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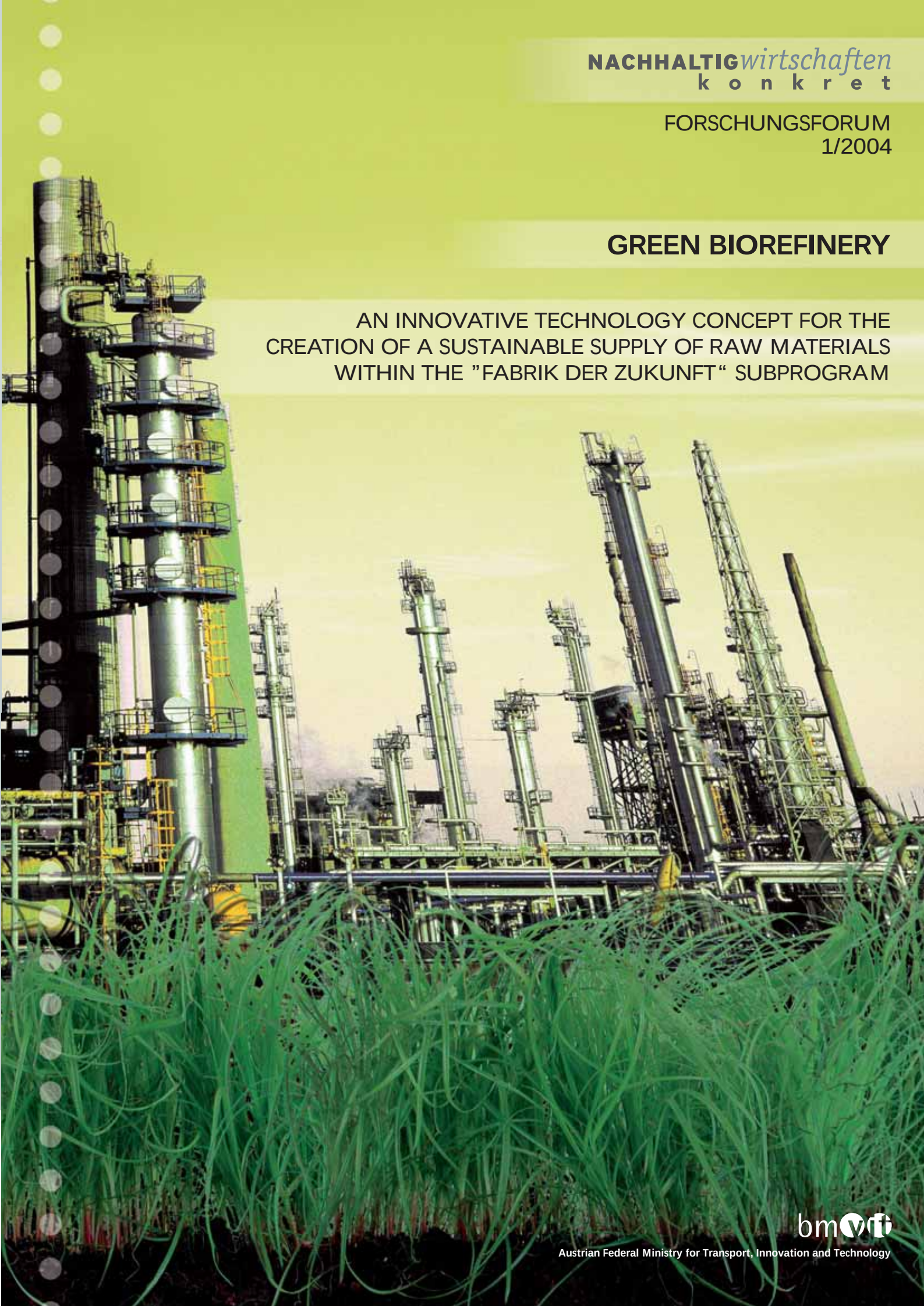
GREEN BIOREFINERY

