The industrial implementation of the Green Biorefinery

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Abstract
The Green biorefinery is a technology for the sustainable production on the basis of renewable material. It uses green crops for the bio-production of bulk and fine chemicals as well as fodder and energy. It was partly implemented first in Denmark. After a proposal by the Working party Ecological bioprocessing of the European Federation of Biotechnology first trials of its implementation in Brandenburg have been made since 1991. It became clear, that a complex view and a co-operation of many research fields, as technology development, ecological research, and social aspects, as well as market economy, are necessary. The paper summarises needed activities in these different fields.

Zusammenfassung
Die Grüne Bioraffinerie ist eine Technologie für die nachhaltige Produktion auf der Grundlage von nachwachsenden Rohstoffen. Genutzt werden Grüne Biomassen für die Bioproduktion von Massen- und Feinchemikalien sowie von Futter und Energieträgern. Nach Vorarbeiten in Dänemark wurde die Technologie auf Vorschlag der Arbeitsgruppe Ökologische Biotechnologie der Europäischen Föderation Biotechnologie seit 1992 in Brandenburg stufenweise ausgearbeitet und eingeführt. Es zeigt sich, daß eine komplexe Berücksichtigung technologischer, ökologischer und sozialer Erfordernisse, verbunden mit Aktivitäten zur Kostenminderung, die Chancen der Markteinführung verbessert. Der Beitrag stellt die erforderlichen Aktivitäten zusammen.

Preface

The Green biorefinery is a technology for the sustainable production on the basis of renewable material. It uses green crops for the bio-production of bulk and fine chemicals as well as fodder and energy. To implement the Green biorefinery as a technology of industrial importance, there several aspects have to be estimated, which cover all items of what is defined as sustainable development, as economical, ecological and social objectives.

The first implementation aspects of the Green biorefinery in the Land of Brandenburg/Germany were intensively discussed during a symposium of the Task Group on Ecological bioprocessing of the European Federation of Biotechnology held at Potsdam University in 1992 [SOYEZ ET AL. 1993]. It was continued during the 1st Symposium "Green biorefinery", held at Neuruppin in 1997 [SOYEZ ET AL., 1998A]. There an ad-hoc working group came down with some thesis about the most important topics [SOYEZ ET AL., 1998B]. These thesis were meanwhile further completed,especially at the 2nd Symposium, held at Kornberg/Austria in October 1999 [NARODOSLAWSKY 1999]. But nonetheless they are of preliminary character, and shall be continuously discussed in the further work for the biorefinery as a future technology for sustainable development.

As a result of the discussions of an international panel, special needs are seen in i) the role of agriculture as the primary producer of the raw material as a renewable resource, ii) the integration of the biorefinery into the industrial production system, iii) the sustainable land use, iv.) the development of the technology and the apparatus, and v.) of special importance, the market needs, as well as vi.) consumer acceptance and public perception. Topics discussed make clear, that many items overlap and can only be solved by an integrated approach. Their estimation is necessary to establish the biorefinery without a further lag phase.

In the following paper some thesis are given and explained with some special aspects.

Thesis 1: Renewable resources are a great chance for an technological input into regional processes having in mind the sustainable development. The compensation of fossil resources and the minimisation of the carbon dioxide output is an important feature, but not a primary target in that point of view. The biorefinery is suited for this approach. This technology could be the principle item of such a system, which uses renewable resources instead of fossils, can apply a high diversity of raw materials, and comes up with a broad variety of products.

