

IENICA

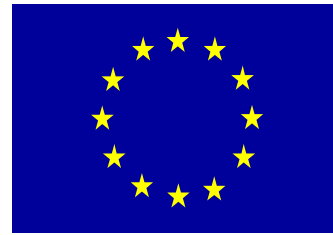
Interactive European Network for Industrial Crops and their Applications

REPORT FROM THE STATE OF

THE NETHERLANDS

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PREFACE

IENICA (the Interactive European Network for Industrial Crops and their Application) primarily aims to create synergy within the EU industrial crops industry by developing an integrated network, and by using this network to identify and create scientific, industrial and market opportunities for specific crops or applications. It also tries to identify the strengths of each EU member state in order to maximize the efficiency of RTD funding for industrial crops and to enhance collaboration among member states in these areas.

One way to realize these primary objectives is to determine the current state of scientific industrial and commercial knowledge of industrial crops or their applications at member state level.

This report on the state-of-the-art and on the opportunities for development of non-food industrial crops and their products in the Netherlands has been compiled as one of country reports to serve this specific goal.

The report first provides an overview of the research programs on crops which have been tested for their potential as oil crops, fibre crops, carbohydrate crops, and other crops in the Netherlands. It then estimates the amounts and qualities of the products that can be obtained from these non- food crops. It then discusses the technologies used in primary production and in the processing industry to produce and utilize these products. Finally, it considers opportunities, chances, threats and barriers for the successful

introduction of new non- food crops and their industrial products and it analyses production systems, markets, technologies and potential comparative advantages of the Netherlands for the production and processing of these products. In a number of annexes specific and detailed information on the current status of production and use of non-food agricultural products is provided in support of the statements made in the report itself.

To compile this report we have used many different sources, both official and informal ones. We want to thank all the contributors who have made this report possible.

The authors

SUMMARY AND CONCLUSIONS

At present, Dutch arable farming is mainly focussed on growing crops like sugar beet and potato, both for food and non-food use. In the Netherlands, the costs of arable production are high; among the highest in the EU. Meanwhile, prices for the main agricultural commodities decrease continuously due to (inter-)national policies related to WTO and the extension of the EU. For the individual farmer, these developments lead to a decrease in the nett added values of his products, and thus to a lower income. A possible solution to this problem is to lower the costs per unit land by making production more extensive. However, given the extreme high pressure on land-use in the Netherlands, this option is not realistic. A scenario that is more plausible for the average Dutch farmer is one in which the added value of the primary products is increased by specific quality characteristics tailored to specific end-uses. In this scenario, also opportunities for non-food crops exist. However, to make this scenario viable, integrative and multi-disciplinary research, extension, education and processing should be supported.

The non-food industry in the Netherlands, is important in terms of financial turnover, but it uses a very limited number of industrial non-food crops as raw material only.

The main oil crops cultivated for use in the non-food industry are rape seed and flax. Although Dutch vegetable oil production is negligible, an important processing industry exists, generating a food and non-food production value of near Dfl 5,200 million (€ 2,342 million).

Arable crops that are cultivated for fibre are hemp and flax. The former has much higher yield potentials than the latter, but its production and quality is seriously hindered by legislative aspects. For natural fibre three main potential markets exist: paper, textile and materials for construction, either for buildings or automotive purposes. As a whole, the natural fibre industry in the Netherlands is insignificant.

The main carbohydrate crops for industrially applied raw material are starch potato and sugar beet. To some extent, also chicory can be considered as important for the Dutch industrial carbohydrate market. The main consumer of non-food starch-related products within the EU is the paper and carton industry, while other industrial uses of starch are: textiles, metallurgy, mining and construction. Sugar as industrial product is mainly used in the fermentation industry and the alcohol industry.

Other industrial crops of some importance in the Netherlands are: caraway, dill, herbs (for the food and non-food markets), and some grasses.

An overview of the relative production of primary metabolites of some arable species grown in the Netherlands is used to calculate actual average productions of given plant parts. Also their primary metabolites per unit land and the maximum attainable productions per ha are assessed. Most progress in terms of production can be made with hemp for which stem yield can be increased by 150%. Actual production levels of this crop are far below their potential, which most likely can be explained by the lack of recent research on this crop. It may be expected that similar progress in production can be made with minor crops for which only a limited research experience exists.

Main barriers to application of non-food agricultural primary products are the following: i) a lack of knowledge in several areas (tissue-culture, GMO's, plant metabolisms, production systems tailored to the specific given environment), ii) a heavily subsidised European agriculture provoking artificial competition between crops, iii) a shortage of intermediate industry transforming primary products into basic material for industry, and iv) a limited amount of incentives for industry to invest in alternative (non-petrochemical) product development. Based on these conclusions recommendations are formulated to promote the non food industrial use of agricultural raw material. These recommendations are subsequently elaborated for each of the main groups of industrial crops (oil, fibre, carbohydrates and others, respectively).

For the Netherlands, it is concluded that the comparative advantage for non-food production lays in the historically grown cooperation between primary production, industry and retail trade. By combining the available competence in the latter three sectors of the agricultural industry, a strong international market position can be acquired. Potential markets can be explored by offering end-products that are distinct from those of other producers and by ensuring a competitive production of raw material. Hence, a market approach based on offering tailor-made products of high performance, seems most suitable for the Netherlands.

1 IMPACT OF (INTER-)NATIONAL POLICY ON NATIONAL DEVELOPMENTS IN PRODUCTION AND USE OF NON-FOOD INDUSTRIAL CROPS

The question whether cultivation of industrial crops for non-food purposes may partly offer a viable alternative to the cultivation of food crops to the Dutch farmers, is difficult to answer. On the one hand, market factors such as product-prices, quality of products, alternative products and consumer preferences need to be considered, on the other hand, prices of production factors and the contribution of a given crop to farmer income play a role. Moreover, crop production can be free of or subjected to price-regulation or quotation. Therefore, market positions of given crops may partially not reflect the real demand for that crop. In some cases, the development of alternative crops is even hampered because of the artificial increase in competition created by such price-support mechanisms. Despite the complexity of the question whether industrial crops may experience a change in the Netherlands, the following overview aims to present some elements of the actual situation of Dutch arable production from which some conclusions can be drawn to answer that question.

At present, industrial food crops like sugar beet and potato are the main arable crops around which the Dutch arable production is centred. An important part of that production is exported, either in a processed or in its primary form. In the Netherlands, the area cropped to potato represents about 12 % of the total European potato area (Eurostat, 1996). To be able to produce these root and tuber crops, minor crops like grain crops have to be present in the crop rotation, even if these crops contribute little to farmer's income. In some years, grain crops

even show negative balance figures because of low prices and high (fixed) costs, mainly for land.

The increasing amount of national and EU-regulations aiming to reduce the environmentally negative consequences of arable production results in a significant increase in production costs, despite partial compensation in the form of subventions. Already, the arable production costs in the Netherlands are among the highest in the EU because of the intensive nature of that production in terms of use of seed, bio-chemicals, machines and labour (Smit, 1992). At the income site, the tendency is towards decreasing prices for the main agricultural commodities. According to Agenda 2000, the EU envisages to reduce guarantee-prices of dairy products, arable products and beef with, respectively, 15, 20 and 30 percent over the next decade, and new WTO-negotiations and the extension of the EU with some E-European countries will put an increasing pressure on the agricultural markets. Because of these developments, it may be foreseen that a further increase of production costs will either result in lower net added values, or will lead to more extensified production. Lower net added values is the result of the higher production costs that are not compensated by comparable increases in the productivity per unit area. Direct, general and depreciation costs can be lowered by making primary production more extensive. This latter option seems not realistic for the Netherlands, because farmer's income is also determined by factor-costs like those of land which tend to increase continuously because of the ever-increasing pressure on land-use in the Netherlands.

The difficulty to make Dutch arable production more extensive is well illustrated by some statistics. The average size of a Dutch arable farm is 34 ha. Farmers consider that size too

small to remain competitive within the European market and they indicate a size between 85 and 100 ha as being viable. From a survey among 250 farmers (Boerderij, 1998), it was concluded that 45% of the farmers would like to expand their arable land. The increasing percentage of farmers that stop their arable activities (an envisaged 2,450 out of 14,666 farms (16.7 %) in the next five years) and those who decide to continue their arable production activities in foreign countries (590 farms (4.0 %) over the next five years), do release 103,000 ha. However, this only represents about 8.9 ha extra land-availability per farm for the remaining 11,626 farms.

From the same survey (Boerderij, 1998) it was concluded that 68% of the farmers thought about diversifying their professional activities. The remaining 32%, mostly young farmers, preferred to specialise in the more traditional arable crops. Surprisingly, and despite the intensive stimulating national policy to make agriculture more biological, about 85% of the arable farmers was not interested in shifting towards biological production. This may be related to the high costs involved in a shift from a traditional to a biological production system and the significant efforts required to make such a change successfully.

Initiatives to control the quality of production or products are, or have been, undertaken in the Netherlands; government-induced national ones such as MINAS (monitoring and control of nutrient-use), as well as private ones, usually local initiatives from farmers or farmer organisations. Some examples are: i) a green label (“keurmerk”), mainly meant to monitor the use of agro-chemicals on a given product, ii) a quality registration system (“kwaliteitszorgsysteem”) with or without certification, to produce a complete data-set on all aspects of primary production per farm or field (a system especially stimulated by the

processing industry), and iii) the HACCP-system (Hazard Analysis of Critical Control Points), in which food-quality is checked by registration and control of hygienic measures during the production-process. The most common green labels in the Netherlands are the 'Agro Milieu Keurmerk', that controls the use of agro-chemicals, the 'TNO-keurmerk' that does the same for potatoes but also involves control in the processing, packaging and retail industries, and the 'Eco-keurmerk' that guarantees an ecological production without use of artificial fertilisers or chemical plant protecting agents.

An other option open for farmers is a critical evaluation of their methods to produce, store and market their products. From such evaluations it may appear that other farming systems have to be introduced involving 'new' crops and crops generating higher added values. To be viable, such initiatives need to be supported by research, extension and education because new multi-disciplinary insights on the whole chain from crop production to end-product need to become available for farmers. In the Dutch situation, highest comparative advantage of research, extension and education is realised when concentrating on special high-value production instead of production of bulk. Furthermore, to give the 'new' primary products a change, an EU and national policy is required that stimulate industry to process these products for end-use. These recommendations for research, extension, education and policy are in line with the Gmunder Deklaration of Oktober 1998 and with the objectives of Agenda-2000.

2 OPPORTUNITIES FOR NON-FOOD INDUSTRIAL CROPS AND THEIR PRODUCTS

2.1 *Primary production*

2.1.i Crop species

Nowadays, in the Netherlands a very limited number of industrial non-food crops are being cultivated on a commercial basis. However, during the last decade research has been carried out on a number of potential non-food crops of which knowledge has been developed and of which the genetic material has been preserved. Therefore, it may be useful to provide in this chapter a broad overview of the research efforts that have been undertaken in the field of crop production for industrial purposes and to give a short description of those crops that are commercialised.

Research efforts

In 1986 and 1987, the upcoming saturation of the agricultural market and the simultaneous decrease in prices for primary products, lead to a research program ('MCB') in which the potentials of alternative arable crops for industry were studied (de Meijer *et al.*, 1989). In this program entries of about 90 crops were collected. Of those, 32 were sown for initial testing and seed production (Table 1).

