The Unbeatable Beet: Biorefining of Sugar Beet Pulp

R. Nolles*, F. Staps** and G. van Engelen***

*Cosun Biobased Products
PO Box 641955, San Jose, CA 95164, USA, robert.nolles@cosun.com
**Cosun Biobased Products, Roosendaal, The Netherlands, francesco.staps@cosun.com
***Cosun Biobased Products, Roosendaal, The Netherlands, gerald.van.engelen@cosun.com

ABSTRACT

The biobased economy is unstoppable and will affect the current supply chains and business structures. Drivers that fuel the biobased economy include climate change, expected future scarcity of fossil-based raw materials and the need for rural area development. However, challenges exist in the form of obstructing regulation, competition with well-established value chains and lack of incentives by companies and consumers. Despite the abovementioned challenges Royal Cosun is committed to the biobased economy and therefore decided to invest in an integrated and cost-effective cascading biorefinery to refine sugar beet pulp and isolate high value components. The overall objective is to establish new value chains based on microcellulose fibers, L-Arabinose and galacturonic acid in high value markets. These new products are an extention of Cosun's current portfolio of available biobased products such as carboxymethyl inulin, cationic inulin and bio-methane.

Keywords: biorefining, sugar beet, L-Arabinose, microcellulose fibers, galacturonic acid

1 THE BIOBASED ECONOMY

The biobased economy is unstoppable. It will seriously affect the current supply chains and business structures. Moreover, it will push technology and market development in all global regions. In a few centuries time, mankind may look back on the fossil-based era as nothing more than a short hickup of the biobased economy.

The biobased economy is about making best use of the bioresoures that are regionally available: crops vary per region and are subject to seasonal changes. Therefore, logistics and variation in quality or price of feedstocks are challenges to overcome. In order for a region to be successful in the biobased economy, various strategic aspects are of importance. Firstly, in those areas where the costs of production of raw materials are high, like the United States and Europe, it is crucial to focus on high value products and to develop biorefinery concepts that lead to 100% utilization of the raw materials. Secondly, it is evident that R&D investments are needed for the development of the necessary technological competences, know-how and IP positions. For instance, pre-treatment technologies for biomass, selective (molecule-targeted) separation and conversion technologies are all relevant. Finally, the simultaneous technology and market development is complex and requires strategic partnerships with companies throughout the whole value chain from crop via industry to consumer. Complementary technological competencies and combined market knowledge are required to generate synergies, reduce risk and costs and speed up technology and business development.

True innovations are essential for Europe and the United States to stay ahead of the growing competition from Asia. With that in mind, the biobased economy is offering new opportunities for innovative products and new business concepts. In this case, innovation means focus on high value products, if possible with new functionalities, that offer a competitive advantage for the (end)user. Areas to focus on are pharmaceuticals & fine chemicals, food & feed and chemicals & materials (Fig. 1).

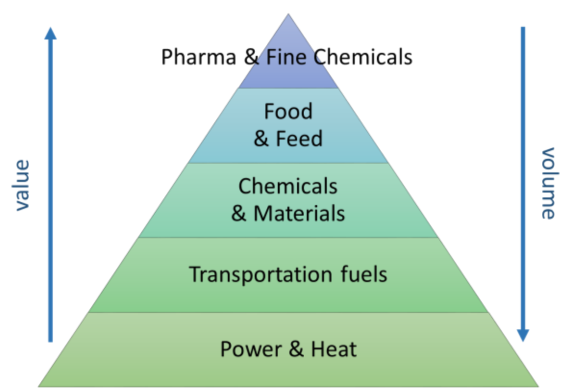

Figure 1: Value vs. volume for markets relevant to the biobased economy.

2 DRIVERS & CHALLENGES

It is eminent that our current food and manufacturing economy and society in general cannot prevail on current feedstocks. Alternatives are a necessity but come at a price, literally. The first step into change is finding biobased offerings that also provide economical sustainability.

