Small-scale Integrated BIOrefineries

SMIBIO Project Ref. ELAC2014/BEE0249

D.1.1
Report on Selection of Business Case Studies

February 2017



The SMIBIO project is implemented in the framework of ERANet-LAC, a Network of the European Union (EU), Latin America and the Caribbean Countries (CELAC) co-funded by the European Commission within the 7th Framework Programme for Research and technology Development (FP7).

About the SMIBIO project

The aim of the SMIBIO project is to study the technical economic and environmental viability of small-scale integrated biorefinery units capable of processing different kinds of biomass produced in short radius catchments of rural and small urban areas, both in Europe and in LAC countries. The biorefinery concept to be developed is a highly integrated, energy efficient complex, incorporating individual processes (lignocellulosic biorefinery for ethanol, sugars and lignin for further biological/chemical conversion and wet biomass for biogas through anaerobic digestion) that synergistically convert different biomass feedstocks (dry and wet) into power, biofuels and value added chemicals and biomaterials. These small-scale biorefineries will be able to use a biomass–feedstock mix to produce multiple products by the integration of various technologies with the objective of creating new employment opportunities, generating new economic incomes and contributing to reduce environmental impacts in rural LAC and European regions.

Further information about the project and the partners involved are available under www.smibio.net.

Project coordinator

Project partners

About this document

This report corresponds to D1.1 (Report on Biorefinery Conceptual Design and Selection of Business Case Studies) of SMIBIO. It has been prepared by: Ana Susmozas and Mercedes Ballesteros (CIEMAT). Other contributions include LNEG, UNC, PUCV, IBt-UNAM and WIP.

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1 Introduction

SMIBIO is a three-year research project funded by the first ERANet-LAC Joint call. The aim of the project is to study the techno-economic and environmental viability of small scale integrated biorefinery units capable of processing different kinds of biomass produced in short radius catchments of rural and small urban areas, both in Europe and in LAC countries.

The project focuses on modelling five case studies under proper and real conditions, considering optimal processing of local biomass in each selected region (two in Europe and two in LA). Biorefinery concepts to be developed are highly integrated energy efficient complexes, incorporating individual processes that synergistically convert different biomass feedstocks (dry and wet) into power, biofuels and value added chemicals and biomaterials by the integration of various technologies for the efficient production of a portfolio of bio-based products.

This deliverable describes the four biorefinery concepts, agreed upon by the whole consortium that will be analyzed under proper and real conditions. Furthermore, as it was decided at the kickoff meeting, an additional case study based on residues generated in the Colombian coffee industry will be analyzed. The selection of base case areas was made considering different biomass availability in Europe and Latin America and market needs for bioproducts selection. The Case Studies are based on real available biomass in the radius of maximum 50 km from the particular place in the given country. Each biorefinery concept involves both Lignocellulosic Biomass (LC) and Anaerobic Digestion (AD) platforms. The techno-economic and environmental assessments of the five biorefinery concepts will be developed using available modelling tools such as ASPEN software and will be based on material and energy flow balances obtained by modelling the whole value chain from biomass supply to bioproducts production.

The following biorefinery systems were selected:

(i) cereal residues and swine manure (Portuguese and Chilean cases),

(ii) olive residues and wastewater from olive oil extraction (Spanish case),

(iii) agave bagasse and tequila´s industry stillage (Mexican case),

(iv) grass clippings and grass-like garden waste stillage (German case) and,

(v) coffee residues and mucilage (Colombian case).

2 Cases studies definition

2.1 Cereal residues and swine manure based biorefinery

Taken into account the location of the biorefinery, two parallel cases studies are included, one located in Portugal and another one located in Chile.

- Portugal case study: this biorefinery uses as dry biomass feedstock the corn stover available in Chamusca region (30,000 – 100,000 ton/year) and swine manure (303 m3/day) as wet biomass. Corn is the major cereal crop in Portugal where particular conditions for its cultivation can be found. In Portugal around 110 thousand hectares are dedicated to corn cultivation and the productivity can reach up to 14 ton/ha. This production is mainly concentrated in certain geographical areas. One of this is Chamusca region where corn is also the major crop of an associated partner of this project. Corn cultivation also generates an important amount of residues (corn stover) that can reach up to 80% of corn grain and that is available as biorefinery feedstock. Associated to agriculture crops there are also livestock farms producing important amounts of swine manure that need to be treated and is available for energetic valorization.

Through this biorefinery design, the following bioproducts could be produced: ethanol, pentoses molasses, biogas, xylooligosaccharides (XOS), xylitol and residual lignin. Lignin could be used for power production.