Following the 'MCB's-research program, some other research projects on industrial crops were initiated. In the Dutch National Oil Program (NOP) from 1990 to 1994 and the Dutch

Table 1 Crop species and their characteristics as evaluated in national research during 1986-1987

Species	Special plant-products	Possible application	Evaluation (1986-1987)
<i>Cardamine impatiens</i>	hydroxy-fatty acids	polyethylene, lubricants, rubber	stunted growth, bi-annual,
<i>Dimorphotheca pluvialis*</i>	hydroxy-fatty acids	coatings, paints, varnish, plastic, lubricants, polymers and surfactants	lodging, seed-shed, variable seed-set, low oil-conter reasonable seed production, no pests and diseases
<i>Dimorphotheca sinuata</i>	hydroxy-fatty acids	coatings, paints, varnish, plastic, lubricants, polymers and surfactants	lodging, seed-shed, variable seed-set, low oil-conter reasonable seed production, no pests and diseases
<i>Crepis alpina</i>	crepenine-acid	coatings, resins and lubricants	low oil-content
<i>Crepis rubra</i>	crepenine-acid	coatings, resins and lubricants	very low oil-content
<i>Crepis foetida</i>	crepenine-acid	coatings, resins and lubricants	hardly any yield
<i>Crepis biennis</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	only few of the entries produced seed
<i>Crepis vesicaria</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	seed shed, variable seed-set, low seed-yield
<i>Crepis capillaris</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	seed shed, variable seed-set, low seed-yield
<i>Crepis sibirica</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	no germination
<i>Crepis auria</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	no germination
<i>Stokesia laevis</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	no germination of seed
<i>Vernonia spp.</i>	vernol-acid	polymers, membranes, paints, lacquer, embedding electrical parts	no flower initiation, stunted growth
<i>Borago officinalis</i>	γ -linolenic-acid (GLeA)	pharmaceuticals, food-additives, health-care	high seed shed, high GleA-content seed, high in proteins
<i>Boraginaceae</i>	γ -linolenic-acid (GLeA)	pharmaceuticals, food-additives, health-care	seed shed
<i>Oenothera spp.</i>	γ -linolenic-acid (GLeA)	pharmaceuticals, food-additives, health-care	seed shed
<i>Oenothera biennis</i>	γ -linolenic-acid (GLeA)	pharmaceuticals, food-additives, health-care	high yield potential, high linolenic acid content
<i>Oenothera lamarckiana</i>	γ -linolenic-acid (GLeA)	pharmaceuticals, food-additives, health-care	high yield potential, high linolenic acid content
<i>Limnanthes spp.</i>	unique and long fatty-acids	lubricants, detergents, cosmetics, softeners	seed shed
<i>Limnanthes alba</i> *	unique and long fatty-acids	lubricants, detergents, cosmetics, softeners	high potential yield, irregular flowering and seed set, seed shed
<i>Limnanthes douglasii</i>	unique and long fatty-acids	lubricants, detergents, cosmetics, softeners	high potential yield, irregular flowering and seed set, seed shed

Table 1 (continued) Crop species and their characteristics as evaluated in national research during 1986-1987

Species	Special plant-products	Possible application	Evaluation (1986-1987)
<i>Cuphea spp.</i>	short to medium size fatty-acids (C6 to C14)	detergents, soaps, plasticizers, lubricants	irregular flowering, seed shed, difficult yield process
<i>Malva spp.</i>	short to medium size fatty-acids (C6 to C14)	detergents, soaps, plasticizers, lubricants	low oil-content, general oil-content
<i>Arabis hirsuta</i>	long fatty-acids (C16 to C18)	food-oils, paints	bi-annual
<i>Camelina sativa</i>	long fatty-acids (C16 to C18)	food-oils, paints	large spectrum of fatty acids, high seed yield
<i>Cucurbita foetidissima</i>	long fatty-acids (C16 to C18)	food-oils, paints	germination and establishment problems, no flower initiation
<i>Euphorbia lathyris</i>	long fatty-acids (C16 to C18)	food-oils, paints	bi-annual, high oil content seed, late-maturing
<i>Helianthus annuus</i> *	long fatty-acids (C16 to C18)	food-oils, paints	sensitive to <i>Botrytis</i> and <i>Sclerotinia</i>
<i>Hesperis matronalis</i>	long fatty-acids (C16 to C18)	food-oils, paints	bi-annual
<i>Lallemantia iberica</i>	long fatty-acids (C16 to C18)	food-oils, paints	low oil-yields
<i>Althaea spp.</i>	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	stunted growth, lodging and irregular maturation
<i>Brassica carinata</i>	extremely long fatty-acids (C20 to C24); e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	reasonable yield eruca-acid
<i>Conringia orientalis</i>	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	host for beet-cyste nematode, low seed content eruca-acid
<i>Crambe abyssinica</i> *	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	host for beet-cyste nematode, reasonable yield of eruca-acid
<i>Eruca sativa</i>	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	yield stable (self-pollination), reasonable eruca-acid yield
<i>Lunaria annua</i>	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	bi-annual but some entries are annual

Table 1 (continued) Crop species and their characteristics as evaluated in national research during 1986-1987

Species	Special plant-products	Possible application	Evaluation (1986-1987)
<i>Thlaspi arvense</i>	extremely long fatty-acids (C20 to C24; e.g. eruca-acid)	polymers, lubricants, synthetic rubber, wax	low eruca-acid content seed, seed shed
<i>Amaranthus spp.</i>	proteins/carbohydrates/oil	health food, starch	no industrial demand, low yields bird damage at maturity, host for beet-cyst nematode
<i>Chenopodium quinoa</i> *	proteins/carbohydrates/oil	shampoos, chocolate	
<i>Cichorium intybus</i>	inulin	sweetener, polymers, epoxides, resins	good growth, adapted to heavy soils
<i>Helianthus tuberosus</i> *	inulin	sweetener, polymers, epoxides, resins	large gene pool available, adapted to light soils
<i>Cannabis sativa</i> *	fibres, wood, oil	paper, cellulose, textile, composites, pharmacy, etc.	needs some adaptation to Dutch circumstances (flowering time)
<i>Mentha pulegium</i>	etheric oil (pulegon)	pharmacy, aromatics and flavouring compounds	creeping growth, difficult to harvest leaves
<i>Mentha spicata</i>	etheric oil (carvon)	sprouting inhibitor	

Species of which the names are printed in bold were further evaluated in research-programs from 1988-1990 (derived from Meijer *et al.*,1989). Species of which the names are printed in bold and are marked with a * were considered in research-programs from 1988-1994.

participation in the EU-program ECLAIR-VOICI (1991-1995), several oil crops and production-chains for vegetal oil based industrial production were analysed (Table 2). Within these projects, five typical vegetal oils were considered (NOP, 1995): 1) those with long fatty acid chains, 2) those with conjugated bonds, 3) those with conjugated bonds and containing hydroxy-groups, 4) those without conjugated bonds but with hydroxy-groups, and 5) those with an epoxy-configuration. Oils with other characteristics like i) 18:1 isomers, ii) cyclopropene-type oils, iii) with a special type of unsaturation and iv) galactolipids, were put on a waiting list. Not all existing plants containing the first five types of oil could be considered in the research and the choice of 22 species depended partly on the availability of seed. A full inventory was made of the genetic variation in *crambe*, *euphorbia*, *dimorphotheca* and *calendula*, while from *lesquerella* and *lunaria* an inventory was started.

In a national programme on *Carum carvi* (caraway) from 1990 to 1994, it was examined how a high and stable production of the etheric oil of caraway could be realised and applications for this oil were searched for. The programme had three main themes (Meijer & Oosterhaven, 1994): 1) to stabilise the production of seed and carvon, meanwhile increasing the concentrations of carvon in the seed, 2) to unravel the mechanisms of the biological activity of carvon as inhibitor of the germination of potatoes and as a fungicide, and 3) to synthesise from carvon a variation of useful compounds for the pharmaceutical and food/beverage-industries and to convert carvon and limonene into useful compounds by microbial conversion.

In a Dutch programme on fibre hemp (1990-1994), hemp has been evaluated for its agronomic potentials and as a potential raw material for the paper industry. Within this

Table 2 Crop species and their characteristics as evaluated in national research during 1990-1995

Species	Special plant-products	Possible non-food application	Current state (1998)
<i>Calendula officinalis</i> L.	conjugated triens	coatings, cosmetica	pilot-project
<i>Cannabis sativa</i> L.	fibres, wood, oil	paper, cellulose, textile, composites, etc.	commercially applied
<i>Carum carvi</i> L.	carvon	sprout-inhibitor, fragrances and flavouring	commercially applied
<i>Chenopodium quinoa</i> Wild.	proteins/carbohydrates /oil	shampoos, chocolate, animal-feed	commercial application stopped
<i>Coriandrum sativum</i> L.	petrosilic acid	oleochemistry	more research needed
<i>Crambe abyssinica</i> Hochst. ex Fries	long chains	oleochemistry	pilot-project stopped
<i>Dimorphotheca pluvialis</i> (L.) Mnch.	hydroxy fatty acids	coatings, paints, varnish, plastic, lubricants, polymers and surfactants	more research needed
<i>Euphorbia lagascae</i> Sprengel	epoxy fatty acids	coatings, polymers	more research needed
<i>Helianthus annuus</i> L.		spice-oil	more research needed
<i>Helianthus tuberosus</i> L.	inulin	sweetener, polymers, epoxides, resins	commercially applied
<i>Lesquerella</i> spp. (<i>L. grandiflora</i> and <i>L. densipila</i>)	lesquerol acid, densipol acid	fragrances and flavouring, coatings, lubricants	more research needed
<i>Limnanthes alba</i> Benth.	unique and long fatty acids	lubricants, detergents, cosmetics, softeners	more research needed
<i>Linum usitatissimum</i> L.	fibre, wood, oil	paper, cellulose, textile, composites, etc.	commercially applied
<i>Lunaria annua</i> L.	long chains	oleochemistry	more research needed
<i>Osteospermum</i> spp.	conjugated oils	paints, varnish, polymers, lubricants	more research needed

Species of which the names are printed in bold are currently (1998) grown on a commercial scale.

project a business concept was developed for a commercially viable production-chain involving hemp cultivation, pulping, and paper production. A following EU-concerted action (Hemp for Europe) is currently in its final stage (1996-1999), in which also other applications of hemp like fibre boards, composites, geo-textiles, *etc.*, are considered.

This overview of research on industrial crops for non-food applications can not be complete because of the simple fact that much research is of a confidential nature. Other projects involve research on end-products without considering primary production. Examples of those two types of research-projects are programs on: i) multiple end-use of grass-species (fibre, proteins, sugars), ii) application of natural resins in water-based paintings, iii) production of crude oil out of biomass using the HTUR-process, iv) the application of natural pigments and dyes for technical applications, v) the application of natural fibres in composites, vi) the development of cellulose-technology and cellulose-based products, and vii) products and energy out of arable crops. Some smaller projects involving small and medium size enterprises (SME's) and farmer's organisations mostly escape from attention because of the small scale or disappointing results. Examples of such initiatives are cultivation of *Rubia tinctorum* and of *Miscanthus sinensis* in the North of the Netherlands for dye-purposes and fibre-boards, respectively, and the cultivation of *Cannabis sativa* for textile in Overijssel (E-Netherlands).

Oil crops

Despite all the research-efforts on non-food oil crops just described, at present none of the crops that were investigated are commercially cultivated in the Netherlands. The

production of *Crambe* has ceased completely and *Calendula* is actually only cultivated in the European pilot-project CARMINA in which the company Cebeco participates. Although the results in the NOP-project showed some promising perspectives for *Lesquerella*, this crop was never taken into commercial production. Some companies process products from some small oil crops like *Oenothera spp.* for food and non-food purposes. However, these activities are difficult to quantify, firstly because production is for niche-markets and secondly, because the companies involved are reluctant to give information. Nowadays, the main crops of which the oil is partly applied in the non-food industry are *Brassica napus* and *Linum usitatissimum*.

Brassica napus or oilseed rape is cultivated on 880 ha (1998), mainly in the North of the Netherlands. *Brassica napus* is related to *Brassica campestris* but the latter is not cultivated in the Netherlands. Oilseed rape provides two main products: the oil from the seeds and the meal remaining after crushing the seeds. Most of the oil is sold to the food-industry but some is used as a lubricant and as biodiesel fuel. On the Dutch oilseed rape market severe competition exists with the East-European countries. This, the high production costs in the Netherlands and the future eastward enlargement of the EU, make that the perspectives of the Dutch oilseed rape production are far from promising, unless other markets can be developed. Oil-seed meal is used as a high protein feed supplement for livestock and poultry. Existing cultivars can be divided into traditional ones having high levels of glucosinolates and erucic acid, cultivars high in glucosinolates and low in erucic acid (0-types), and those low in glucosinolates and low in erucic acid (00-types). Oilseed use for industrial purposes mostly require that the oil contains high levels of erucic-acid, while for human

consumption low erucic-acid oil is needed. Production of oilseed for industrial purposes may be conflicting with the cultivation for human consumption because of crossing-over between cultivars. Regarding the cultivation aspects of oilseed rape an important aspect for the Netherlands is the limitation that this crop can not be grown in rotation with beets because oilseed rape is a host for beet cyst nematodes. Furthermore, the crop is sensitive to many pests and diseases. The necessity to use crop protecting agents makes this crop rather environmentally unfriendly (Biewinga & van der Bijl, 1996).

Oil from *Linum usitatissimum* or flax is hardly a reason why flax is cultivated in the Netherlands, as the seed is mainly exported as sowing-seed. The main product from flax is the fibre that is used in textile and more and more in composites. For this reason flax is discussed under the heading 'Fibre crops'.

