is no increase of the greenhouse effect using renewable resources. Products from the crops are crude oils, lecitins, fatty acids and glycerol. The vegetable oils are mainly used for lubrication purposes in chainsaw oil, cutting oils and hydraulic oils. Other important applications are in paints (linseed oil) and varnishes and for printing inks. The two major companies in Sweden dealing with technical products from vegetable oils are two subsidiaries to Karlshamn, Tefac AB and Binol AB. Tefac AB produces and markets fatty acids (48,000 tonnes) and glycerol (6,000 tonnes) while Binol AB produces technical oils and lubricants (in total 4,000 tonnes). The fatty acids are mainly used as a raw material in the chemical industry and glycerol has a broad range of application areas such as cosmetic, food products, explosives and paints. Hemp seed oil has a high content of essential fatty acids that can be used in food and cosmetic applications.

General issues in the oil crop sector

The price/performance ratio of vegetable oils could be improved by using genetically modified plants that produces higher yields of oil and/or higher degree of chemical functionalisation. Public opinion will greatly influence the development of genetically modified plants. Genetic engineering of oils crops is, for example, carried out at the Swedish University of Agricultural Sciences (SLU) in Svalöv and Uppsala. One project is about improving pest resistance in oilseed rape.

In the Centre for Surfactants based on Natural Products, SNAP (www.surfchem.kth.se/yki/snap/) located at The Royal Institute of Technology in Stockholm research has been carried out developing natural raw materials (sterols, fatty acids, sugar) for surfactant synthesis. One of the aims of the recently started Greenchem (www.greenchem.lu.se) project is about the enzymatic production of fatty epoxides from vegetable oil. These chemicals will then be used for surfactant synthesis, surface coatings and wax esters.

Research on lubrication of rapeseed oil and water-based lubrication is carried out at the Institute for Surface Chemistry (YKI). One of the aims is to replace mineral oil in hydraulics, greases and metalworking with more environmentally friendly water based systems based on renewable materials. A new project at SLU is aimed at studying multifunctional industrial hemp (hemp) for northern Sweden. Fibre, oil and protein quality of the hemp will be investigated.

It is likely that the growing environmental awareness in the EU will expand the market for renewable technical oils by 10–15% in the next five years. At the same time the market for traditional mineral oils will shrink. The most important potential for oilseed plants is believed to be the production of plastics [4].

FIBRE CROPS

The crop species that have received some attention in Sweden within this area are flax, hemp and reed canary grass (RCG). The production of fibres from crops is very low in Sweden (for example less than 500 ha of RCG are grown [5]) and there is no registration of any fibre production in Sweden for non-food use in the FAOSTAT Agricultural Database.[6]

Industrial Applications

There is major potential for plant fibres to be used in a lot of different industrial areas. They can be used in the pulp and paper industry, for building materials, furniture and flooring, but also in the automotive industry as fibres in composite materials in car details. For example, flax and hemp bast fibres can be used for non-wovens, tissues, absorption products, packaging materials and fibre-reinforced plastics and construction materials as a replacement for glass fibre. The advantages of flax and hemp in comparison with glass fibre are its light weight and the fact that the entire composite can be recycled (mainly as energy). The fibres from reed canary-grass can be used as a short fibre raw material for the pulp and paper industry[5] and the delayed harvesting method has been shown to be particularly useful for this application. Delayed harvested RCG is also used as a fuel raw material and this sector is rapidly expanding. There are most likely more possibilities for RCG as a raw material in products ranging from fibreboards to dissolving pulp, but more research is needed. Hemp and flax fibres can be used in biofibre composites in car details, as additives in high strength paper and for textiles, ropes, yarn, nets, isolation material, and fibreboards. Combinations of short flax fibre/polypropylene with good mechanical performance are now being used in applications such as automobile interior panelling [7].

General issues in the fibre crop sector

The market for bio composites is expected to grow in the future and research within this area is prioritised by EU and the Swedish funding agency VINNOVA. The growing of hemp has been allowed in Sweden since 2003 so the research about applications for this crop will increase. The possibilities of using RCG as a raw material for the pulp and paper industry have been studied at the Swedish University of Agricultural Sciences (SLU) [5]. A new project at SLU is aimed at studying multifunctional industrial hemp (Finola) for northern Sweden. The hemp will be grown for both seed and fibre production. Biofibre.net (www.biofibre.net) is a Nordic network and a centre of knowledge within the bio-fibre field. The network is a forum for industry and academy, where people may exchange ideas about product development and find partners for research, product development and business activities. The research activities at IFP-SICOMP in the field of fibres and polymers from renewable resources are concentrated on the industrial use of modified flax fibres as a replacement for glass fibre.