- Chile case study: the feedstocks considered are: wheat straw, as dry biomass, and swine manure, as wet biomass. Both are available in the Araucanía region. Total cropped land of cereals is distributed in different regions as follows: 34% Araucania, 25 % Bío-Bío, 17% Maule, 13% O´Higgins and 11% other regions. Within the Araucania the cropped cereals are: 59% wheat, 34% oat and 11% other cereals. Total cropped area of wheat during the period of 2014 to 2015 was around 110.000 hectares with an annual wheat production of 600.000 tons. For a harvest index of 0.45 a total of 730.000 tons of wheat straw per year could be produced in the Araucania region, but assuming an availability factor of 0.75 around 550.000 tons of wheat straw could be potentially exploited. On the other hand, a livestock farm located at the Victoria town (Araucania region) produced every day around 120 m^3 of excreta, which could be transformed into biogas, which could in turn be used for energy cogeneration.

In this case the potential products considered are butanol, acetone and ethanol (or isobutanol, or isobutene), biogas and stabilized sludge which can be used as fertilizer.

2.2 Olive residues and wastewater from olive oil extraction based biorefinery

This case study is located in Spain. The raw materials considered are residues from olive oil industry. This industry has been selected due to its economic importance, mainly in the Mediterranean countries. In fact, there are about 9.98 million hectares dedicated to the cultivation of olive trees in the world. Mediterranean countries account for around 97% of world olive crop area and Spain is the world's biggest olive producer. Besides olive oil (main product), olive oil industry produces a great amount of other by-products or residues, e.g., olive tree pruning, olive stones, leaves, extracted pomace, and wastewater, which can be converted into a wide variety of bioproducts (antioxidants, bioethanol, mannitol, xylitol, etc.).

In this case study, the selected feedstocks are olive tree pruning and extracted pomace as dry biomass and wastewaters from olive oil extraction plant as wet biomass. Taking into account the amount of residues generated in olive industry (1,500 kg/hectare) in Andalucia region, the plant capacity considered is 30,000 ton/year of biomass. The main products obtained through this biorefinery are antioxidants, mannitol, oligosaccharides, xylitol ethanol, and lignin.

2.3 Agave bagasse and tequila´s industry stillage based biorefinery

This case study is located in Mexico. As reported by the Tequila Regulatory Council (CRT), approximately 360 thousand tons per year of dry agave bagasse are produced in the Tequila production area. Most of this residual lignocellulosic material is generated in the state of Jalisco, in the surroundings of Guadalajara City. According to preliminary studies performed by the Mexican SMIBIO team, the hydrolysis of sugar-polymers from this agave bagasse can generate approximately 95.3 thousand tons of fermentable sugars and the efficient fermentation of these sugars (pentoses and hexoses) to ethanol can reach 58.4 million liters of ethanol per year. As a first approach, the main products taken into account from this feedstock are ethanol, xylitol and furfural. A second approach will consider the use of the bacterium *Escherichia coli* as a microbial cell factory for bioethanol, D- and L-lactic acid, and succinic acid production, aiming to the production of organic acids with higher selling price than bioethanol to increase the potential profitably of small scale biorefineries.

2.4 Grass clippings and grass-like garden waste stillage based biorefinery

The location of this case study is Germany. In this case 15,500 ton/year dry and wet biomass (1,000 ton grass clippings and 14,500 ton grass-like garden waste) are assumed to be a non-cost feedstock. The potential plant location is foreseen to be in the District of Straubing-Bogen, close to the city Straubing. As a base for the German Biorefinery process, the Green Biorefinery project from Austria is being considered which used especially grown grass-clover for further processing. The process proved the possibility to produce large amounts of lactic acid from grass. The main products that can be obtained through this base case are amino acids, lactic acid and biogas. The German case study includes sustainable feedstock availability (mainly waste grass to be used), suited conversion technology, legal context of such a plant and integration potential into the existing agro-industrial and agro-food processing value chains. If it can be proven that waste grass is a high-value feedstock then this would mean economic chances for many rural regions throughout the world.

2.5 Coffee residues and mucilage based biorefinery

This case study is located in Colombia. In this case, residues from coffee industries are assumed as raw materials. Coffee is the second most traded commodity in the world after petroleum. In the coffee process is estimated that less than 5% of the generated biomass is used in the production of the beverage and the remaining fraction represents lignocellulosic materials such as leaves, branches and stems, which could be exploited to produce bioenergy and bioproducts. In addition, coffee processing produces some residues, such as mucilage (15%), fresh pulp (44%), dry coffee husk (4%) and coffee grounds (10%), which could be used in the production of high added-value products. In Colombia, an average of 17 ton per hectare per year of dry wood can be obtained and 55,500 ton of fresh mucilage are generated per million of 60 kg-bag of coffee that are exported.

In this case study, the feedstocks considered are coffee cut stems as dry biomass and mucilage as wet biomass. The main products obtained through this biorefinery design are bioethanol, polyhydoxybutyrate (PHB), furfural, xylitol and heat and power. The anaerobic of mucilage produces biogas as main products, however due to the high Dissolved Organic Carbon removal performance, the treated water from the mucilage can be used in the lignocellulosic biorefinery to mitigate the high water requirements of the fractionation processes.