As stated previously, *Calendula officinalis* is only grown in a pilot project of Cebeco Handelsraad, in co-operation with DSM Resins and other European research organisations (Green-Tech Newsletter, 1998). *Calendula* is widely known for its pharmaceutical use and application in personal care products. Seed oil of this plant can be used in resins and paint formulations due to its unsaturated character of the fatty acids. Main component of the oil is calendic acid, which acts as a strong drying compound in alkyd resins. In this project the development of the agrologistic part starting with seed material towards the production of seed oil is investigated. Emphasis is on agronomical and oil recovery aspects. On the agronomical side, efforts are aimed at improving seed yield and oil content which currently are 3,000 to 4,000 kg/ha and 600 kg/ha, respectively (Verheul & Struik, 1994). On the oil recovery side,

efforts are aimed at maximum oil recovery with preservation of the reactivity of the oil.

Fibre crops

Currently, two arable crops are cultivated for fibre in the Netherlands. *Cannabis sativa* or hemp and *Linum usitatissimum* or flax. The companies involved in the processing of the raw material are Hempflax and Van der Bilt, respectively. Although there is a huge potential for grass as a source of short fibre, hardly any attention is given to that aspect. On a very limited scale (less than 20 ha) there is some cultivation of *Miscanthus sinensis* for fibre plates in the province of Drente.

Cannabis sativa or hemp is commercially grown on about 1000 ha (1998) in the North of the Netherlands. The single company present, provides seed and equipment to farmers. Main product is animal bedding from the wooden core of the hemp. Recently, fibre is sold to the automotive industry in Germany. The cultivation of hemp is straightforward and may totally be carried out by contractors. Advantages of hemp are that the crop fits well in the rotation, that it may have a better return than wheat, that few agro-chemicals are needed and that the crop is able to suppress weeds. Disadvantages are mainly related to its image as drug-plant. Some of the EU-legislation that have been developed to prevent drug-abuse of hemp (*e.g.* the '50%-seed maturity rule') seriously hamper optimal production in the Netherlands and moreover, reduce quality. In this way input-use efficiencies can not be optimised. In 1998, prices of whole stems were f 170,- (€ 76) per ton dry matter, and EU-support in that year was f 1456,- (€ 653) per ha (see Annex 5.2).

Of *Linum usitatissimum* 3500 ha was cultivated in the South of the Netherlands in 1998. Like for hemp, the processing is mainly performed off-farm in special processing units. In many aspects the flax-industry is comparable to that of hemp, although fibres from flax are softer and more appreciated for making textile. However, considerable scope exists to improve the fineness and quality of hemp fibre by adapting actual cultivation techniques. With a highest realised experimental yield of total above ground material of 11,500 kg/ha (PAGV, 1992) flax has a much lower yield potential than hemp that can realise an above ground dry mass production of above 20,000 kg/ha (Stutterheim & Struik, 1997). For both crops, crop establishing may be problematic because of sub-optimal soil structure and cold temperatures. In 1998, prices of long flax fibre were f 2,500.- (€ 1,121) per ton, of short fibre f 200.- (€ 90) per ton, and for undamaged seed f 1,850.- (€ 830) per ton. The support in terms of subventions that year were f 1,791.- (€ 803) per ha (see Annex 5.2).

Carbohydrate crops

In the Netherlands, the main carbohydrate crop for industrially applied raw material is starch potato. The multi-national company Avebe plays a dominant role in the production, application and marketing of potato-starch and its derivatives. This company also markets starch derivatives from tapioca, wheat and maize. Main markets are food, paper-industry, textile, oil and gas mining, adhesives, animal feed, pharmaceutical industry, construction and drinking water production. Other major players in the Dutch carbohydrate-market are Cosun (ingredients for food) and CSM-sugars, both using sugar beet as the main base material. Although the latter two companies mainly operate on the food-market, they also created daughter companies and joint ventures operating on the markets for non-food. Examples are the daughter

companies of Cosun, Nedalco (alcohol) and Sensus (chicory-processing), and a joint venture between Cosun, CSM Sugar and Nedalco named OBL (bio-ethanol from agricultural raw materials). Hence, three crops may be indicated as significant for the Dutch industrial sugar market: *Solanum tuberosum* or potato, *Beta vulgaris* or sugar beet, and *Cichorium intybus* or chicory. It is not known how much starch is derived from Dutch grown *Triticum aestivum* (wheat) and *Zea mays* (maize).

Solanum tuberosum for starch potato production is cultivated on 62,900 ha (1996) representing about 7.8% of the total arable area in the Netherlands. The average production is between 43,000 and 46,000 kg/ha. In 1998, prices paid per kg potato were f 110.- (€ 50) per ton. Total production of starch in the Netherlands generally meets the basic allocated quota, which was 484,000 tons starch for 1998. To meet the demand of the processing-industry, farmers can decide to grow potato cultivars of different growth duration, but usually late maturing cultivars are grown. In that case, storage facilities on-farm must be used. This is mostly the case when harvest falls after half October. Some cultivars of starch potatoes contain high levels of glycoalkaloids, mostly α -solanine and α -chaconine. These components are structurally similar glycosides of the same steroidal alkaloid solanidine (Friedman & Dao, 1992). This is not a problem for starch-processing but in case these cultivars are used as seed-potatoes to produce consumption potatoes in the following year, it certainly forms a health risk for humans.

Beta vulgaris is produced on 116,600 ha (1996) covering 14.4 % of the total arable area in the Netherlands. Average production is between 50,000 and 75,000 kg/ha depending on the region of cultivation. In 1998, prices paid were f 126.- (€ 57) per ton

for beets containing 16% sugar categorised as A or B-sugar. If farmers exceeded their individual quota prices of 37.- (€ 17) per ton were paid, for so called C-beets. In fact, price systems for sugar beets are more complicated than this, but a full explanation falls outside the scope of this report. For the farmer it is important to produce enough to meet his quota. Furthermore, some quality aspects such as sugar content, tare weight, and extractability determine the price (Hooijman, 1994). Furthermore, some compensation is given for storage on-farm and early or late delivery. Some management techniques to realise optimum quality are: choosing the right cultivar for the given environment (mainly soil type), optimal seed bed preparation, sowing in time to take maximum advantage of the growing season, using the right density to realise a quick canopy closure and uniform stand, and to adapt nitrogen-management to avoid excessive above ground growth and reduced sugar content and extractability.

Cichorium intybus is cultivated on 4,250 ha (1998) mainly in the South of the Netherlands. The single processor (Sensus) is situated in Roosendaal and also buys part of the chicory in Belgium (350 ha). Average production is between 35,000 and 50,000 kg per ha. Profit per ha depend mainly on dry matter production and inulin content of the roots, but like in sugar beet corrections are made for tare and extractability. Guideline prices in 1998 were f 121,- (€ 55) per ton with a bonus/malus system for inulin-contents deviating from 16% (1998). In the near future, it may be possible that farmers will be rewarded for long inulin chain lengths in their beets, because, to be able to produce high-value inulin chain-lengths above 9 monomers are required. In fact, what is called inulin is a collection of D-fructose-polymers with D-glucose as end-group. In each chain the number of fructose-molecules can range from 2 to 30. The average chain length is determined by the ratio between fructose and

glucose and is thus depending on cultivar, development stage of the plant and the growing conditions.

Other crops

In the Netherlands, other crops are cultivated that may serve industrial end-use, but as noticed before, these activities are difficult to quantify. Furthermore, for strategic reasons internationally operating companies are mostly reluctant to give insight in their production strategies, which makes it impossible to trace the primary raw materials. Nevertheless some crops and activities can be mentioned.

Carum carvi (caraway) and *Anethum graveolens* (dill) are minor crops cultivated on less than 500 ha each (1998). Although the seeds of these crops are mainly sold to the food-industry, some seed is used to extract the etheric oils, mainly to obtain carvon and limonene. For caraway, average production is around 1,500 kg/ha while prices were f 1,700.- (€ 766) per ton good quality seed. For dill the production is somewhat higher and prices are comparable to those for caraway. This makes these cultivations economically not very attractive. However, experimental seed yields are above 3,000 kg/ha for caraway and around 4,000 kg/ha for dill (Mheen *et al.*, 1994), offering some prospects for these crops. Seed-production of caraway and probably also for dill depends strongly on the photosynthetic activity during seed-set. A relative shortage of assimilates during that period leads to significant flower-abortion and therefore to a reduced seed-production. Assimilate supply during the vegetative phase and during the period following seed-set is far less correlated to seed-yields. During a few weeks after seed-set assimilate supply is determining the etheric-oil content in the seeds; the higher the assimilate-supply, the higher the oil levels and the higher is the ratio

between carvon and limonene. Important is that during processing-operations oil-losses of 10 to 15% can occur (Meijer & Oosterhaven, 1994). Main industrial outlets for the oil and its components are biologically active components (for example sprouting inhibitor in seed potato) and plasticizers.

Research and cultivation of herbs in the Netherlands are mostly carried out by VNK, a farmer's co-operation. These herbs are produced for the food and non-food markets, the latter mainly pharmaceutical ones. The following species are cultivated on approximately 500 ha: *Allium schoenoprasum* (leaves), *Anethium* (above ground parts), *Angelica* (roots), *Apium graveolens* (leaves), *Borago officinalis* (above ground parts), *Cerefolium* (leaves), *Chrysanthemum parthenium* (above ground parts), *Digitalis lanatae* (leaves), *Drancunla* (above ground parts), *Lactuca virosae* (leaves), *Levistica* (above ground parts and roots), *Lobelia inflata* (above ground parts), *Melilota* (above ground parts), *Oenothera biennis* (seed), *Petroselina* (leaves), *Pimpinella saxifraga* (roots), *Plantago lanceolata* (leaves), *Rhea sinensis* (roots), *Taraxaca* (leaves and roots), *Thymus vulgaris* (leaves), *Valeriana* (roots) and *Viola tricolor* (above ground parts). Furthermore, herbs and spices are imported.

The *Gramineae*, either grasses or grain-crops are hardly used for non-food industrial applications, although these crops can provide fibre, starch and starch derivatives, proteins and protein deviates, energy, and fodder. Because in the Netherlands starch for non-food applications is mainly obtained from potato, the contribution of *Gramineae* to this market is probably relatively small. Straw is mainly used for animal bedding, in mushroom cultivation and as soil cover in horticulture. These crops may play a more important role in the non-food industry when all plant

components can be processed in a limited amount of operations, and when for all components a market can be developed. This is actually under study.

2.1.ii Crop products

The chemical products contained in crops can be roughly divided into primary and secondary metabolites. The former products can be seen as being necessary to maintain growth and development of the plant (proteins, sugars, cell-wall components, *etc.*), while the secondary metabolites can be considered as supporting the primary metabolic activities of the plant (alkaloids, volatile oils, *etc.*). An overview of the relative production of primary metabolites of some arable species grown in the Netherlands (Table 3), is used to calculate actual average production of given plant parts and their primary metabolites per unit land (Table 4) and maximum attainable productions per ha (Table 5).

Root crops like sugar beet and potato have a relatively high water content, which makes transport of the raw product relatively expensive. This also holds for grass. Main primary products of these three species are respectively, sugar, starch and cell-wall materials like cellulose and hemi-cellulose. Sugar beet and grass also produce high amounts of proteins, while grass is also a good source of sugars. Winter wheat kernels provide mainly proteins, sugars and starch. Starch and cellulose are main components of silage maize, but cellulose may better be extracted from crops like miscanthus, hemp and flax.

Interesting for future industrial use of crops is the information on maximum production levels per unit soil surface area (Table 5). These production levels are

Table 3 Relative production of main primary metabolites per arable crop (1998, the Netherlands)

		Dry Matter	Protein	Ash	Oil	Org. acids	C₆H₁₂O₆ sugars	Starch	H-cellulose	Lignin	Cellulose
		(% of F.M.)	(% of total)	(% of total)	(% of total)	(% of total)	(% of total)	(% of total)	(% of total)	(% of total)	(% of total)
Grass	A.G.	15 – 25	15	8 – 10	2	9	10	-	26	4	26
Silage maize	A.G.	65 – 75	8	3 – 8	-	-	6	32	17	4	22
W-wheat	Seed	86	10	2 – 7	2	-	10	70	<-----3----->		
W-wheat	Straw	90	3	3 – 14	2	-	8	-	22	17	40
Sugar beet	Tuber	20-25	16	-	-	-	75	-	<-----13----->		
Potato	Tuber	20-25	9	2	-	-	1	80	-	0 – 1	1 - 2
Oilseed rape	Seed	85	37 - 45	7 – 8	40 - 45	-	6 - 16	2 – 3	5 - 7	9 – 11	5 - 10
Miscanthus	A.G.	80	-	2 – 7	-	-	-	-	30	21	45
Hemp/Flax	Stem	80 – 85	-	4 – 7	-	-	-	-	13	8	60
Hemp/Flax	Seed	90	-	-	25-35	-	-	-	-	-	-

All percentages are expressed relative to the total dry matter of the specified crop component, except those listed in the third column where dry mass relative to fresh mass (F.M.) of the given component is given. A.G. = Above Ground plant parts, W-wheat = Winter-wheat, Org. acids = Organic acids, H-cellulose = Hemi-cellulose.