AN INNOVATIVE TECHNOLOGY CONCEPT FOR THE CREATION OF A SUSTAINABLE SUPPLY OF RAW MATERIALS WITHIN THE "FABRIK DER ZUKUNFT" SUBPROGRAM



bmvit
Austrian Federal Ministry for Transport, Innovation and Technology

GREEN BIOREFINERY – AN INNOVATIVE TECHNOLOGY CONCEPT FOR THE UTILIZATION OF EXCESS GRASSLAND BIOMASS

In 1999, the Austrian Federal Ministry of Transport, Innovation and Technology (bmvit) launched the research and technology program "Nachhaltig Wirtschaften", which aimed to effectively stimulate the restructuring of the economy towards sustainability. Various research and development projects as well as demonstration and diffusion measures, which give new impetus to innovation in Austria's economy have since been supported within the scope of a number of subprograms. The "Fabrik der Zukunft" subprogram aims to encourage trend-setting pilot projects in the field of sustainable technology development. Model examples include innovative manufacturing processes, future-oriented products or exemplary enterprises. Innovative development should focus primarily on the fields "technologies and innovation in production processes", "use of renewable raw materials", and "products and services". The "Fabrik der Zukunft" subprogram is being financed from the Federal government's special funds for technology development on recommendation of the Council for Research and Technology.

Photo: Joanneum Research

1 Grüne Bioraffinerie – Verwertung der Grasfaserfraktion
Project Leaders: Bruno Wachter, Michael Mandl, Herbert Böchzelt, Hans Schnitzer

2 Grüne Bioraffinerie – Gewinnung von Proteinen aus Grassäften
Project Leaders: Christian Krotscheck, Stefan Kromus, Werner Koschuh

3 Grüne Bioraffinerie – Gewinnung von Milchsäure aus Grassilagesaft
Project Leaders: Christian Krotscheck, Stefan Kromus

Agriculture in Austria (as in other European countries) is currently undergoing structural changes, which are characterized by a decrease of livestock and dairy farming. One of the consequences consists in an increase of unused grassland biomass (grass) and uncultivated grassland (fallow land), respectively. The Bundesanstalt für Alpenländische Landwirtschaft (BAL)-Gumpenstein estimated that, in the medium term, 750,000 tons of dry matter per year will be available from grassland in Austria. Innovative technology concepts for the utilization of this unused grassland biomass can secure the raw material supply for the manufacture of future-oriented products. The objective of research in this area consists in encouraging the development of new products from renewable raw materials with a high market potential thus strengthening regional economies. In the future, grass will serve not only as an energy source, but will be used for the sustainable production of chemicals, biogenic materials and plant fibers. The **Green Biorefinery** is one approach towards the implementation of these objectives. The basic idea here is that, in analogy to concepts applied in petrochemistry, the raw material grassland biomass (grass, clover, lucerne etc.) is used in its entirety (use of the whole plant) to produce a multitude of ***product groups*** without generating waste (zero waste processes).

An important stage in processing grassland biomass consists in the mechanical fractionation of the primary raw materials into a liquid fraction (press juice) and a solid fraction (press cake). The liquid fraction contains valuable water-soluble substances (such as lactic acids and amino acids), the major part of the press cake consists of grass fibers of varying dimensions.

Several sub-tasks within the **"Fabrik der Zukunft"** subprogram aimed to establish the fundamentals for an economically viable model of a Green Biorefinery in Austria. The innovative technology concept has been developed by "KORNBERG Institut für nachhaltige Regionalentwicklung und angewandte Forschung" and Joanneum Research in cooperation with partners from the industry and science.

The projects below contributed to the development of the technology concept:

The three abovementioned sub-tasks were completed in 2003; follow-up projects currently under way aim to further develop fundamentals for the implementation of a Green Biorefinery in Austria. The overall project resulted in Austria's leading position in this area compared to other European research projects. The continuation of research in this field and the realization of a pilot plant could contribute to strengthening this technological leadership. Considering the promising research results in Austria, efforts will have to concentrate on finding partners in the industry in order to further develop and implement this concept.