2.1 Drivers

The environment and sustainability are of growing concern and have led to an increasing awareness in society and by governments. This is related to important themes like: 1) Climate change and the environment in general. 2) Expected future scarcity of fossil-based raw materials and the economic impact of it. 3) Dependence on politically unstable regions for the supply of raw materials. 4) The need for rural development in both developed and poor countries. One important aspect to safeguard is the proper use of landmass and crops. First goal should be to feed the global population. Using plant waste or by-products from the food ingredient industry is a derivative. 5) The impact of economic development in emerging regions. This will put more pressure on availability and price of traditional resources. These are all strong drivers that fuel the biobased economy.

In addition to the abovementioned themes, there also is a growing awareness with companies and consumers that we will have to transform our current economy into a more circular economy. The biobased economy suits a more sustainable way of life, not just important for today's population. Next generations also need an earth they can live on and experience quality of existence.

2.2 Challenges

On the other hand, while R&D activities have created the potential and basis for a technology push, there is limited market pull to propel an actual biorefining industry. There are multiple reasons for the current situation: 1) Regulations that are in place may obstruct the development of the biorefining industry. E.g. renewable energy acts that favor subsidization of bioenergy thus distorting market prices. 2) Biobased products need to compete with well-established fossil-based value chains. I.e. amortized infrastructures; economies of scale; well-developed markets and market positions. 3) There is a lack of incentives. Companies and consumers decide mostly on economic criteria. Moreover, it can be difficult to demonstrate short term benefits for all companies involved in the long supply chain. 4) And last but not least, there's a regional factor to be taken into account. Crops vary per region and therefore cost of logistics and varying feedstocks may hinder large scale exploitation. A decentralised biorefinery implementation model (middle-size and numerous biorefineries) would allow to better address the biomass transport issue, which is much more complicated than in the traditional petrochemical industry, due to the low density of biomass. These challenges have to be overcome in order to develop a sustainable biorefining industry.

3 BIOREFINING AT ROYAL COSUN

3.1 The definition of biorefining

There are many definitions of biorefining, like the one provided by the US Department of Energy in 1997: "A biorefinery is an overall concept of a processing plant where biomass feedstocks are converted and extracted into a spectrum of valuable products", visualized in Figure 2. According to the National Renewable Enery Laboratory [1], "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 creation of a new biobased industry. By producing multiple products, a biorefinery can take advantage of the differences in biomass components and intermediates and maximize the value derived from the biomass feedstock."

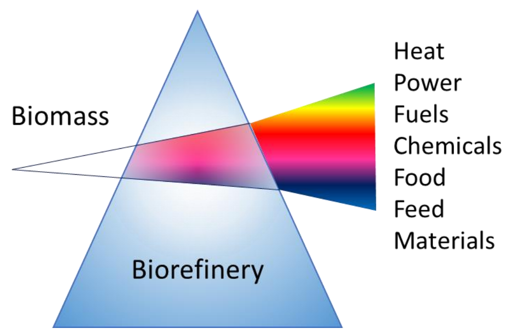

Figure 2: Schematic representation of the biorefining concept.

3.2 Biorefining of sugar beet pulp

Sugar beet pulp is a major residual stream from the sugar beet industry (Fig. 3). It accounts for approximately 13 million tons annually in Europe only and is currently valorized as low value animal feed, green gas or left on the land as fertilizer [2].

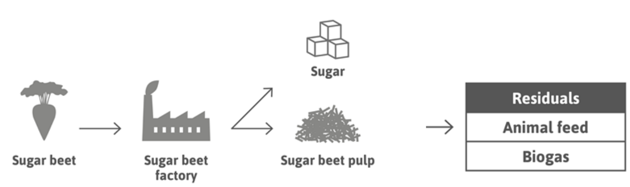

Figure 3: Traditional value chain for sugar beet.