Table 4 Average production of main primary metabolites per arable crop and per unit surface (1998, the Netherlands)

		Dry Matter	Protein	Ash	Oil	Org. acids	C ₆ H ₁₂ O ₆ sugars	Starch	H-cellulose	Lignin	Cellulose
		x 1,000 kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Grass	A.G.	12	1,800	1,080	240	1,080	1,200	-	3,120	480	3,120
Silage maize	A.G.	12	973	660	-	-	660	3,815	2,040	480	2,640
W-wheat	Seed	9	900	405	180	-	900	6,300	<-----270----->		
W-wheat	Straw	6	180	510	120	-	480	-	1,320	1,020	2,400
Sugar beet	Tuber	16	2,560	-	-	-	12,000	-	<-----2,080----->		
Potato	Tuber	9	810	180	-	-	90	7,200	-	45	135
Oilseed rape	Seed	2	820	150	850	-	220	50	110	200	150
Miscanthus	A.G.	13	-	585	-	-	-	-	3,900	2,730	5,850
Hemp	Stem	8	-	440	-	-	-	-	1,040	640	4,800
Hemp	Seed	1	-	-	300	-	-	-	-	-	-
Flax	Stem	7	-	385	-	-	-	-	910	560	4,200
Flax	Seed	1	-	-	300	-	-	-	-	-	-

Table 5 Maximum production of main primary metabolites per arable crop and per unit surface (1998, the Netherlands)

		Dry Matter	Protein	Ash	Oil	Org. acids	C₆H₁₂O₆ sugars	Starch	H-cellulose	Lignin	Cellulose
		x 1000 kg/ha*	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha	kg/ha
Grass	A.G.	22 (+83%)	3,300	1,980	440	1,980	2,200	-	5,720	880	5,720
Silage maize	A.G.	18 (+ 50%)	1,460	990	-	-	990	5,722	3,060	720	3,960
W-wheat	Seed	11 (+22%)	1,100	495	220	-	1,100	7,700	<-----330----->		
W-wheat	Straw	7 (+17%)	210	595	140	-	560	-	1,540	1,190	2,800
Sugar beet	Tuber	23 (+44%)	3,680	-	-	-	17,250	-	<-----2,990----->		
Potato	Tuber	16 (+78%)	1,440	320	-	-	160	12,800	-	80	240
Oilseed rape	Seed	4 (+100%)	1,640	300	1,700	-	440	100	220	400	300
Miscanthus	A.G.	20 (+54%)	-	900	-	-	-	-	6,000	4,200	9,000
Hemp	Stem	20 (+150%)	-	1,100	-	-	-	-	2,600	1,600	12,000
Hemp	Seed	2 (+100%)	-	-	600	-	-	-	-	-	-
Flax	Stem	12 (+71%)	-	660	-	-	-	-	1,560	960	7,200
Flax	Seed	2 (+100%)	-	-	600	-	-	-	-	-	-

* The gain in dry matter production (maximum DM – average DM) is also expressed relative to the average DM-production (percentages between brackets).

derived from various sources and represent measured productions in experimental fields. Hence, they may be considered as reliable estimates of crop production potentials. Most progress in terms of production can be made with hemp (stem-yield +150%), making hemp the most promising source of cellulose. Actual production levels of this crop are far below their potential, which most likely can be explained by the lack of post-war research on this crop. It may be expected that similar progress in production can be made with minor crops not mentioned in Tables 3, 4 and 5, for which only a limited research experience exists. The limited production gains that can be realised in wheat demonstrate also the important role of research in crop production; as wheat is without doubt one of the crops most studied in the world, their actual average grain production levels are only 22% below their potential. For the remaining crops, a significant progress in production of more than 50% can be realised (Table 4 and 5). This means for instance that oil production in oilseed rape can be doubled, and that grass may become one of the main sources of protein.

2.1.iii Novel production technologies

Actual production technologies may be characterised as a mix of three main types of technology, intermediate technology, biotechnology and information technology, respectively.

Intermediate technology is the improved version of conventional technology developed during and after the industrial revolution. Typical examples can be found in any type of processing, *e.g.* physical (breaking, cutting, *etc.*), chemical (cracking, distilling, *etc.*) and biological (plant breeding, fermentation, *etc.*) processing. Although this technology is still the basis of our production, many problems like

inefficient use, shortage of resources, accumulation of residues, pollution and dispersion, urges mankind to search for other methods of processing and production. Partly, this search for alternative technologies results in improved intermediate technologies leading to closed and environmentally sound production systems that deliver custom-made products, but another part of these alternatives comes from new technologies.

Biotechnology comprises the intermediate technologies based on the use of microbes and other living organisms, but goes further than that by genetically modifying plants and animals. Among the most known are technologies like recombinant DNA technology, plant biotechnology, fermentation technology, and enzyme technology (Spelman, 1994). The effects of biotechnology on product formation are that it produces conventional products with new characteristics or completely novel products. Examples in the field of non-food production are bioplastics, speciality chemicals, and genetically modified plants.

Information technology can be considered as a basic technology that supports the development of science and technology in a general sense. It is one of the keystones of the modern information society by offering the possibility of a global wide exchange of information. For agriculture specifically, information exchange can be crucial because of its dependency on the weather and its susceptibility to biological events such as development of pests and diseases. Moreover, in the near future, precision agriculture will make it possible to take into account a multitude of environmental and crop specific variables to fine-tune management operations. As such, primary industry can deliver high quality goods with a minimum negative

impact on the environment. Processing operations are already controlled using information technology, but automatisations can be developed even further. A good example is the developments in combinatorial chemistry where large numbers of chemical variants are automatically tested for bioactivity. In combinatorial chemistry not only the chemical analyses are processed automatically, but also the identification of active compounds is carried out using radiofrequency encoding. With the latter technique, information on large collections of compounds of varied structure (chemical libraries) are stored on microchips. Finally, the end-use industry is also more and more depending on information technology. Market survey, stock management and delivery schedules are among the activities that already can not do without this technology.

2.2 *Industry*

2.2.i Application of non-food agricultural primary products

Oil

Although Dutch vegetable oil production is negligible, an important processing industry exists in the Netherlands, generating a food and non-food production value of near f 5,200 million (€ 2,342 million). Out of the 13 processing companies, Unichema in Gouda is by far the most important one being a multi-national oleochemical industry that processes a multitude of natural oils and fats of vegetable and animal origin. Vegetable oil based products are versatile and range from fatty acids, stearines and oleines, glycerines, polymer chemicals, lubricant esters, acetates and other esters, soaps for cosmetics, solvents and suspension media to suppositories, emollients, emulsifiers, excipients and carriers for pharmaceutical applications. It is extremely

difficult to get an accurate overview of the percentages of vegetable-based oleochemicals used in food and non-food products, but Gray (1993) presented the following differentiation: Detergents – 28%; Others – 24%; Polymers – 22%; Coatings – 7%; Lubricants – 5%; Cosmetics – 5%; Mining – 5%. In general, the main challenge for the oleochemical industry is to be able to offer the same range of products as the petrochemical industry with comparable quality. Considering the fact that oleochemically derived products definitively have environmental advantages above petrochemical ones (biodegradable, mostly non-toxic, infinite), those companies investing in R&D and aiming at tailor made products may expect substantial growth in the near future.

Fibre crops

For natural fibre three main potential markets exist: paper, textile and materials for construction, either for buildings or automotive purposes.

For paper-making, two main pulp-types can be distinguished, pulp for low-value products (*e.g.* cardboard) and that for high-value products (light-weight coated, sanitary products, fluff). Pulp-production can be by chemical or mechanical processes, or by using a combination of those. Chemical pulp has better strength-characteristics than mechanical pulp and lowers the lignin-content below 4%, but the latter pulp is used to obtain better printing-quality (van Berlo, 1993). Semi-chemical pulp is applied to combine the positive aspects of both pulps. The mechanical pulps based on the relatively long bast-fibres from flax or hemp have an exceptionally high tear-resistance compared to the normal mechanical soft-wood pulps. This is not the case for the chemical pulps of the (short) core-fibres, but as mechanical pulps are mainly

used to improve the printing abilities of paper, this should not be a serious disadvantage for application of those pulps. The potential products and applications of natural fibres of hemp and flax on the national market are:

- unbleached mechanical whole stem pulp as strengthener in cardboard
- unbleached mechanical bast-fibre pulp as strengthener in cardboard
- bleached, purified bast-fibre pulp as runability and tear-resistant strengthener in high quality papers
- unbleached mechanical pulp of core-fibre in cardboard, Light-Weight Coated and wood-free paper
- chemical pulp of core-fibre as replacement of the actual existing chemical short-fibre pulps.

For all these applications the applied pulps have to compete with the already available pulps from soft-wood. Moreover, also other crops such as grasses (*e.g. Miscanthus*) may serve as basis of mainly short-fibre pulps.

Natural fibres for textile-making, are normally obtained after a series of processes (see Chapter 2.2.iii) aiming to make the fibres suitable for spinning. The rippling-process is carried out during the harvest. For flax about 50 to 60% seed is obtained out of the harvested seed-bolls. Hemp is not cultivated for seed in the Netherlands. Flax-seed is used as sowing seed or to extract linseed oil. Linseed oil is applied in paintings, lacquer, varnish, soap, and linoleum. Retting of hemp or flax is mostly carried out in the field by spreading the stems in swads and turning them regularly. Depending on the end-use of the fibres the degree of retting varies. For applications in

thermoplastics an intermediate retting is required, while for textile-purposes retting has to be more prolonged. After retting the inner-core of the stems can be separated from the bast-fibres by scutching. Actually, the wooden parts represent the main commercially interesting product of hemp because of the course nature of the fibres making them less acceptable for textile. Applications for hemp shives are animal bedding, paper, and boards.

The flax fibres used to produce yarns are those fibres having a length of more than 60 cm after scutching (technical fibres). During the last processing-step of scutching (roving) slivers of 1,000 m are made. The quality of the slivers can be adapted to the specific needs of the spinning industry, but on average they have a specific weight of Nm 0.5-8.0 i.e. 0.5-8.0 m/g. Stretching and warm-water treatments during the following spinning process may help to produce very fine yarns of Nm 120 using ring spinning equipment. The length of the technical fibres determine which fibre-fineness can be obtained; the shorter the fibres, the coarser the yarns. Other spinning techniques like rotor-spinning are mostly applied to produce yarns of cotton, but also fine fibres of flax and hemp with a elementary fibre lengths of about 20 mm can be used to spin mixed yarns. These elementary fibres may be obtained by steam-explosion techniques and already dry-spun yarns of Nm 60 fineness were obtained using steam-exploded fibres.

The fibres that can not be used for spinning are applied as filling material in thermoplastics (composites) or construction material (boards), or serve for paper-making. Intermediate quality fibres are used to make ropes or geo-textiles.

Carbohydrate crops

The main carbohydrates are based on C5 (furanose) and C6 (pyranose) molecules. These molecules often contain chiral carbon-atoms which make that several enantiomers of the same molecule exist. Besides, carbohydrates may also be non-cyclic. Monosaccharides (glucose, mannose, galactose, and fructose) are the most elementary C5 and C6 sugars. Disaccharides (sucrose, saccharose, lactose, maltose) are two coupled rings of monosaccharides and are part of the family of oligosaccharides that contain the sugars having up to ten rings coupled together. Polysaccharides like starch and cellulose are made up of many rings. Because of chirality and these many different structures with and without additional reactive groups, the number of different applications in food and non-food products is overwhelming and impossible to evaluate in the context of this report. A multitude of different industries use carbohydrates.

