BIOPOL

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Description of the general biorefinery concept

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Content

1. Introduction

Sustainable economic growth requires safe resources of raw materials for the industrial production. Today's most frequently used industrial raw material petroleum, is neither sustainable, because limited, nor environmentally friendly. While the economy of energy can be based on various alternative raw materials, such as wind, sun, water, biomass, as well as nuclear fission and fusion, the economy of substances is fundamentally depending on biomass, in particular biomass of plants. Special requirements are placed to both, the substantial converting industry as well as research and development regarding the efficiency of raw material and product line as well as sustainability. "The development of biorefineries represents the key for the access to an integrated production of food, feed, chemicals, materials, goods, and fuels of the future" [National Research Council U.S.A. 1,2].

Nature is a permanently renewing production chain for chemicals, materials, fuels, cosmetics and pharmaceuticals. On one hand one has to mention that due to the help of biotechnological processes and methods feedstock chemicals are produced such as ethanol, butanol, aceton, lactic acid and itaconic acid as well as amino acids, e.g. glutaminic acid, lysine, tryptophan. On the other hand, currently only 6 billion tons of the annual produced biomass, 1,7 -2,0 $x10^{11}$ tons, are used, and only 3,0 to 3,5 percent of this amount is used in the non-food area, such as chemistry [3]. The basis reaction of the biomass is photosynthesis according to:

$$nCO_2 + nH_2O \Rightarrow (CH_2O)_n + nO_2.$$

Industrial utilization of raw materials from agriculture, forestry and green landscape care for the energetic, biotechnological and chemical industry is still in the beginnings.

2. Biorefinery

2.1 Principles of biorefineries

Biomass has similar to petroleum a complex composition. Its primary separation into main groups of substances is appropriate. Subsequent treatment and processing of those substances lead to a whole palette of products. Petrol-chemistry is based on the principle to generate from hydrocarbons simply to handle and well defined chemically pure elements in refineries. In efficient product lines, a system based on family trees has been built, in which basic chemicals, intermediate products and sophisticated products are produced. This principle of petroleum refineries must be transferred to Biorefineries. Biomass contains the synthesis performance of the nature and has another C:H:O:N-ratio than petroleum. The biotechnological conversion will become, beside the chemical. Thus biomass can already be modified within the process of genesis in such a way, that it is adapted to the purpose of subsequent processing and particular target products already have been formed. For those products the term “precursors” is used.

Plant biomass always consists of the basic products carbohydrates, lignin, proteins and fats, beside various substances such as vitamins, dyes, flavours, aromatic essences of most different chemical structure. Biorefineries combine the essential technologies between biological raw materials and the industrial intermediates and final products. A technically feasible separation operation, which would allow a separate use or subsequent processing of all these basic compounds, exists up to now only in form of an initial attempt. Assuming that out of the estimated annual production of biomass by biosynthesis of 170 billion tons 75 percent are carbohydrates, mainly in form of cellulose, starch and saccharose, 20 percent lignin and only 5 percent other nature compounds such as fats (oils), proteins and various substances, the main attention firstly should be focused on an efficient access to carbohydrates, their subsequent conversion to chemical bulk products and corresponding final products. Glucose, accessible by microbial or chemical methods from starch, sugar or cellulose, is among other things predestined for a key position as basic chemical, because a broad palette of biotechnological or chemical products is accessible from Glucose. In the case of starch the advantage of enzymatic compared to chemical hydrolysis is today already realized. In the case of cellulose this is not yet realized. Cellulose-hydrolyzing enzymes can only act effectively after pre-treatment to break up the very stable lignin/cellulose/ hemicellulose composites. These treatments are still mostly thermal, thermo-mechanical or thermo-chemical and require a considerable input of energy. The arsenal for microbial conversion of substances out of glucose is large, the reactions are energetically profitable. It is necessary to combine the degradation processes via glucose to bulk chemicals with the building processes to their subsequent products and materials (according [4], [5] and inside given references]).

2.2 Definition of the term biorefinery

The young working field "Biorefinery Systems" in combination with "Biobased Industrial Products" is, in various respects, still an open field of knowledge. This is also reflected in the search for an appropriate description. A selection is given (according [4] und [5]:

The term "Green Biorefinery" was been defined in the year 1997 as: "Green biorefineries represent complex (to fully integrated) systems of sustainable, environmentally and resource-friendly technologies for the comprehensive (holistic) material and energetic utilization as well as exploitation of biological raw materials in the form of green and residue biomass from a targeted sustainable regional land utilization" [2]. The original term used in Germany "complex construction and systems" was substituted by "fully integrated systems". The US Department of Energy (DOE) uses the following definition (according [4] und [5] and inside given references): "A biorefinery is an overall concept of a processing plant where biomass feedstocks are converted and extracted into a spectrum of valuable products. Based on the petrol-chemical refinery." The American National Renewable Energy Laboratory (NREL) published the definition according [4] und [5] and inside given references: "A biorefinery is a facility that integrates biomass conversion processes and equipment to produce fuels, power, and chemicals from biomass. The biorefinery concept is analogous to today's petroleum refineries, which produce multiple fuels and products from petroleum. Industrial biorefineries have been identified as the most promising route to the creation of a new domestic biobased industry."

In general biorefining is the transfer from logic and efficiency from the today's substantial converting industry, and chemical industry as well as production of energy onto the biomass industry [5].

