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Green biorefinery – Industrial implementation

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Dedicated to Michael Kamm, Founder of biorefinery.de GmbH

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ABSTRACT

Oil refineries currently generate a multitude of products for almost every sphere of life at very high efficiency. However, fossil raw materials are just available in limited quantities. The development of comparable BIOREFINERIES is necessary to make a variety of competitive biological products regarding their equivalent products based on fossil raw materials. The product range of a biorefinery comprises products that can be manufactured on the basis of crude oil, as well as such products that cannot be produced on the basis of crude oil (Kamm, Gruber, & Kamm, 2011). GREEN BIOREFINERIES [GBR's] are complex systems of sustainable, environment- and resource-friendly technologies for a comprehensive material and energy use or recovery of renewable raw materials in form of green and waste biomasses from a sustainable land use as target (Kamm et al., 2009; Digman, Runge, Shinners, & Hatfield, 2013).

1. Introduction

Since crude oil and biomass differ in various properties, new primary fractionation methods of biomass, secondary conversion pathways and processes have to be developed. Biorefineries combine the necessary technologies of the biogenic raw materials with those of intermediates and final products. The chemical industry is experiencing a fundamental shift as cost competitive biobased platform chemicals become a commercial reality (Kamm, Gruber, & Kamm, 2011). This paper is focused on green biomass biorefinery concepts, which are favoured in research, development and industrial implementation.

Green biorefineries are multi-product systems and act regarding to their refinery fractions and products in accordance with the physiology of the corresponding plant material, i.e. they preserve and use the diversity of the synthesis generated by nature (Digman, Runge, Shinners, & Hatfield, 2013; Kamm, Schönicke, & Kamm, 2009).

In addition to the biorefinery concept, GBR's are strongly based on sustainable principles (sustainable land use, sustainable raw materials, gentle technologies, autarkic energy supply etc.) as reported in Fig. 1.

The primary fractionation of Green Biomasses and the production of proteins, fermentation media, animal feed and biogas is demonstrated in a facility connected directly to the green crop drying plant in Havelland (Germany – Brandenburg) in a pilot scheme with an annual capacity of 20,000 tons of alfalfa and grass biomass (primary refinery-basic grade). This primary refinery can be diversified in modules for the production of different platform-chemicals. By reference to the basic engineering of the primary refinery, processes, products, investment costs, economic efficiency consideration and climate effects are published. The production site and the planned demonstration plant are presented (Kamm, 2013; Kamm, Hille, Schönicke, & Dautzenberg, 2010).

2. Green biomass as raw material for proteins and platform chemicals

Green biomass for processing in a biorefinery is field grass from arable land and permanent grasslands. The average yields in Germany and Europe are estimated to 7 tons of dry matter per hectare per year (Biorefineries Roadmap, 2012). The main purpose, the production of feed for livestock loses importance through limited production quotas and rising performance of animal populations (Osterburg, Isermeyer, Lassen, & Roeder, 2010). Thus, grasslands as a raw material for material and energy utilisation is available for use. In Germany, green biomass is cultivated on approximately one third of the total agricultural area of about 17 million hectares.

Abbreviations: DSZM, German collection of microorganisms and cell cultures; DM, dry matter; ha, hectare; MRS, type of bacterial growth medium.

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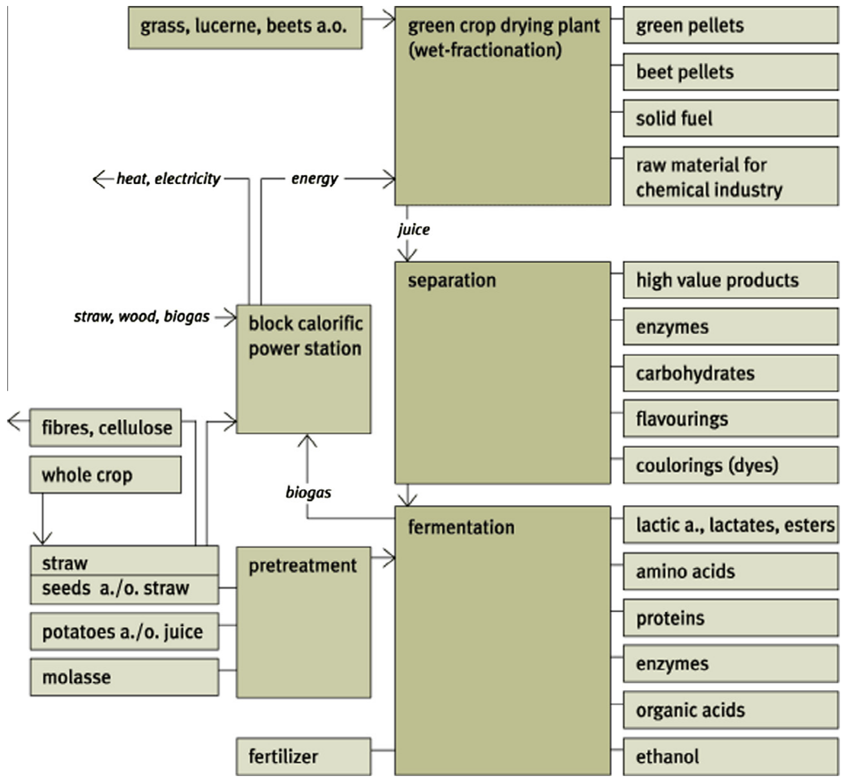