Because starch is the major primary product used for non-food industrial applications in the Netherlands, a short overview of the starch industry will be given. The major producer of starch is Avebe (see Chapter 2.3.ii). An overview of the non-food use of starch-related products within the EU shows that the main consumer is the paper and carton industry (Figure 1). In this industry, starch is added at the pulping stage to promote internal cohesion; the greater the use of recycled paper in the pulp, the more starch is used to counter fibre quality deterioration. Most of the starch, however, is used to reinforce surface fibres and to provide a smooth finish (Carruthers & Vaughan, 1994). Biodegradable polymers compete with petrochemical-based polymers. Production can either be via fermentation or via integration of starch in synthetic polymers. Some promising applications of biodegradables are agricultural

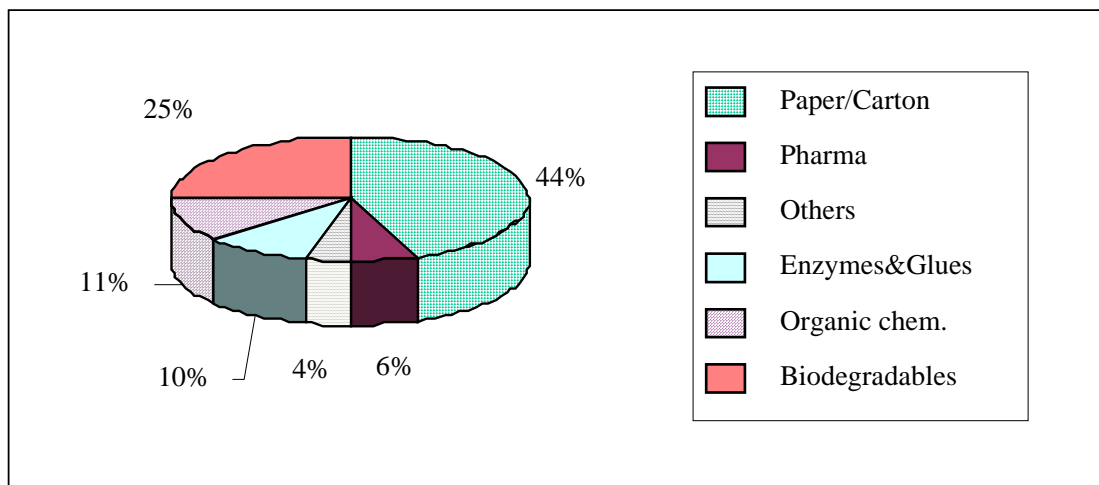


Figure 1 A global overview of the non-food uses of starch in Europe (from: Spelman, 1994)

plastics, food-packaging, waste disposal and supermarket bags. Pharmaceutical use of starch and use into cosmetics can be as excipients, binders, coatings, stabilisers, etc. Other applications in these industries are mainly based on other sugars (glucose, sucrose, lactose, mannitol, sorbitol). Starch may be used as basis for the production of enzymes and more directly to make glues. Enzyme production is an important activity in the Netherlands with the company Gist-Brocades as market leader (see Chapter 2.3.ii). Chemistry serves mainly the market for detergents involving products like whiteners, surfactants and sequestrates. Also sugar-derivates (alcohol, sorbitol, sucrose fatty-acid esters) are used as surfactants in detergents. Other industrial uses of starch are: textiles, metallurgy, mining and construction.

2.2.ii Promising and potential plant species

Although the search for a ‘new’ crop that could provide bulk industrial raw material will never cease completely, the actual developments in society and agriculture makes it unrealistic to believe that important bulk crops may appear in the following decade

as alternative for the already existing crops. It is already a fact that most of the new developments in the application of raw crop materials are originating from the multi-national industries that control the cultivation, processing and marketing of traditional food- and non-food crops like beet and potato. Examples are genetically modified sugar beets that produce inulin and potatoes with high amylopectin contents. Apart from the thorough knowledge of production, processing and marketing, the multi-nationals have considerable financial resources to stimulate new developments. This of course, will mainly be in the advantage of the traditionally grown crops.

However, if there is any 'new' crop to be mentioned that has the potential to become a bulk provider of industrial raw material then it must be *Cannabis sativa* or hemp. Hemp is very easy to cultivate, is relatively environmentally friendly, has a high production potential (Table 5) and provides the basic material for a range of products varying from shampoos to construction material for houses (Figure 2). The levels of the psychedelic active substance THC in modern fibre hemp cultivars are very low (less than 0.3 %) and far beneath the levels of THC-rich cultivars (12-15 %) that are used as drug. Eventhough, many barriers still exist before this crop can become a major industrial crop (see Chapter 2.2.iv).

For the Netherlands, it can be stated that the majority of novel crops with some potential for industrial use are niche-market crops. Such crops serve some small but commercially interesting markets where a relatively high price is paid for the given raw material. Examples in the Netherlands are groups of farmers trying to cultivate and process hemp for fashion-designed clothing, groups producing and marketing

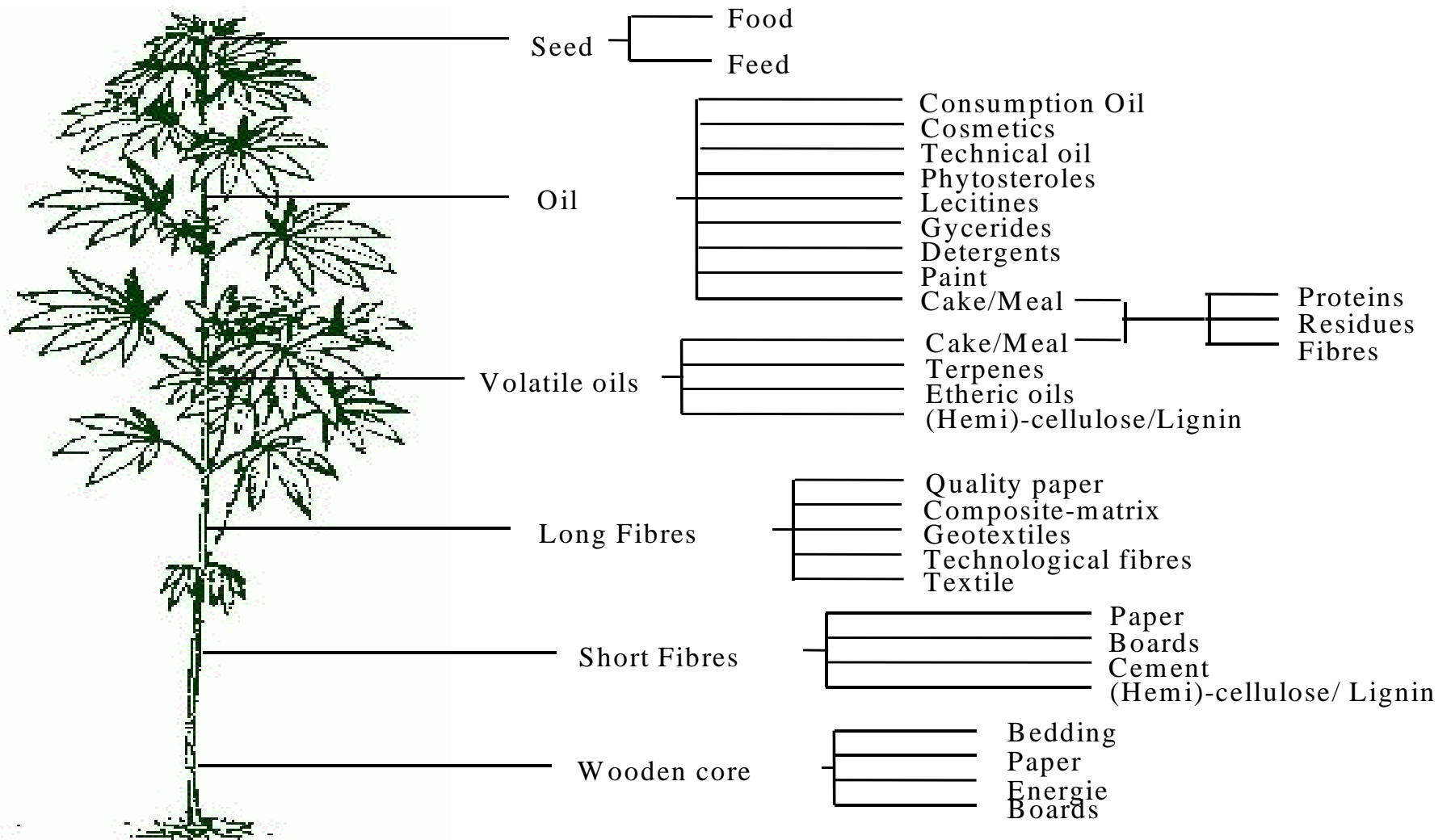


Figure 2 Hemp as basic raw material for a range of industrial products

Ginseng as pharmaceutical supplement, a cooperation that produces herbs for pharmacy and food, *etc.* Although these initiatives seem too small to be significant for the EU-agriculture as a whole, they are very important in maintaining employment and economical activities in the rural areas.

2.2.iii Processing

Industries involved in the processing of non-food products are not very cooperative when they are asked to give insight in their processing capacity and the methods they follow in processing. Therefore, no information could be collected on these topics. To obtain a global idea of production capacities the reader is referred to Annex 5.3.

2.2.iv Barriers to application of non-food agricultural primary products

Although in the Netherlands a blooming non-food industry exists that uses agricultural primary products as raw material, major problems still exist to broaden the industrial application of agricultural non-food products. Brouwer (1991), listed the following bottlenecks:

- Production of specific raw materials with constant quality is still problematic because of a lack of knowledge in several areas (tissue-culture, GMO's, plant-metabolisms, production systems tailored to the specific given environment)
- Agriculture is still heavily depending on subsidies. Differences in subsidy levels per crop lead to artificial competition between crops and more importantly, reduce the possibilities to develop alternative non-food industrial crops.
- There is a shortage of intermediate industry transforming primary products into basic material for industry. A good example of successfully operating intermediate

industries are Avebe and Unichema. They sell modified primary products as raw material to a multitude of other industries.

- The industry does not have enough incentives to invest in alternative (non-petrochemical) products. Taxes on non-sustainable goods, research subsidies and consumer preferences are good stimulants for industry to consider green raw material.

Based on these conclusions the following recommendations can be formulated:

- More research is needed to understand the production of primary and secondary metabolites in plants. This research ideally takes place at different levels of aggregation: cellular, plant-level, field level and higher levels. Research at the cellular and plant level may help to understand the bio-chemical aspects of the given metabolisms. At the field level, more knowledge is needed on how to optimise the interactions between genotype, environment and management to obtain a ideal end-use oriented product. At the regional and higher levels macro-economical aspects and chain-management are the important issues to be studied. Traditional plant breeding and bio-technology play an important role in this framework of research.
- Policy is needed to create better opportunities for the agricultural non-food industry. Research and development on industrial crops need to be stimulated. Production of non-food crops need an initial support to make these cultivations viable. Such support measures may be linked to the requirement to process or sell the harvest to avoid the cultivation of crops for subsidy reasons only. In this way it should be possible to avoid over-production of a given crop.
- More insight is needed in how plant products may serve industrial purposes. Crops and animals are a rich source of all kinds of biological, chemical and physical

components that can be used for industrial purposes. However, for most of these components industrial application is still lacking. Fundamental research in this field should be able to create a multitude of possibilities to make better use of the rich potential that is surrounding us.

- Incentives are required to promote a better exchange between producers and industry. In the Netherlands, intermediate industries have proven to be highly successful in taking those incentives.
- The use of green and sustainable raw materials needs to be promoted. This may be done by a variety of measures taken by national states or the EU (eco-taxation, subsidies, tax-reductions, *etc.*), but also industry itself should be more aware of the advantages to invest in 'green'-technology. The new technologies not only create opportunities for novel applications, but also the production costs may be positively influenced by the use of green raw material. In the near future, a limited supply of fossil resources will exist, making the products based on them more expensive. Price levels of raw material will then partly depend on the life-cycle of products made out of them and generally this is in favour of products based on agricultural green material.

2.3 Markets

2.3.i Cropping and land-use

Of the 4.15 million ha in the Netherlands, 2.4 million ha is available for agricultural production (Annex 5.2) on 70,588 farms. On average this is 34 ha per farm. In 1997, arable production was on 808,800 ha involving 57,271 farms. Of the total green area in the Netherlands, 57.1 % is used for agricultural purposes, 7.3 % is covered by wood, 3.5 % is natural area and 0.3% is occupied by horticulture. This makes that in

total, around 2.8 million ha of green area is present, *i.e.* 68.3 % of the national area. The remaining surface is occupied with buildings (28.4 %), roads (3.0 %), railway (0.3 %) and airports (0.1 %).

On a typical Dutch arable farm cultivation activities are centred around three major crops: potato, wheat, and sugar beet, covering respectively, 31, 23, and 19 % of the cultivation area of the average arable farm (Annex 5.2). In 1997, cash crops like rape seed, caraway, flax, *etc.* were cultivated on 1037 farms on 6,900 ha.