Key products of the Austrian Green Biorefinery include:

- *Lactic acid products as starting material for synthetics, solvents, the food processing industry*
- *Protein products as high quality "GE-free" animal feed*
- *Fiber products as for insulation materials, fiber boards, products used in horticulture, speciality animal feed*
- *Biogas / "green" electric power*

EXTRACTION OF PROTEINS AND LACTIC ACID FROM GRASS AND GRASS SILAGE JUICES

The Green Biorefinery concept for Austria is different from other international projects in so far as it takes into account special needs typical of rural regions in Austria. The main objective is to facilitate a continuous all year round operation of the plant. For that reason, the concept involves not only processing of direct-cut grass, but also of silage, which can be prepared in the growing season and stored in a silo. A wide range of completely different products from grass as a raw material, which can be provided by agriculture on the basis of sustainable methods could be produced in a single plant.

Main characteristics of the Green Biorefinery include:

- Zero-waste and zero-emission extraction of valuable substances from grass (residual material is converted in a biogas plant)
- Non-use of auxiliary materials in the manufacturing process
- Self-sufficient energy supply for the plant
- Serves as an example for the processing and utilization of renewable raw materials (The generation of a variety of products from a single raw material or a mixture of raw materials increases the economic efficiency of manufacturing processes)

Functional Diagram of the Austrian Green Biorefinery

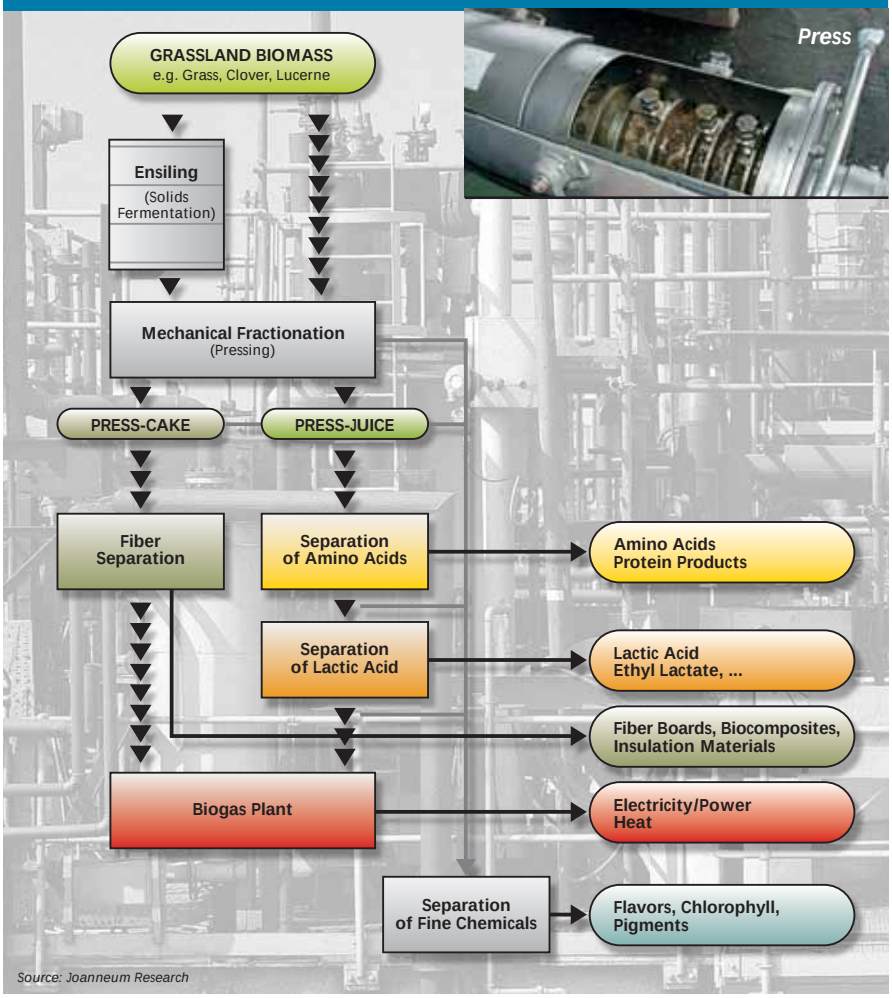


Photo: Kornberg Institut

PROTEINS

Proteins are an essential element of the nutrition for humans and animals; they also are an important raw material for technical applications such as adhesives and for the pharmaceutical and cosmetics industries. So far, studies conducted worldwide investigated exclusively the extraction of proteins from the leaves of fresh green plants, which requires a cost intensive campaign operation from May to October. Storing green crop material in the form of silage and the extraction of proteins from silage juice would permit all year round production. This form of protein production has not been studied sufficiently as yet. One of the studies contributing to the development of a concept for a Green Biorefinery in Austria **"Gewinnung von Proteinen aus Grassäften"** investigated the aspects below:

- Differences between proteins from direct-cut green material and from silage concerning structure (proteins, peptides, free amino acids), separability, and processing
- Suitability of "GE-free" grass juice proteins for the production of high-performance specialty animal feed (milk substitute)
- Demonstration of potential alternative products for milk substitutes

Cooperation with partners from the industry (e.g. the casein manufacturer LACTOPROT AG) and various research institutions (Institut für Ressourcenschonende und Nachhaltige Systeme (RNS) and Institut für Biotechnologie at the TU Graz; BAL Gumpenstein / Institut für Pflanzenbau und Kulturlandschaft, IFA Tulln / Abteilung für Umweltbiotechnologie) is to contribute to the realization of these objectives.