Aspects:

- The choice of the products has to be oriented after the local or regional needs with highest priority to the needs of the production system, the biorefinery is involved in. An example is the farm which is coupled with a biorefinery.
- For the internal use, the needs of the application are to be covered, only. Thus, e.g in respect to purity of products, only the purity needed must be observed, not the normal needs of products for the external market. In the case of an application of lactic acid for silage production or for desinfection of staples, or in the case of lysine for feed mixtures, no applied standard have to be met. In analogy, for internal use, products must not necessarily be confectionated. This comes down in lower prices, but also in lower environmental costs, e.g. in terms of carbon dioxide production of the whole process.
- If a market is available, than special products of low capacity should be produced, e. g. lactic acid as surgery material.
- The biorefinery as a low scale decentral plant should start from a small production profile, for which a guaranteed market, especially an internal market, exists. Diversification is possible, if market needs are covered, but it shall not be overestimated - even stating, that long production chains are to be preferred generally.
- The production of energy, e.g. via biogas, pellets for power stations, or other ways, is not to be favoured principally. But it may even dominate the whole production, if advances for the process or for the establishment of the green biorefinery can be seen.

Thesis 2: The biorefinery should be an economically sustainable system, which produces food, energy, and materials. It could be organised as a principle item of a environmentally sound production site, including agricultural plants, handicraft, waste management, chemical and other production processes. It should be the integrating part, by which a closed cycle economy of materials and energy is possible. As a first approach, the biorefinery could be coupled with an existing plant of different type, e.g. an green drying factory. Every plant type can be used.

Aspects:

- To produce electrical energy, heat, and materials from biomass is a targeting principle of sustainability.
- To guarantee the sustainability of the production systems all plants and processes should cover the needs of eco-technologies. That means first to be integrated into the targeting biosphere wholly. As steps in the direction of sustainability, even uses of bioenergies, as biogas, can be accepted.
- The production of the biorefinery could be organised in such a way, that the internal need of such a production site is fully satisfied by the biorefinery products, and visa versa, the production profile should be eventually changed for that aim.
- For a biorefinery, a combination with animal farms can be useful. It includes the application of biorefinery products (lysine, pellets, lactic acid, etc.), the use of manure for biogas production. Another option is the combination with food processing plants, as potatoes processing, where by-products, as starch containing wastes, could be used.
- A silage production by use of self made starter cultures on farm (Richter, 1999) could be a first step into the green biorefinery
- A combination with a drying plant seems to be especially useful. The pellets could be produced by mechanical processes, instead of thermal processes, with strong reducing of the energy needed. Produced grass juices are directly applicable.

Thesis 3: Land use and biorefinery have to be seen in complex. They have to be optimised with respect to optimum sustainability. Extreme positions of land use, as intensive production versus strict protection of nature, have to be avoided.

Aspects:

- A given area of greenland can be used in different ways. Some parts can be cultivated in an extensive or in an intensive way, respectively. Deeply invasive methods of land use are to be avoided according to the principles of sustainability. This means especially the intensive use of fertilisers and pesticides.
- In the case of the Land of Brandenburg, a part of the whole greenland area can be furthermore used as intensively cultivated land. The portion is to be estimated after an equilibrium of economy and ecology.
- The biorefinery is not limited to grass, but can be driven by other plants, also. An example is alfalfa. Other types of plants, as oil containing plants, may lead to other types of biorefineries, but should be included into the complex approach.
- Extensive agricultural production leads to a broader plant diversity. This is favourable under the aspect of natural protection. But a variety of plants is more hardly to process, so that expenditure arises, followed by adverse environmental effects.
- The different fields of application calls for good choice of the plants used. In the case of protein production, alfalfa is preferred. Grass can best be used for fermentation processes, but also as construction material, isolation material etc. On the other hand, for every plant, a broad variety of applications must be found, especially innovative applications.
- The harvest of the grass is to be optimised both after the needs of nature protection and extensification (blossoms, protection of fauna), and the biorefinery needs (continuous apply, high output of juice, high sugar contents, etc.)
- Dry grass has normally a lower sugar contents and a higher cellulose content. They are lower suited for juice production. For them, other fields of application are to be found (as for energy production, construction material, paper - see Grass, 1999)
- The needs of the local natural protection are to be kept in mind in the case of the raw material balancing and are to be widely used for the material management, e.g. the different times of grass harvesting an various plantation areas.
- To ensure a sustainable productivity of the soil, an abrupt finish of the application of fertilisers is to be avoided. The K-fertilisation is of special value. A step by step reduction of the nutrient concentration of the soil is to be optimised via controlled plantation.
- In the case of an overall evaluation of effects it is to be consider, that in intensively cultivated crops nutrients can be washed out into the groundwater. This effects the balances and influences the overall economy.