For information on the production of several industrial crop components Table 4 can be consulted.

2.3.ii Existing and potential markets

In the Netherlands, main existing markets of industrial non-food products are those for sugar, oil and starch derived products.

Sugar as industrial product is mainly used in the fermentation industry. Example is the company Gist-Brocades which is specialised in enzyme and fermentation technology. This company had an annual nett turnover of f 2,300 million (€ 1,036 million) in 1997 (Gist-Brocades, 1997) of which 4.9 % was realised in the Netherlands, 49.3 % within the EU and the remaining 45.8% in the rest of the world. Non-food applications are in cosmetics, feed, pharmacy (ceramids, polyunsaturated fatty acids, penicillines, cefalosporines, clavulane acid), enzymes, and yeasts. According to Gist-Brocades, the market for biopharmaceuticals will become more and more important in the near

future. New technologies like Metabolic Pathway Engineering (MPE) are used to create a strong competitive advantage in this market-sector.

Sugar-derivates from inulin are marketed by Sensus, a business unit from Cosun. Inulin is a plant polysaccharide which is produced from chicory roots and is marketed under the trade name Frutafit®. Inulin is a polydisperse mixture consisting of linear chains of D-fructose units and a small percentage of D-glucose units. The average degree of polymerisation is approximately 10. Inulin is used as a feedstock for the production and development of environmentally friendly derivatives for non-food applications. The products find their way in markets with a demand for environmentally friendly biodegradable alternatives for petrochemicals. Some examples are carboxymethyl-inulin and dicarboxy-inulin which can be used as a replacement of polyacrylates in detergents, products for industrial cleaning, water treatment and textile treatment. In these applications, inulin inhibits Ca^{2+} -salts precipitation. Other application areas for inulin and inulin derivatives are paper chemicals, cosmetics, soil remediation, coatings and adhesives. In 1997, a 60 % increase in the sales of fructose was realised compared to 1996. For the near future, positive developments are mostly expected in the food-market (replacements for fat, nutritional fibres).

In Europe, Nedalco is one of the largest producers of natural alcohol. Within the Benelux, it is even the only producer. Factories are located in Bergen op Zoom and Delfzijl, but also in Italy (Orbat). The raw material is molasses that is bought from Suiker Unie and CSM Suiker. Other raw materials used are molasses from sugar cane and grain. Rest-products like yeast and vinasse (rich in proteins) are sold to the animal

feed market. Those alcohols that have lower quality are destined to become spirit or to serve as raw material in fragrant and flavouring products. An important recent development is the support of the Dutch government of a pilot-project on bio-ethanol production that will minimally last till 2007. In 1998, the cooperation with Cargill in Bergen op Zoom has lead to a fixed pipe-line connection for the supply of raw materials for the production of grain-based alcohols. This signifies that in the near future main developments can be expected in the production of alcohols derived from several raw materials.

As already presented in Chapter 2.2.i, the main outlets of the oleochemical industry are detergents, polymers, coatings, lubricants, cosmetics and mining. Future growth in the production of oleochemicals by Unichema is expected to be based on the use of novel technologies (biotechnology, nickel catalyst hydrogenation), on application of a quality assurance system covering all aspects from the purchase of raw materials to the delivery of goods, and on customer specific service (Unichema, 1993).

As the main world producer of starch, the activities of Avebe determine for an important part the actual trends in the starch market. Around 2800 people work at Avebe, of which 1000 outside the Netherlands. The yearly net turnover was nearly f 1,500 million (€ 676 million) in 1996-97. Of the gross turnover, 11 % was realised in the Netherlands, 46 % in other EU-countries and the remaining 43 % in the rest of the world (Avebe, 1997). The breakdown of gross turnover by sales category was: starch 29 %, derivatives 63 % and 8 % by-products. Specialised laboratories are doing fundamental and applied research in several fields (biotechnology, analyses, processing) to support production, processing and marketing. For the near future,

Avebe sees a growing market for starch from wheat and tapioca. Furthermore, production and manufacturing will increase strongly outside Europe. However, the parent company in the Netherlands will continue to be the most important supplier of knowledge and capital. A considerable amount of research and development efforts will continue to be devoted to the raw material: firstly to further differentiate the end-products from those of other producers and secondly to ensure a competitive production of raw material. New business is initiated using a niche-market approach, *i.e.* custom-made products of high performance (e.g. biodegradable starch polymer Paragon®).

2.3.iii Market survey systems

Statutory public organisations (SPO) in the Netherlands, have the task to promote the functioning of business in given sectors of industry and to defend the Dutch public interest in their fields of competence. This means that these organisations represent specific sectors of industry, meanwhile acting as policy-making public bodies.

For arable production, the main SPO is called ‘Hoofdproduktschap Akkerbouw’ (SPO Arable Production) that has three executing bodies or Commissions: the Commission Potato, the Commission Coffee and Tea and the Commission Flax. Furthermore there are three other SPO’s, respectively, ‘Produktschap Diervoeder’ (livestock feeding), ‘Produktschap Granen, Zaden en Peulvruchten’ (Grain, Seeds, and Pulses) and ‘Produktschap Wijn’ (Wine). For a given industrial sector the main tasks of a SPO are:

- to collect and distribute information
- to advice

- to take measures to improve the quality of the sector
- to direct and finance research
- to stimulate sales
- to execute restructurations in the sector.

The SPO Arable Production has also a mandate to execute all market planning measures of the EU on behalf of the Minister of Agriculture.

The specific position of the SPO's between business and policy, makes that the information these organisations possess are amongst the most reliable that can be obtained. The Documentation and Statistics units within each SPO have as main task to collect, treat, store and distribute information on the flow of products and goods within the given sector. Meanwhile, the sectors that are represented are limited in number and therefore only information can be obtained on the production and trade of the following products: cacao, foodstuffs, sugar, coffee, flax, tea, potato, feed products, grain products, planting material, and wine.

The Central Office of Statistics (CBS) is a public body belonging to the Ministry of Economics. The information collected by CBS is on a multitude of topics: social economy, macro economics, social affairs, prices, demography, *etc.* Data are collected by making inquiries in companies, households, and all kinds of private and public institutes. From the CBS-data no information can be retrieved on individual entities, but the data depict actual and time series of main entities in the Dutch society. Data overviews can be generated via Internet where the search engine Statline is available in Dutch (<http://statline.cbs.nl/witch/indexned.stm>).

The DLO Agricultural Economics Research Institute (LEI-DLO) is the central organisation for socio-economic research in agriculture, horticulture, fisheries, forestry and rural areas. It focuses on the increasing connection of agriculture and agribusiness with the social surroundings. The institute therefore deals with issues on competition, management of production chains, spatial planning, environmental protection, revision of the European agricultural policy and liberalisation of world trade. Data on these topics are collected by LEI-DLO, but also yearly data are obtained on the relevant parameters of farming activities. These data are used in the Dutch contribution to the farm accounting system of the EU (Farm Accountancy Data Network).

2.3.iv Economic considerations

Agro-business, *i.e.* all economic activities related to agriculture and its products, is the main branch of industry of the Netherlands. Main exchange of goods and products within this business is between agriculture and the food and luxury product industry, that processes around 50% of the economic value of agricultural production estimated at Dfl 37,500 million or € 16,892 million (CBS, 1996). Other output of agriculture and fishery was to export (Dfl 15,900 million or € 7,162 million), household consumption (Dfl 1,500 million or € 676 million) and remaining sales (Dfl 1,400 million or € 631 million). In 1994, total input to agriculture was equivalent to Dfl 19,200 million or € 8,649 million (Figure 3). Therefore, the gross added value of this sector for 1994 can be estimated at Dfl 18,300 million (€ 8,243 million), representing 95 % of the value of the used input.

In 1994, the food- and luxury product industry exported Dfl 38,100 million (€ 17,162 million), representing 50 % of the total value of Dfl 75,600 million (€ 34,054 million) produced. Hence, the gross added value realised in this industry was Dfl 20,600 million (€ 9,279 million) or 37.5 % of the value of used input. Although further calculations can be made to obtain the nett income of production by accounting for depreciation on fixed assets, indirect taxes, subsidies, labour costs, paid interest and other income, already, the gross added value expressed relative to the value of used input gives an indication of the resource-efficiency of the industry.

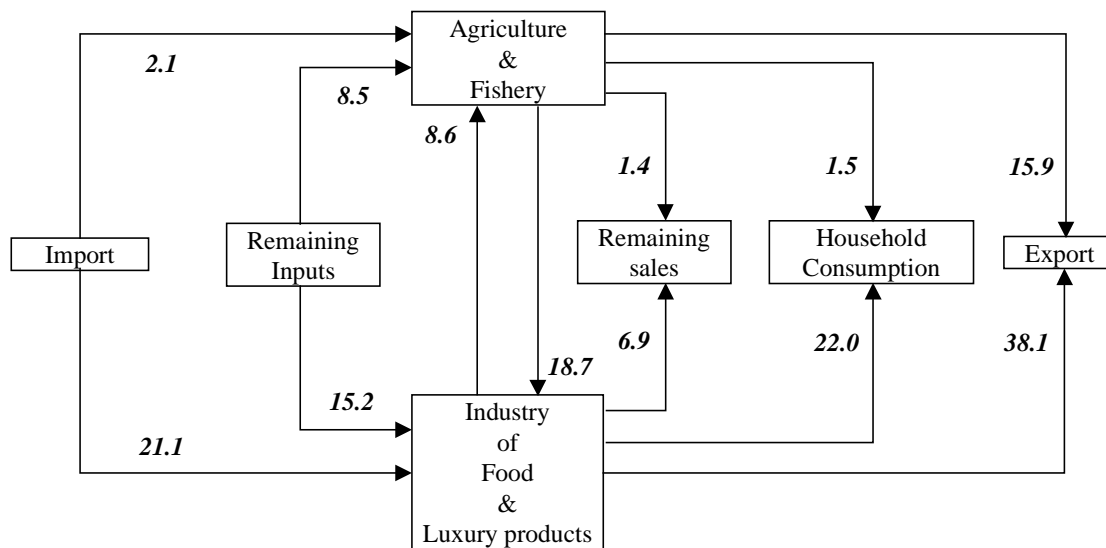


Figure 3 Input and output of Agriculture and the industry of food and luxury products in the Netherlands (1994). Figures represent values in Dfl (1 Dfl = € 0.45). Information is derived from of the Ministry of Agriculture, Nature conservation and Fishery.

Remarkable is the fact that the primary industry is about 2.5 times more efficient in producing gross added value than the food- and luxury product industry. This makes the primary industry very resource efficient.

Further information on the production value generated over several years in the two types of industry can be found in Annex 5.3. Furthermore, an overview is provided of the gross margin that is realised with the cultivation of arable crops in the Netherlands (Annex 5.2).

2.4 Environment

A Dutch study on the ecological criteria of different types of crops (Biewinga & van der Bijl, 1996) provides some information on the effects of crop cultivation on the environment. Although the study was on energy crops, useful information can be derived on the environmental aspects of non-food crop production. In the study, the following criteria were taken into account: energy balance, emission of greenhouse gasses, emission of acidifying gasses, emission of ozone depleting gasses, emission of minerals to soil and water, emission of pesticides, soil erosion, ground water depletion, use of resources, waste production and utilisation, contribution to biodiversity, and contribution to landscape values. Also indirect effects like those on soil structure, soil fertility, *etc.* were taken studied. Finally, socio-economic sustainability was assessed in terms of cost price of energy produced, costs of abated CO₂-emission and job creation per unit area.

The results of the study show that energy and greenhouse budgets and economic efficiencies tend to increase with higher crop yields, whereas scores on many other criteria were negatively influenced by higher yields. In Table 6 final assessments are shown for all criteria, when applied to practice in the North of the Netherlands. Major inputs of energy are drying and distilling operations. Manure applications contribute most to gross emission of NH₃, while machine-use contribute greatly to NO_x-

emission. Losses of nitrous oxide are higher for rape, beet, wheat and maize than for hemp and miscanthus. Losses from the latter are similar to those of grass fallow. The annual crops have higher nitrogen surpluses than the perennials. Annuals require more PK-fertiliser than perennials, especially beet and maize. Between the annuals, hemp has the lowest nutrient surplus whereas maize has the highest. For pesticide emission, winter wheat scores badly, followed by silage maize. Hemp and miscanthus are relatively pesticide-free. For rape, beet, maize and perennials, pesticide-use can be important due to the use of nematicides. Erosion risks are relatively high with sorghum, maize, hemp and beet, mainly due to lack of winter cover and wide row distances. Altogether, the general assessment of ecological criteria shows that rape, sugar beet, and winter wheat score low, while hemp comes out as one of the best. Potato was not considered in the study, but it can be expected that it will have a very low score for the ecological criteria because of nematode problems and the sensitivity of the crop to many diseases.