Test series used various species of high-protein grassland biomass (clover/grass mixture, hybrid rye-grass, permanent meadow lucerne, orchard grass), direct-cut and as silage. It has been shown that the technologies used (ultra-filtration and coagulation / centrifuging) can extract only a small part of the

Photo: Kornberg Institut

Lucerne Press Juice

crude proteins contained in the juices. Only direct-cut lucerne yielded sufficient amounts of protein. The separation of protein concentrate from direct-cut lucerne would be a technologically feasible method to generate a high-quality product.

The tested silage press juice contained only 5 to 10% of the crude protein available in the silage. This means that none of the tested technologies is suited for an economically reasonable, large-scale separation of proteins from silage juice. However, the silage juices contained a substantial proportion of free amino acids. The separation of these amino acids would require more complex technologies. The analysis of silage amino acids from an economic perspective has nevertheless shown that investing in the further development of new separation technologies will be necessary.

LACTIC ACID

Lactic acid is much in demand as a raw material for the chemical industry and is used in the production of biodegradable plastics, environmentally friendly solvents, and special chemicals as well as in the foodstuff industries. There is a wide domestic and international market for lactic acid. Currently, Austria's imports of lactic acid amount to some 770 tons per year. However, the market potential is estimated to be much higher with some 15,000 tons per year.

One of the most economical methods of manufacturing lactic acid consists in the fermentation of solids. Ensiling, especially when using green crops, is a process relying on lactic-acid fermentation; this process involves the formation of lactic acid and, at the same time, uses the preservative effect of this substance. Improvements in ensiling technology may increase lactic acid yields to such an extent that a valuable and marketable product will be generated in this process.

Comprehensive studies of the extraction of lactic acid from grass silage have not been conducted as yet. The sub-task **"Grüne Bioraffinerie – Gewinnung von Milchsäure aus Grassilagesaft"** aimed to develop the fundamentals of an integrated separation technology that permits to extract lactic acid and amino acids from grass silage juices thus generating marketable products.

The dry matter contained in silage press juices consists of approx. 30% lactic acid, 8 to 22% sugars, 24 to 34% crude protein, and 23 to 30% of ash. Free amino acids account for 85 to 100% of the crude protein. The extraction of silage press juice requires a highly developed fractioning technology. The first successful trial pressings in 2001, which resulted in an average lactic acid yield of some 50% were followed, in 2002, by dual pressings of silage with a higher moisture content and re-humidification of the first press cake. This method achieved lactic acid yields of approx. 85%. A pilot plant for the fractionation, pre-filtration and press cake conditioning will be realized in the season of 2004 and perform a trial run.