Fig. 1. System green biorefinery for the manufacture of food and non-food products.

Thereby, green biomass is estimated at 6 million hectares. This gives a yield of about 42 million tons of green biomass (FAOSTAT, 2012). In Europe (EU TOTAL), the agricultural area is estimated at about 470 million hectares. One-third of the agricultural land are field grass on arable land and permanent grassland. This calculates to an area of 156 million hectares with a yield of 1 billion tons (FAOSTAT, 2012). Worldwide 4.9 billion hectares are used for agricultural purposes of which two thirds are covered by green biomass, i.e. approximately 3.3 billion hectares with different yields (FAOSTAT, 2012). In Europe, the most important forage crop is alfalfa (Lucerne) due to its ability to absorb nitrogen from air and to enrich it in the soil. Alfalfa is cultivated on about 30 million hectares worldwide, of which 25% (7.12 million hectares) is produced in Europe (Cash, 2009).

In the U.S.A., intensive research in the field of biorefineries has been going on over the past 10 years. The Alfalfa New Products Initiative (ANPI), to which five of the states belong, aims at the intensification of the cultivation and use of Alfalfa. Thereby known technologies, implemented at large scale only in France, like dehydration and fractionation are utilised (Lamsal, 2004).

The high protein content and the favourable amino acid pattern make alfalfa exceptionally interesting for feedstuff production, and research and development efforts on water soluble proteins that are about 15% of the average protein content. 40–60% of the water soluble proteins, also called white proteins is RuBisCo (ribulose 1,5-bisphosphate carboxylase/oxygenase) (Koegel & Straub, 1977; Lamsal, 2004). RuBisCo is reported to constitute about 65% of the total water soluble proteins in alfalfa leaf-juice (Ellis, 1979).

Generally the crop of ‘‘nature wet” grass and the direct use of mechanically pressed green juice are interesting for the biotechnological industry. Existing agricultural structures of grassland cultivation like green crop drying plants provide good opportunities for the implementation of green biorefineries. Thereby, note should be taken of the fact that the current thermal drying is partially obsolete and modern methods in feed production should be applied. However, it would be reasonable to take advantage of the existing agricultural structures in the grassland agriculture to ensure an agricultural added value by the production of semi-finished products like press-juice and press-cakes. Modern green crop drying plants can be regarded as agricultural intersections in the grass and green crop agriculture. Considering the vast diffusion of green crop drying plants, the presented project not only should be a demonstration of the linkage of agricultural and renewable raw material industry and R&D facilities in Germany, but rather in the majority of European countries (Kamm et al., 2011; Kamm & Kamm, 2007).

Green biorefineries are multi-product systems that perform and produce in accordance with the physiology of the corresponding plant material, preserving and using the diversity of the synthesis generated by nature. In addition to the general biorefinery concept, GBR’s are strongly based on sustainability principles (sustainable land use, sustainable raw materials, gentle technologies, autarkic energy supply etc.). Existing agricultural structures of the green crop processing industry, like green crop drying plants, offer good opportunities for the implementation of biorefinery technologies that will help overcoming energy-intensive and partially obsolete technologies like the thermal drying of feedstock.

Currently green harvests are mainly used as green or dry fodder. An important part of these harvests is dried in biomass or multi-fruit drying plants and is placed on the market as pellets or bales. In the future such drying plants will play a major role as agricultural-industrial intersection within the industrial processing of biomass (Fig. 2).

In the frame of roadmap biorefinery Germany (Biorefineries Roadmap, 2012), several green biorefinery operations are considered. One concept encompasses the configuration of an alfalfa based green biorefinery for the production of platform chemicals lysine lactate, lactic acid, acetic acid, proteins and biogas, produc-