A recent study on the sustainability of the processing industry of non-food crops could not be found. Processing seems to put a relatively heavy burden on the environment, because of concentration of yield products in a centralised processing unit. Therefore, the use of energy has to be substantial and the quantities of remaining products high. On the other hand, as a processing plant can be equipped with filters and other devices to minimise harmful emission and because remaining heat from processing can be recycled into other functional systems, it must not be taken for granted that processing is environmentally harmful. Obviously, to come to useful conclusions on this matter, quantitative data on a per site basis are required.

Table 6 Assessments of ecological criteria for different crops when optimally used for energy supply (derived from Biewinga & van der Bijl, 1996).

Species	Energy Net budget (GJ foss./ha)	Greenhouse Net budget (ton CO ₂ /ha)	Acidification Net em. (kg SO ₂ eq./ha)	Ozone depl. Net em. (kg N ₂ O/ha)	Minerals Min. surpl. (kg N eq./ha)	Pesticides Total score (points)	Water use Crop evap. (mm)	Resource use (kg K eq./ha)
rape seed	85	5.3	13	4.1	124	4.5	211	0
sugar beet	89	7.6	-11	4.7	139	5.6	256	117
winter wheat	124	8.6	0	5.2	158	13.2	216	0
silage maize	248	17.6	13	6.3	194	9.0	217	113
hemp	206	14.2	-7	1.9	57	1.5	221	168
miscanthus	153	10.7	-5	1.1	33	2.9	211	100
grass fallow	-5	-0.8	5	1.3	50	0.0	258	0

- Net energy budget represents the amount of saved primary fossil energy
- Net greenhouse emission budget represents the amount of saved CO₂ emission
- Net emission of acidifying gasses represents the contribution to acidification by substances emitted during production and conversion
- Net emission of ozone depleting gasses represents the emission of substances during production that contributes to the depletion of the ozone layer
- The mineral surplus represents the difference between input and output of minerals per ha per year
- Pesticide scores represent the environmental burden due to pesticide use in crops
- Water use represents the use of water during crop growth due to evapotranspiration (not accounting for losses due to an excess water availability)
- Resource use represents the withdrawal of energy and minerals from the environment due to cultivation

3 BARRIERS TO PROGRESS IN APPLICATION OF NON-FOOD PRIMARY PRODUCTS

3.1 *Science*

Although plants offer a wide range of possibilities for industrial applications, the availability of cheaper resources like crude-oil makes that these applications are developing only slowly. Actually, only those crops with a high price and performance reach the industrial markets. However, it is not only the price or the performance that determines the introduction of agricultural crops as source for industry. Other factors of main importance in this respect are: 1) the large scale production of crop specific components is not yet feasible because of a limited knowledge in various fields, 2) the agriculture complex (science, R&D and production) is not sufficiently market oriented, 3) the gap between primary production and final end-use is too large; a specific intermediate industry needs to be developed, and 4) the processing industry is mostly reluctant to change the production processes in favour of the use of other raw materials. From this, some overall research themes may be deduced.

More insight on crop specific components is obtained by putting emphasis on crop based knowledge systems. These systems may vary from crop specific expert systems for crop management and processing, to extended databases containing information on species, quality, and biological, physical and chemical characteristics, among others. Furthermore, the application of the already described novel technologies (Chapter 2.1.iii) may create a considerable momentum in acquiring the necessary knowledge.

An other primary requirement to progress in the sustainable production of crop specific components is to organise scientific research in such a way that on the one hand a horizontal integration exists between scientific disciplines and on the other a vertical one between science and the market (processing industry, SME's). By organising research-themes in such a matrix structure, the agricultural complex can be made more market oriented, meanwhile having the possibility to maintain the necessary fundamental and strategic research. In this view, universities should learn to co-operate more with young enterprises that want to be linked to research, thus creating possibilities for a highly specific intermediate industry to develop.

3.2 *Technology*

Oil crops

Many oil crops are quite recently discovered as potential arable crops. Therefore, many production technological questions remain to be investigated. On the crop level, the main problems in most of the oil crops are: 1) low seed production, 2) highly variable yields, 3) poor quality, and 4) sensitivity to weeds, pests and diseases.

A low seed production is related to: i) slow crop establishment, ii) a short growing period of the crop, iii) non-optimal light interception, iv) inefficient light-use, and v) a low harvest index. Yield stability is improved when using: i) genetically uniform plants, ii) plants that have a limited seed shed, iii) plants that are relatively insensitive to the negative influence of the weather during the flowering and seed filling periods, and iv) plants that do not require a low temperature induction for germination. Quality is related to factors such as: i) oil content, ii) fatty acid composition, iii) the presence of toxic components, and iv) the presence of seed hulls. The sensitivity of the crop to

weeds is mainly related to its capacity to quickly cover the soil at the onset of the growing season, while fungal diseases mostly become problematic during the flowering and seed filling stages when periods of crop wetness are lengthening.

The main technological challenges related to harvesting, storing and processing to be solved are: i) assessing the optimal method of harvesting and the right timing with respect to obtaining maximum yields and best quality, ii) quantifying and controlling the factors that influence the time course of oil content and quality during storage, iii) improving extraction methods, iv) developing optimal processing steps, and v) finding uses for crop residues and remaining fractions after processing.

Fibre crops

Fibre crops have a high yield potential, because cell wall components like cellulose are produced in a biochemically efficient way. Therefore, the output per unit intercepted radiation is high. As soon as fibre crops are used for oil production the light use efficiency decreases significantly. In the Netherlands, most of the potential advantages of C4-crops (miscanthus, maize) relative to C3-crops (hemp, flax) do not become apparent because the seasonal temperature regime and the radiation levels are too low and water shortage is not frequent. Technical problems on the crop level are (Verheul & Struik, 1994): i) poor crop establishment, ii) sensitivity for a too low (flax) or a too abundant (hemp) water availability, iii) variability in fibre yields and fibre quality, iv) weeds, pests and diseases (flax), and v) high energy requirements during transport and processing.

Research on crop establishment is highly required as fibre crops are extremely sensitive to poor establishment conditions. Water availability seems less a problem for miscanthus and hemp than it is for flax, although all three crops are sensitive during the crop establishment phase. Fibre yields and fibre quality are strongly related to crop management and crop phenological stage (Stutterheim, 1997). Insight in how to fine-tune management with environment and genotypes is highly required to be able to obtain uniform quality and optimum quantity of fibre. Problems related to weeds, pests and diseases are comparable to those described for the oil crops. Regarding the energy requirements during transport and processing, substantial improvements can be made by striving to on-field pre-processing. Furthermore, an increased use of other crop fractions other than fibre alone could make the resource use per unit marketable product lower.

Carbohydrate crops

Of the actual crops cultivated for carbohydrates, chicory does have most problems because of the limited research experience on this crop. On a crop level, chicory has: i) a relatively low yield, ii) an poor yield stability, iii) an inferior quality, iv) a sensitivity for weeds, pests and diseases, and v) a high energy requirement for harvest and transport. Many of these points require the same research attention as described for the oil and fibre crops, but specific quality aspects related to chicory are: inulin percentage, the degree of polymerisation and tare weight. Together with sugar beet and starch potato, chicory is relatively detrimental to soil structure, creates volunteers in the next season and creates the possibility of an increased infestation of nematodes. As the production of carbohydrate crops are in hands of large industries with

important budgets for R&D, research priorities are mostly determined by those industries making research and development for these crops mostly market-driven.

Other crops

Technological problems in other crops are mostly comparable to those already described above.

3.3 *Environment*

The production and processing of non-food crops do not make more use of resources than traditional crops, nor do they put an extra burden on the environment. On the contrary, some of these crops (hemp, miscanthus) are evaluated very positively with respect to their sustainability (see Chapter 2.4). Additionally, in many instances the use of crops for industrial purposes may replace less sustainable raw materials like petrol. Overall, no important barriers to progress seem to arise from the environmental point of view.

3.4 *Legislation*

Ironically, the crop with the highest potential as industrial non-food crop is also the crop that is hampered by legislation most. Proper crop husbandry of hemp is not possible because rules exist on the moment of harvest (at 50% seed maturity), seed availability is limited because many cultivars contain a slightly higher THC-level than the extremely low level of 0.3 % and finally, local authorities make it very difficult to grow hemp or to sell products in which hemp components are processed. Although it is understandable that some people are afraid of the psychedelic effects of THC, no

sound scientific argumentation exists to defend the discrimination of hemp relative to other crops or even relative to other stimulants (alcohol, cigarettes) or pharmaceutical products. Therefore, rationally reasoned, the Commission should work on a further liberation of the laws concerning the cultivation of hemp and to try to refute the historically grown suspicion against this crop.

3.5 *Economy*

As explained in Chapter 1, the Dutch arable farming is intensive, something that will not be easy to change given the developments presented before. Nevertheless, on the European scale extensive arable farming remains a viable option to reduce arable surpluses. Therefore, the economic implications of a more extensive non-food arable production will be discussed briefly.

A advantage of extensive crop production is that generally crop rotations become wider to avoid weeds, pests and diseases and that inputs per unit surface are reduced compared to intensive cultivation. However, when input-use can not be reduced enough, extensive production may lead to a less efficient input use per unit product, which is potentially harmful to the environment. The loss of farmer's income generated by the lower yields under extensive production makes it in many cases necessary to increase the prices of primary products like it is the case in biological agriculture. However, this kind of compensation mechanisms for lost income are hard to apply on primary products serving as raw material for bulk industry, because of the low margins that are realised in this type of industry. This means that at the actual prices a policy striving to a more extensive production would hamper the development of industrial green bulk products unless those products receive

additional financial support. Such financial support could be justified by the following positive aspects of green bulk industrial production: i) use is made of CO₂-neutral and renewable resources, ii) most of the products can be recycled, iii) a contribution is made to landscape conservation, and iv) possibilities are created to maintain and develop a social-economic infrastructure in rural areas.

4 COMPARATIVE ADVANTAGES

Dutch arable production (excluding the production of silage maize) covers about 33.7 % (808,800 ha) of the available 240 million ha for agriculture and horticulture. As the production-value is only 8% of the production-value of the total agricultural sector, arable farming is economically relatively insignificant. Compared to European and world arable production-systems the Dutch production is intensive with a high price per unit product. For this reason, extended production of bulk for industrial applications in low-value products is not to be expected in the Netherlands. Already, a trend can be observed towards specialised production on a small (e.g. herbs) or a large (potato for starch) scale.

Hence, in the near future the average Dutch farmer will strive to further reduce his production-costs (*e.g.* by innovation and improved quality-management) and to increase the added value of his products (Gaasbeek *et al.*, 1994). The comparative advantage can be found in the historically grown co-operation-structures representing the integration of primary production, industry and retail trade. By combining the available competence in these three sectors of agricultural industry, it becomes possible to acquire a strong international market position. Moreover, these co-operation-like structures may also represent acceptable counterparts of already existing multinational food and non-food industries, in this way facilitating commercial exchange. Finally, co-operations can follow an own, relatively independent strategy to improve the economic position of their members. This makes it possible to take more or less risky initiatives to develop potential markets.