Elektrodialyseanlage

Photo: BOKU Wien, Inst. f. Lebensmitteltechnologie

The composition of the grass silage juices (lactic acid and free amino acids) shows a high potential for economic exploitation. However, separation of these products requires the development of new, more complex technologies. An interesting alternative, for example, consists in the re-fermentation of the press juice. This approach was successfully tested and resulted in the conversion of sugar into additional quantities of lactic acid.

In order to promote the development of new separation technologies researchers initiated a co-operation with the Institut für Lebensmitteltechnologie of the Universität für Bodenkultur, Vienna. They tested and assessed various types of process. The proposed methods involve a combination of membrane technologies (ultra and nanofiltration as well as electrodialysis) with chromatography. Electrodialysis was especially successful in separating lactic acid from amino acids and ashes in a two-step process; this method achieved a lactic acid yield of 91%. A combination with chromatography will probably permit to extract various fractions of valuable substances.

Other tests aimed to prepare ethyl lactate, which could be used as a "green" solvent. It has been shown that a sustainable design of the process requires further research and development. An economic calculation performed within the project established the costs to be expected for this process technology.

UTILIZATION OF THE GRASS FIBER FRACTION

Extraction of Raw Materials – Characterization of Fibers – Product Groups

The fiber fraction constitutes the largest material flow in a green biorefinery. For this reason, the overall economic efficiency of such a plant will depend to a great extend on the gains achieved from the utilization of the grass fibers. In addition to research of potential commercial applications and tests concerning the mechanical fractionation of primary raw materials, the sub-task **"Grüne Bioraffinerie – Verwertung der Grasfaserfraktion"** aimed to develop a systematic characterization of grass fibers and performed tests to establish the suitability of this raw material for the manufacture of various fiber products. In addition, the project identified the prerequisites for the planning and realization of a Green Biorefinery and assessed the economic efficiency of such a plant under the conditions prevailing in Austria.

A review of products that use "grass-like" plant fibers as essential raw material resulted in the following potential applications for grass fibers: insulation materials (fiber boards, mats, fleeces, dry-blow injection insulation materials), building panels (chip boards, fiber boards, MDF boards, fireproof boards), materials for gardening and landscaping (mulch boards, plant bolsters, peat substitute), fiber reinforced composites (biocomposites, preformed parts for the automotive industry), packaging materials, additives for various building materials (bricks, plasters, mortars, wall fillers), gypsum fiber boards, paper and pulp, energy source (fuel pellets, biogas), and animal feed (pellets).

Compounds Extrusion Die

Photo: W. Stadlbauer

Grass Pellets

Photo: W. Haslinger, FH Wiener Neustadt

Ensiling and pressing tests used different species such as orchard grass, rye grass, wheat grass, lucerne, clover-grass mixtures, and various grass and herb mixtures from different types of meadow. Testing of mechanical fractioning yielded satisfactory results. The crude fiber yield from the press cake amount to some 300 kg / ton of dry substance, which corresponds to 95% of crude fiber available in the feedstock. An analysis of the fiber properties has shown that grass fibers are comparable to bast fibers such as jute and hemp concerning tenacity, elongation, and fineness. They have, however, a very low bending strength and are therefore not suitable for textile applications. For this reason research should concentrate on potential products using the whole stem and/or leaf.

Tests have shown that the **utilization of the grass fiber fraction** for the applications below is feasible and should be further developed in follow-up projects.

Insulation boards

With a view to density, compression strength as well as thermal and acoustic insulation characteristics, grass fiber boards are comparable competing products such as wood-wool boards. The data for bending strength and water resistance of the tested grass fiber boards were, however, not satisfactory. Another unsolved problem refers to the smell emitted by grass fiber boards. Further research should focus on solving these problems. Grass fiber materials have a high potential in the field of acoustic insulation.

Fiber Boards and Planting Pots

Photo: Joanneum Research

Materials for gardening and landscaping

The utilization of grass fibers as raw material for the manufacture of mulch boards and planting pots also seems to be feasible. The typical smell emission of grass fibers is less disturbing with these products. Follow-up projects should include long-time tests under field conditions to establish the suitability of these products for practical applications. These projects should also investigate whether the material is suitable for other product groups such as greening and erosion protection mats, peat substitutes, products for cemetery gardening etc.