Thesis 4: For the green biorefinery, a high number of suited process units are available. The technical problems are solved or can be solved. Adaptation to the regional characters are necessary.

Aspects:

- The realisation of a production over the whole year of the biorefinery is possible, e.g. after storage of material, including silage, and it is generally useful for the avoidance of expensive starting processes and for the depreciations. But it is not generally needed; best solution is to be found after optimisation.
- A main target is the internal closing of the material cycles, e.g. by combination of raw material and waste, use of waste products for energy uses.
- Combinations of biorefinery with other production processes of the raw material production and preparation, the juice production, or the bioprocesses, are to be studied and to be optimised.
- An approach for the process optimisation is given by solid state fermentation, especially by the liquefaction of sugers by bacteria growing naturally on grass-habitates. They can cause an intensive break-down of materials into sugar and an enrichment of water soluble carbohydrates in the

pressing water. Effects are to be envisaged, if starter cultures can be used as production cultures in the lactic acid forming bioprocess, as *lactobacillus paracasei* (Kiel, 1998).

- Silage production can be a process step in the biorefinery, e.g. for storage and realisation of economically sound production cycles. But silage is also applicable for the production of organic acids, as lactic acid, acetic acid, etc. For that, the process is to be optimised as a solid state fermentation. Application of different starter cultures is necessary, and already proven an technical scale (Danner, 1999).
- Genetical engineering of microorganisms for the biorefinery seems not to be necessary, for a wide range of suitable organisms is present in nature. Any special case has to be decided for itself obeying ecological principles.
- Native proteins from grass presumable will have special properties, which cannot be found in traditional sources of functional proteins, as soya or alfalfa. The potential is to be used. It can contribute to the improved economy. But only small quantities of grass juice will be needed for that purpose, so that large scale effects are not to be foreseen.

Thesis 5: Market prices and quality needs often call for a process capacity in a large scale, which does not favour sustainability. A small scale decentral production can be economised, if the process is optimised under application of all complex effects. Quality guarantees are needed. Thus, the development of analytical procedures and TQM are necessary. Conformity of the biorefinery with the needs of sustainability is a market factor and should be proven and pronounced.

Aspects:

- The whole production range of the biorefinery is to be studied in more detail to come up with substitutions for a broad range of established products. This gives better chance for an overall economy of the biorefinery. On the other hand, for known products of the biorefinery, new applications are to be found. This has to be done parallel to the process development.
- The quality of the pellets is defined by physiological factors of animal digestion, but also on quality normatives of the European Commission, e.g. crude protein contents of the pellets by an EU-normatives.
- The realisation of the biorefinery is to be evaluated after economic, as well as after sustainability characters. The SPI-Index (Krotscheck, 1999) is applicable.
- The existing market for fine chemicals in the low mass range is to be used as far as possible.
- Production capacities of 200 to 300 tons are a useful capacity for a decentral production.
- A close co-operation with potential product users during the process development can lead to fortunate solutions for all process steps, especially for downstream processes. It may lead to technical solutions and integrated techniques. An example is given by the use of wet press cake for animal nutrition n a co-operating enterprise instead of drying with high expenditure (Grass, 1999)

Thesis 6: Public perceptance and political assistance are mayor needs.

Aspects:

- Week public perception of biotechnology may cause disadvantages also in the case of the biorefinery. Thus, broad public activities are useful for the development of the biorefinery. Use of this technology as an example for sustainable biotechnology should be pronounced.
- Political decision makers and public institutions, as NGO's, should be involved into all activities.
- The development of the farming practice from traditional agriculture with food and feed production as the main task towards an integrated approach including environment protection, supply of energy and raw material as well as waste management, should be stressed. The biorefinery is an example for that.

Literature :

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