5 ANNEXES

5.1 Cropping

Table 7 Average yearly production of arable crops in the Netherlands

Period	Wheat 16% moisture (Gkg)	Rye 16% moisture (Gkg)	Barley 16% moisture (Gkg)	Oats 16% moisture (Gkg)	Triticale 16% moisture (Gkg)	Grain maize (Gkg)	Pulse crops (Gkg)	Winter oil seed rape (Gkg)	Fibre flax (non rippled) (Gkg)	Linseed from fibre flax (Gkg)
'70-'75	527.8	62.8	335.9	158.1	-	-	35.8	36.6	32.8	-
'76-'80	882.2	38.6	257.8	94.1	-	-	20.3	28.5	31.1	-
'81-'85	851.0	19.3	197.4	85.1	-	-	90.8	30.6	35.7	-
'86-'90	1,075.9	36.2	218.8	16.1	11.2	-	83.0	25.5	39.6	-
'91-'95	1,028.4	35.6	224.7	22.1	12.6	75.9*	29.2	10.2	29.7	-
1996	1,268.9	38.2	234.8	10.7	19.6	87.2	18.8	3.1	-	5.7
1997	1,062.6	27.9	268.3	10.9	16.4	-	16.8	2.0	-	5.1

Averages marked with * are calculated over the period 1992 – 1995. Source: CBS

Table 7 (continued) Average yearly production of arable crops in the Netherlands

Period	Oil flax (Gkg)	Caraway (Gkg)	Poppy seed (Gkg)	Chicory (Gkg)	Ware potatoes (Gkg)	Starch potatoes (Gkg)	Sugar beet (Gkg)	Fodder beet (Gkg)	Forage maize (Gkg)	Corn cob mix (Gkg)
'70-'75	-	5.2	2.8	-	2574.3	2428.8	5926.8	249.6	-	-
'76-'80	-	4.0	0.3	-	3950.1	2316.5	5931.0	135.4	-	-
'81-'85	-	3.1	0.9	-	4688.4	2461.2	6334.8	189.1	1992.7	-
'86-'90	-	0.5	0.4	-	4658.4	2377.8	8623.4	292.1	2363.0	-
'91-'95	1.0*	1.0	2.0	-	4927.9	2415.6	7103.6	201.2	2621.1	40.5*
1996	-	1.0	0.5	-	5432.7	2622.9	6415.7	114.3	2694.6	51.6
1997	-	0.3	0.9	173.5	5151.4	2821.2	6606.0	100.1	-	-

Averages marked with * are calculated over the period 1992 – 1995. Source: CBS

5.2 *Primary production and products quantified*

Table 8 Average area of arable crops in the Netherlands

Period	Grain crops 1000 ha	Pulse crops 1000 ha	Winter oil seed rape 1000 ha	Caraway 1000 ha	Poppy seed 1000 ha	Flax 1000 ha	Grass seed 1000 ha	Ware potatoes 1000 ha	Seed potatoes 1000 ha	Starch potatoes 1000 ha
1975	242.7	11.9	14.1	3.5	2.1	5.1	20.0	54.5	23.7	73.0
1980	223.5	8.2	7.9	2.9	0.2	4.1	19.3	68.9	33.2	70.6
1985	182.9	25.3	10.1	2.2	0.7	4.4	15.6	74.8	34.0	60.2
1990	193.0	26.3	8.4	0.3	0.3	5.5	26.3	76.9	35.6	62.8
1995	184.7	10.9	1.5	1.2	1.4	4.4	21.9	80.2	37.8	61.3
1996	189.2	11.3	0.9	0.6	0.3	3.9	21.3	83.6	38.7	62.9
1997	189.3	8.6	0.6	0.2	0.6	4.3	23.9	77.5	40.0	62.4

Source: CBS

Table 8 (continued) Average area of arable crops in the Netherlands

Period	Sugar beet 1000 ha	Fodder beet 1000 ha	Forage maize 1000 ha	Corn cob mix 1000 ha	Grain maize 1000 ha	Chicory 1000 ha	Hemp 1000 ha	Remaining crops 1000 ha	Total 1000 ha
1975	<i>136.5</i>	<i>3.5</i>	<i>77.3</i>	-	<i>1.3</i>	-	-	<i>5.6</i>	<i>674.8</i>
1980	<i>120.6</i>	<i>1.7</i>	<i>139.1</i>	-	<i>0.5</i>	-	-	<i>4.0</i>	<i>704.7</i>
1985	<i>130.5</i>	<i>2.2</i>	<i>176.6</i>	-	<i>0.4</i>	-	-	<i>6.2</i>	<i>726.1</i>
1990	<i>125.0</i>	<i>3.0</i>	<i>201.8</i>	-	-	-	-	<i>34.2</i>	<i>799.4</i>
1995	<i>116.1</i>	<i>1.6</i>	<i>219.2</i>	<i>5.0</i>	<i>9.0</i>	-	-	<i>40.2</i>	<i>796.4</i>
1996	<i>116.6</i>	<i>1.4</i>	<i>222.9</i>	<i>5.6</i>	<i>10.9</i>	-	-	<i>37.1</i>	<i>807.2</i>
1997	<i>114.1</i>	<i>1.2</i>	<i>232.0</i>	<i>5.4</i>	<i>12.7</i>	<i>4.2</i>	<i>1.2</i>	<i>30.6</i>	<i>808.8</i>

Source: CBS

Table 9 Average yield of arable crops in the Netherlands

Period	Winter wheat	Spring wheat	Winter rye	Winter barley	Spring barley	Oats	Triticale	Grain maize	Pulse crops	Winter oil seed rape	Fibre flax (non rippled)
	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)	(kg/ha)
'70-'75	5,100	4,600	3,500	4,500	4,000	4,600	-	-	3,000	2,600	6,400
'76-'80	6,400	4,800	4,000	5,500	4,600	5,200	-	-	2,700	3,600	7,650
'81-'85	6,700	5,700	4,200	5,500	5,000	5,200	-	-	3,650	3,050	8,250
'86-'90	7,700	6,100	4,200	5,500	5,400	4,700	4,800	-	4,500	3,050	7,150
'91-'95	8,400	6,820	5,180	6,240	5,720	5,380	5,500	7,950*	3,670	3,090	7,880
1996	9,100	6,900	5,500	6,600	6,600	5,600	6,000	8,000	3,700	3,600	-
1997	7,800	7,000	5,600	6,300	6,400	5,600	5,600	-	4,000	3,400	-

Averages marked with * are calculated over the period 1992 – 1995. Source: CBS

Table 9 (continued) Average yield of arable crops in the Netherlands

Period	Linseed from fibre flax (kg/ha)	Oil flax (kg/ha)	Caraway (kg/ha)	Poppy seed (kg/ha)	Chicory (Mg/ha)	Ware potatoes (Mg/ha)	Starch potatoes (Mg/ha)	Sugar beet (Mg/ha)	Fodder beet (Mg/ha)	Forage maize (Mg/ha)	Corn cob mix (Mg/ha)
'70-'75	-	-	1,450	1,300	-	32.9	33.5	43.5	71.7	-	-
'76-'80	-	-	1,350	1,100	-	38.0	33.0	49.0	81.0	-	-
'81-'85	-	-	1,400	1,200	-	43.2	41.0	48.5	84.5	11.5	-
'86-'90	-	-	1,500	1,550	-	41.4	38.0	69.0	96.5	11.5	-
'91-'95	-	2,025*	1,440	1,430	-	42.8	39.7	60.1	89.7	12.1	10.1*
1996	1,500	-	1,700	1,500	-	44.4	42.0	55.0	84.0	12.1	9.2
1997	1,200	-	1,400	1,500	41.0	43.8	45.0	58.0	86.0	-	-

Averages marked with * are calculated over the period 1992 – 1995. Source: CBS

Table 10 Examples of gross margins per ha realized with the cultivation of arable crops in the Netherlands (1998). Prices in Dfl ((1 Dfl = € 0.45), unless indicated otherwise. Only costs are considered that are directly related to the production of the specific crop. Hence, costs for equipment, buildings, *etc.* are not taken into account. Costs for labour of the farmer are also not directly crop related, so are ignored. The gross margin calculated per crop represents how much a crop can contribute to the payment of all indirect costs of the farm.

Sugar beet

Returns	Quantity	Price	Total
A + B beets (kg)	64,000	0.12	7,680
Gross return			7,680
Costs of production			
Direct costs for planting material / seed	100,000 seeds		387
Direct costs for biochemicals			331
Extra crop related costs			805
Total costs			1,523
Gross Margin			6,157

Source: Boerderij (1998)

Chicory

Returns	Quantity	Price	Total
Beets (kg)	40,000	0.121	4,840
Inuline premium	40,000	0.0036	144
Late delivery premium	40,000	0.012	480
Gross return			5,464
Costs of production			
Direct costs for planting material / seed	50,000 seeds		160
Direct costs for biochemicals			596
Extra crop related costs			1,451
Total costs			2,207
Gross Margin			3,257

Source: Boerderij (1998)

Ware potatoes

Returns	Quantity	Price	Total
Tubers (kg)	46,500	0.14	6,510
Gross return			6,510
Costs of production			
Direct costs for planting material / seed	1,100	1.54	1,694
Direct costs for biochemicals			696
Extra crop related costs			1,360
Total costs			3,750
Gross Margin			2,760

Source: Boerderij (1998)

Seed potatoes

Returns	Quantity	Price	Total
Tubers (kg)	34,000	0.42	14,280
Oversized potatoes (kg)	2,500	0.15	375
Gross return			14,655
Costs of production			
Direct costs for planting material / seed	6,000	0.35-0.75	2,300
Direct costs for biochemicals			1,940
Extra crop related costs			6,335
Total costs			10,575
Gross Margin			4,080

Source: Boerderij (1998)

Starch potatoes

Returns	Quantity	Price	Total
Tubers (kg)	34,593	0.11	3,805
Gross return			3,805
Costs of production			
Direct costs for planting material / seed	2,000	0.35	700
Direct costs for biochemicals			594
Extra crop related costs			136
Total costs			1,430
Gross Margin			2,375

Source: Boerderij (1998)

Winter wheat

Returns	Quantity	Price	Total
Grain (kg)	9,100	0.2325	2,116
Straw (kg)	4,000	0.025	100
EU-support			850
Gross return			3,066
Costs of production			
Direct costs for planting material / seed	185 kg	1.00	185
Direct costs for biochemicals			478
Extra crop related costs			395
Total costs			1,058
Gross Margin			2,008

Source: Boerderij (1998)

Rape seed

Returns	Quantity	Price	Total
Rape seed (kg)	3,400	0.58	1,972
Straw (kg)	3,000	0.09	270
EU-support			1,300
Gross return			3,542
Costs of production			
Direct costs for planting material / seed	4 kg	39.08	156
Direct costs for biochemicals			580
Extra crop related costs			184
Total costs			920
Gross Margin			2,622

Source: Boerderij (1998)

Caraway

Returns	Quantity	Price	Total
Caraway seed (kg)	800	1.70	1,360
Straw (kg)	2,000	0.07	140
Gross return			1,500
Costs of production			
Direct costs for planting material / seed	14 kg	11.00	154
Direct costs for biochemicals			264
Extra crop related costs			188
Total costs			606
Gross Margin			894

Source: Boerderij (1998)

Poppy seed

Returns	Quantity	Price	Total
Poppy seed (kg)	1,432	2.33	3,337
Gross return			3,337
Costs of production			
Direct costs for planting material / seed			58
Direct costs for biochemicals			411
Extra crop related costs			743
Total costs			1,212
Gross Margin			2,125

Source: Boerderij (1998)

Flax

Returns	Quantity	Price	Total
Long fibre (kg)	950	2.50	2,375
Short fibre (kg)	1,150	0.20	230
Linseed (kg)	1,050	1.85	1,934
Inferior seed (kg)	30	0.40	12
EU-support			1791
Gross return			6,351
Costs of production			
Direct costs for planting material / seed	121 kg	2.75	333
Direct costs for biochemicals			305
Extra crop related costs			2,330
Total costs			2,968
Gross Margin			3,383

Source: Boerderij (1998)

Hemp

Returns	Quantity	Price	Total
Stems (kg)	8,000	0.17	1,360
EU-support			1,465
Gross return			2,816
Costs of production			
Direct costs for planting material / seed	35 kg	7.00	245
Direct costs for biochemicals			39
Extra crop related costs			952
Total costs			1,236
Gross Margin			1,580

Source: Boerderij (1998)

Blue peas

Returns	Quantity	Price	Total
Peas (kg)	6,440	0.59	3,800
Gross return			3,800
Costs of production			
Direct costs for planting material / seed			400
Direct costs for biochemicals			258
Extra crop related costs			657
Total costs			1,315
Gross Margin			2,485

Source: Boerderij (1998)

5.3 End-products**Table 11** Value of sales of some industrial products in the Netherlands in 1996

Industrial product	MDfl	MEuro
Food and drinks	71,007	31,842
Raw fats and oil	2,109	946
Refined fats and oils	2,157	967
Vegetal oil and fractions	413	185
Fats and oils for consumption	362	162
Starch and starch derivates	2,243	1,006
Glucose	494	222
Starch from maize	236	106
Animal feed	8,635	3,872
Spices and herbs	1,305	585
Textile	4,542	2,037
Wood	75	34
Pulp, paper and carton	10,212	4,579
Glass fibre	461	207
Abrasive materials	53	24

Source: CBS

5.4 *Key-contacts concerning non-food primary products and applications*

5.4.i Science

➤ Crop production:

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- **Cebeco Handelsraad (Agricultural Products).** N.M. Knottnerus. Blaak 31, P.O. Box 182, 3000 AD Rotterdam. Tel.: +31.10.4544359, E-Mail: knottnerus@cebeco.nl.
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5.4.iii Technology transfer

none

5.4.iv Other interest groups

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- *Willem Meijer*. AB-DLO.
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