Animal feed pellets

The first trials aimed at pelleting the press cake of different grass species with various forms of pretreatment. Researchers succeeded to produce high-quality grass fiber pellets from the press cake without adding any binding agent. The tested pellets from clover/grass silage and direct-cut lucerne, respectively are suitable, both, for roughage for pet animals and as roughage used in the production of complete feed for rodents.

Altogether, the study of possible applications for the fiber fraction performed within the scope of this project yielded positive results. Research should focus on the further development of alternative products and pave the way for the implementation of a Green Biorefinery.

THE "AUSTRIAN GREEN BIOREFINERY" IN COMPARISON WITH INTERNATIONAL PROJECTS

M. Narodoslawsky

The concept of a biorefinery is, in fact, a general technology concept, which involves the fractionation (i.e. separate use) of products derived from the processing of renewable raw materials. On an international scale, different trends of technology development can be identified in this field. One principal differentiation between approaches results from the type of raw material used in the process: While processing of materials with a high lignin content (wood, waste wood etc.) usually involves thermal processing (gasification, hydrogenation), which yields synthesis gas or liquid products with a low molecular weight, the first stage in processing green biomass (but also biogenic waste material from animal or vegetable sources) usually relies on microbial conversion.

Technology concepts belonging to this category (some plants of this type already exist) differ particularly with a view to the range of products they generate and concerning the methods of microbial conversion they use. Many of these concepts involve the fractionation of the direct-cut grass in a solid and the liquid phase. Concepts developed in Germany (Brandenburg), Switzerland, and Denmark belong to this group. The solid phase is used in the form of fibers (e.g. insulation materials, 2B AG, Switzerland). The liquid phase is further processed by means of biotechnological methods. The resulting products vary depending on the concept used and on the market situation; the present state of technology encompasses the generation of lysine (Denmark), lactic acid, lysine and other fine chemicals (Germany) or protein concentrate (by separation), and utilization in a biogas plant (Switzerland). The Danish and the Swiss concepts have already been put to practice.

The "Austrian Green Biorefinery" also belongs to this class. A distinguishing feature of this concept consists in the fact that it uses silage as feedstock. Contrary to other approaches, biotechnological conversion in this concept is effected in the solid phase. Fractionation is performed only after ensilage. Products generated in this process include lactic acid (from silage) as well as amino acids, which are extracted from the silage juice. The solid phase is used either for the production of fibers (similar to the Swiss approach), of animal feed or it is fed into a biogas plant to generate energy.

An important change in the overall situation is due to the development in the U.S.A. where large quantities of renewable raw materials (corn, grain) are processed to yield lactic acid, which in turn is used as a starting material for other products.

PROJECT SPONSORS

Grüne Bioraffinerie – Verwertung der Grasfaserfraktion
B. Wachter, M. Mandl, H. Böchzelt, H. Schnitzer, et.al.
Joanneum Research, Institut für Nachhaltige Techniken und Systeme (JOINTS), External Branch Hartberg, Hartberg 2003

Grüne Bioraffinerie – Gewinnung von Proteinen aus Grassäften
W. Koschuh, S. Kromus, C. Krotscheck
Kornberg Institut für Nachhaltige Regionalentwicklung und angewandte Forschung, Steirisches Vulkanland Regionalentwicklung GmbH, Feldbach 2003

Grüne Bioraffinerie – Gewinnung von Milchsäure aus Grassilagesaft
C. Krotscheck, S. Kromus
Kornberg Institut für Nachhaltige Regionalentwicklung und angewandte Forschung, Steirisches Vulkanland Regionalentwicklung GmbH, Feldbach 2003

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The three studies were conducted within the scope of the "Fabrik der Zukunft" subprogram in cooperation with other partners from science and industry.

INFORMATION PUBLICATIONS

The final reports on the above-mentioned studies have been published in issues 19/2003, 20/2003 and 3/2004 of the bmvit series "Reports on Energy and Environment Research" and are available from:
www.NachhaltigWirtschaften.at

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