CARBOHYDRATE CROPS

The crops grown in Sweden for their high content of carbohydrates/starches are potato, sugar beet, barley and wheat. The production of these crops are given in Table 2.

Table 2. Hectares, tonnes and yield of the largest carbohydrate/starch crops in Sweden 1998-2002

		1998	1999	2000	2001	2002
Potato for food	***Hectares***	25,133	24,422	23,610	23,776	23,142
	Tonnes ('000)	792.5	675.2	654.4	621.9	612.5
	Yield, kg/ha	34,720	28,820	26,720	26,160	26,470
Potato for starch	***Hectares***	8,567	8,391	9,293	8,460	8,589
	Tonnes ('000)	406.4	315.6	325.7	303.1	301.1
	Yield, kg/ha	47,440	37,620	38,700	35,820	35,050
Sugar beet	***Hectares***	58,737	59,881	55,484	54,834	54,820
	Tonnes ('000)	2,570.8	2,752.6	2,602.2	2,659.4	2,800
	Yield, kg/ha	43,768	45,967.1	46,900	48,499.1	50,992.5
Barley	***Hectares***	444,960	481,987	411,224	397,499	416,842
	Tonnes ('000)	1,686.9	1,852.5	1,634.4	1,642.1	1,777.9
	Yield, kg/ha	3,791.1	3,843.5	3,974.5	4,131.1	4,265.2
Wheat	***Hectares***	398,045	275,418	401,565	399,165	339,599
	Tonnes ('000)	2,248.7	1,658.9	2,399.9	2,344.8	2,112.6
	Yield, kg/ha	5,649.4	6,023.2	5,976.4	5,874.3	6,220.9

Source: [1, 2]

The major part of starch is produced by Lyckeby Stärkelsen Industrial Starches and AB Stadex [8]. A variety of starch derivatives are manufactured by National Starch & Chemical AB. The production of native potato starch in Sweden is approximately 63,000 tonnes and of wheat starch 10,000 tonnes. The wheat starch is mainly for food applications whereas 50,000 tonnes of modified potato starch is produced for industrial use [personal communication with Olle Wikström, Lyckeby Stärkelsen].

Industrial Applications of carbohydrate crops

There is a wide range of uses for carbohydrates. They can for example be used for surfactant and polymer synthesis, packaging materials and coatings. Starch is mainly used in Sweden as cationic starches for wet end application in the paper industry. The starch improves the paper strength and retention. It is also used in surface application for surface sizing and coating to improve surface strength and printability. In addition starch is used as an adhesive in corrugated boards, for sizing glass fibre fabrics and in gypsum and concrete to control the water retention and the flow properties.

The paper and paper processing industry in Sweden uses in total approximately 130,000 tonnes of modified starch for wet-end, surface and corrugating applications. Other industrial applications in the mining industry, the chemical industry and the adhesive industry consumes 20,000–30,000 tonnes. [personal communication with Olle Wikström, Lyckeby Stärkelsen]. Relatively small volumes are used for the production of biodegradable materials. The mechanical properties of starch bioplastics are very good; they are waterproof, of high quality, colourless and transparent.

General issues in the carbohydrate crop sector

In the Centre for Surfactants based on Natural Products (SNAP) research has been carried out characterising sugar-based surfactants with special properties. The enzymatic production of these surfactants has been investigated in SNAP and continued research will be performed in the new Greenchem project mentioned earlier. Starch derived polymers have been studied at the Centre for Amphiphilic Polymers from Renewable Resources (CAP, www.amphipol.lth.se). Modifications and use of starch has also been studied within the programme PROFYT (New Products from Renewable Raw Materials) and at Biopolymer Technology, Chalmers University of Technology. One of the projects at Chalmers is about using xylane as oxygen barrier for packaging.

Plant Science Sweden AB develops genetically modified potatoes with an increased level of amylopectine and resistance to antibiotics.

PROTEIN CROPS

The most interesting protein for non-food use is wheat gluten. By utilising the gluten for high value products the cost for producing for example ethanol from wheat will decrease. Gluten can be processed into plastics with useful properties. Research on using wheat gluten as a packaging material is conducted at the department of Fibre and Polymer Technology at KTH. The gluten has very good gas barrier characteristics and the wheat gluten is relatively hydrophobic which means that it is less sensitive to moisture than other proteins.

The Swedish Research Institute STFI-Packforsk is funding a project at KTH about renewable packaging materials from nature. The materials studied in the project are cellulose, wheat gluten protein, chitosan, and whey protein.

The enzymatic production of surfactants having amino acids as hydrophilic group will be investigated in the new project Greenchem (see earlier).