The biorefinery definition has been developed in this Biopol-project (according IEA-Task 42: 'Biorefinery is the sustainable processing of biomass into spectrum of marketable products and energy' (www.biorefinery.nl/biopol)

There is an agreement about the *objective*, which is briefly defined as: "Developed biorefineries, so called "phase III-biorefineries", start with a biomass–feedstock-mix to produce a multiplicity of most various products by a technologies-mix" [5].

An example of the type "phase-I biorefinery" is a dry milling ethanol plant. It uses grain as a feedstock, has a fixed processing capability, and produces a fixed amount of ethanol, feed co-products, and carbon dioxide. It has almost no flexibility in processing. Therefore, this type can be used for comparable purposes only.

An example of a type "phase-II biorefinery" is the current wet milling technology. This technology uses grain feedstock, yet has the capability to produce a variety of end products depending on product demand. Such products include starch, high-fructose corn syrup, ethanol, corn oil, plus corn gluten feed, and meal. This type opens numerous possibilities to connect industrial product lines with existing agricultural production units. "Phase-II biorefineries" are, furthermore, plants like NatureWorks PLA facility [4,5] or ethanol biorefineries, for example the Abengoas wheat straw to ethanol plant or the Iclandic Alaska Lupine Straw to ethanol-plant [see Leaflet BIOPOL].

Third phase (phase-III) and more advanced biorefineries have not yet been built but will use agricultural or forest biomass to produce multiple products streams, for example ethanol for fuels, chemicals, and plastics [4,5].

3. Current status of the industrial implementation of biorefinery-plants

Biobased products are prepared for an economic use by a reasonable combination of different methods and processes (physical, chemical, biological and thermal). Therefore it is necessary to develop basic biorefinery technologies. For this reason a profound interdisciplinary cooperation of the various compartment disciplines in research and development is inevitable. Thus it appears to be reasonable to refer to the term “biorefinery design”. Biorefinery design means: bringing together smart scientific and technologic basics with practical technologies, products and product lines inside the biorefineries. Special attention is given to the combination of biotechnological and chemical substance-converting and the required energy input for the conversion. The basic conversions of each biorefinery can be summarized as follows:

Currently four complex biorefinery systems are forced in research and development [4,5]:

(1) the 'Green Biorefineries' using ‘nature-wet’ biomasses such as green grass, alfalfa, clover, or immature cereal [6].
(2) the 'Lignocellulosic Feedstock Biorefinery' using 'nature-dry' raw material such as cellulose-containing biomass and wastes [7].
(3) the 'Whole Crop Biorefinery' uses raw material such as cereals or maize [8].
(4) the ‘Biorefinery Two Platforms Concept’ includes the sugar platform and the syngas platform [9].

References

[1] National Research Council (NRC, U.S.A.) Biobased Industrial Products: Priorities for Research and Commercialization, National Academic Press, Washington D.C. **2000**.

[2] B. Kamm, M. Kamm, K. Soyez, (Eds) *Die Grüne Bioraffinerie/The Green Biorefinery. Technologiekonzept*, 1st International Symposium Green Biorefinery/Grüne Bioraffinerie, Oct. 1997, Neuruppin, Germany. Proceedings, Berlin **1998**, ISBN 3-929672-06-5,

[3] H. Zoebelin, (Ed) *Dictionary of Renewable Resources*, WILEY-VCH, Weinheim **2001**.

[4] B. Kamm, M. Kamm, P. Gruber, Biorefinery Systems –an Overview, In: *Biorefineries – Industrial Processes and Products. Status Quo and Future Directions*. (Eds: B. Kamm, M. Kamm, P. Gruber), WILEY-VCH, Weinheim **2006**, Vol. 1, pp. 3-40.

[5] B. Kamm, P. Gruber, M. Kamm, Biorefineries- Industrial Processes and Products, *Ullmann's Encyclopedia of Industrial Chemistry*, 7th ed. WILEY-VCH **2007**.

[6] S. Kromus,, B. Kamm,, M. Kamm,, P. Fowler, M. Narodoslawsky,, The Green Biorefinery Concept – Fundamentals and Potentials, in *Biorefineries – Biobased Industrial Processes and Products. Status Quo and Future Directions*. (Eds: B. Kamm, M. Kamm, P. Gruber), WILEY-VCH, Weinheim **2006**, Vol. 1, p.p. 253-294,

[7] A.A. Koutinas, R. Wang,, G.M. Campbell, C. Webb,, A Whole Crop Biorefinery System: A closed System for the Manufacture of Non-food-Products from Cereal, in *Biorefineries-Industrial Processes and Products, Status Quo and Future Directions* (Eds: B. Kamm, M. Kamm, P. Gruber), WILEY-VCH, Weinheim **2006** Vol. 1, 165-191,

[8] B. Kamm, M. Kamm,, M. Schmidt, T. Hirth,; M. Schulze,, Lignocellulose- based Chemical Products and Product Family Trees, in *Biorefineries-Industrial Processes and Products, Status Quo and Future Directions* (Eds: B. Kamm, M. Kamm, P. Gruber), WILEY-VCH, Weinheim **2006** Vol. 2, 97-149,

[9] T. Werpy, G. Petersen, *Top Value Added Chemicals from biomass* [U.S. Department of Energy, Office of scientific and technical information, No.: DOE/GO-102004-1992, www.osti.gov/bridge], **2004.**