Biorefining of sugar beet pulp is the way forward and therefore Royal Cosun decided to invest in an integrated and cost-effective cascading biorefinery to refine sugar beet pulp and isolate high value components for use in a great variety of end products including detergents, paints, coatings and composites, but also for application in the personal care, oil and gas industry. The overall objective is to establish the value chains based on microcellulose fibers, arabinose and galacturonic acid in high value markets (Fig. 4). Cumulative these three constituents account for 65% of the mass of sugar beet pulp. The residuals of the biorefinery are still suitable to generate biogas. Regional factors have been taken into account since sugar beets are grown on large scale in the area surrounding the biorefinery.

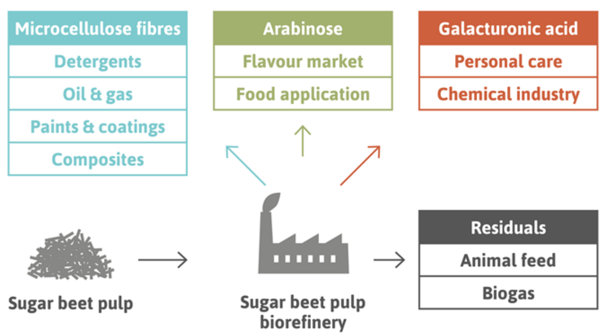

Figure 4: Biorefing of sugar beet pulp.

4 BIOBASED PRODUCTS PORTFOLIO

Royal Cosun has commercialized several biobased products such as carboxymethyl inulin and cationic inulin. In 2015 Cosun has invested in an industrial production facility for microcellulosic fibers and powdered sugar beet pulp. And at the moment Cosun is preparing for industrial manufacturing of L-Arabinose and galacturonic acid.

4.1 Cellulosic materials

Our patented microcellulosic fibers show unique structuring and particle carrying properties in for instance laundry detergents and oil drilling fluids. It is a 100% natural biopolymer and has not been chemically modified. The microcellulosic fibers deliver high zero shear viscosity at low dosage levels and have extraordinary particle carrying properties. More importantly, these properties of the microcellulosic fibers are maintained under challenging conditions, including high temperatures, at high and low pH values, at high ionic strength and in the presence of oxidizing or reducing agents.

Sugar beet pulp is rich in cellulosics and pectins. In dry powdered form it shows remarkable water binding properties and could be used as a free water binding agent in powder premixes or tablets. In addition, through swelling powdered sugar beet pulp can aid fast disintegration of a tablet in water.

4.2 Arabinose and other rare sugars

L-Arabinose is a novel health food ingredient that reduces the glycemic index and insulin response of sucrose through sucrase inhibition in the small intestine. The effects demonstrated are 30-60% reduction of the glucose (Fig. 5) and insulin peak after sucrose digestion [3, 4]. At the same time the glucose produced is released into the body more gradually and thereby lowers the Glycemic Index of the sucrose from 65 to 45. A low glycemic diet may have benefits like reduction of heart disease, lowering of blood cholesterol, management of body weight and composition, and prevention of type 2 diabetes.

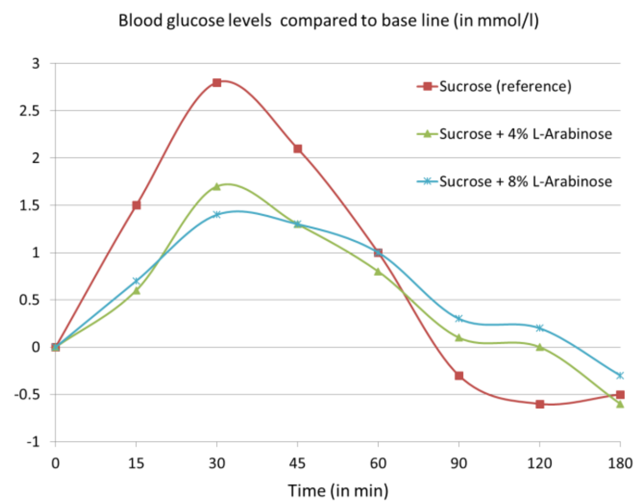

Figure 5: Effect of L-Arabinose on blood glucose.

L-Arabinose is a versatile and reactive sugar that is also being used for applications in flavors as reducing sugar in Maillard reactions. Moreover, L-Arabinose is an intermediate for synthesis of surfactants. Other rare sugars that can be obtained from sugar beet pulp are for instance rhamnose, mannose and galactose.

4.3 Galacturonic and galactaric acid

Galacturonic acid is directly derived from the pectin of the sugar beet pulp. Through a patented catalytic oxidation process, galacturonic acid can be transformed into galactaric (or mucic) acid. Galactaric acid itself has various functionalities such as pH control and chelation that make it suitable to use as a natural organic acid in for instance personal care products. However, it also is considered a platform building block. From this central key intermediate a number of chemical building blocks can be produced that can be applied in various applications in the chemical industry. More details can be found in Chapter 5.

4.4 Inulin derivates

Cosun has commercialized inulin derivatives such as carboxymethyl inulin and cationic inulin, which are based on the polysaccharide inulin, extracted from chicory roots.

Carboxymethyl inulin has been applied for many years as an carbonate and sulfate scale inhibitor in various industrial applications, such as detergents, oil and gas, water treatment, paper and pulp and drinking water. Its excellent safety profile, renewable origin, biodegradability and being both phosphorus and nitrogen free are all clear advantages in terms of sustainability and will help to prevent future legislative issues arising [5].

Cationic inulin has, like other cationic polymers, the ability to adsorb on surfaces and consequently charge a surface positively or to neutralise negatively charged surfaces. Hence, its obvious fields of application are fabric care (softening) and hair care (conditioning), but it can also by applied as coagulant in water treatment and separation processes [5].

5 CHEMICAL BUILDING BLOCKS

The strategy of Cosun is to identify unique molecular structures and convert these molecules into new chemical building blocks with unique and new functionalities. With galacturonic acid as starting molecule, Cosun has developed several building blocks which can be classified as di-acids, di-ols and di-amines with rigid, cyclic structures for the application in high performing engineering plastics. The following industrial and consumer applications are researched:

- Packaging materials
- Household appliances
- Automotive parts
- Coatings & resins

Cosun's chemical building blocks can also be used as starting point for the development of new chemical products and additives such as biobased surfactants, chelants and plasticizers. Several projects with external partners from the industry and academia are pending to determine the opportunities.

6 BACKGROUND INFORMATION ROYAL COSUN

Royal Cosun is a Dutch agro-industrial cooperative. Our ambition is to optimally use vegetable raw materials. We manufacture ingredients for food, non-food applications and the chemical industry. In addition, Royal Cosun is a proud partner in Pulp2Value governed by the Bio-Based Industries Joint Undertaking, which is a new €3.7 billion Public-Private Partnership between the European Union and the Bio-based Industries Consortium [2].

As member and project leader of the Pulp2Value project Cosun Biobased Products has an extensive R&D program in place to develop a production processes and applications for microcellulosic fibers, L-Arabinose and galacturonic acid.

REFERENCES

[1] National Renewable Energy Laboratory, http://www.nrel.gov/biomass/biorefinery.html, Mar 2016

[2] PULP2VALUE, Processing Underutilised Low value sugar beet Pulp into VALUE added products, http://pulp2value.eu/, Mar 2015

[3] Krog-Mikkelsen I, Hels O, Tetens I, Holst JJ, Andersen JR, Bukhave K. The effects of L-Arabinose on intestinal sucrase activity: dose-response studies in vitro and in humans. The American Journal of Clinical Nutrition. 2011 August 1, 2011;94:472-8

[4] Inhibition of intestinal disaccharidase activity by pentoses, Halschou-Jensen et alii, Aug 2013

[5] G. van Engelen and H. Raaijmakers, Harvesting the Sun, Speciality Chemicals Magazine, May 2012