Press release

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The European project BIOCORE delivers an important result and reaches a milestone: the pilot scale production of 2nd generation bioethanol

The rarefaction of fossil energy resources and climate change are favoring the replacement of fossil carbon by renewable carbon. In this context, lignocellulosic biomass is a promising resource, as long as it can be used in a sustainable way. INRA, coordinator of the European project BIOCORE, in association with two industrial partners of this project CIMV S.A. (Levallois Perret, France) and DSM Bio-based Products & Services B.V. (Delft, The Netherlands), announces the successful pilot scale production of 2nd generation bioethanol from wheat straw. This achievement demonstrates the feasibility of 2nd generation bioethanol production and ultimately opens the way towards the production of polymers, such as PVC, from renewable lignocellulosic biomass. In general terms, the technologies that are being developed in BIOCORE favour the use of non-food resources, these being either non-food residues of food crops or woody biomass.

In the framework of the Euopean project BIOCORE, collaboration between the companies CIMV and DSM has led to the production of 2nd generation bioethanol from wheat straw. The result constitutes a key step in the BIOCORE project, which aims to demonstrate the feasibility of producing 2nd generation bioethanol as precursor for materials such as bio-PVC, from non-food lignocellulosic biomass. To achieve this, CIMV first converted wheat straw into cellulose, hemicellulose and lignin (*i.e*. the three major components of non-food lignocellulosic biomass) using its pilot facility located in Pomacle (Marne, France) and supplied DSM with refined cellulose. Using proprietary thermostable enzymes, DSM (located in Delft, The Netherlands) converted the cellulose into glucose, which was then used as feedstock for fermentation converting the glucose into bioethanol. In a final step, Arkema S.A. will use the 2nd generation ethanol to produce ethylene, which is a precursor of PVC.
"*We are extremely satisfied with this collaboration with DSM, which has allowed us to clearly demonstrate the power of our cutting edge organosolv technology for biorefining of non-food, lignocellulosic biomass*" explained Thierry Scholastique, CEO of CIMV. "*Today, thanks to the BIOCORE project, which puts our technology at the heart of the biorefinery process for the pretreatment of biomass, and to the various BIOCORE partners who are currently working on the three biomass fractions arising from our process, we have made a critical step towards the future industrialization of our technology*".

For DSM this pilot-scale production of bioethanol derived from non-edible feedstocks was an anticipated result. Oliver May, R&D Director DSM Bio-based Products & Services is delighted with this next step. *"We are extremely excited about the BIOCORE project which brings various technology and value chain partners together to speed up innovation enabling efficient use of cellulosic feedstock. This is our future and the project results confirm that together with our partners, we are on the right track to deliver a robust bioethanol process based on wheat straw. The thermostable DSM enzyme mix performs very well on the pretreated feedstock and combined with our strong yeast technology as well as operational experience of the Delft pilot facilities we are reaching commercially attractive bioethanol yields and the required high product quality for materials applications."*

According to Dr. Michael O'Donohue, coordinator of BIOCORE, this success is the logical result of the highly positive, dynamic atmosphere that reigns within the project's consortium, which is formed by 25 partners from 13 different countries. *"Today, progress in BIOCORE is excellent and several innovations are in the*

pipeline. The production of 2nd generation bioethanol is symbolic of this progress and reaching this milestone earlier than expected is highly motivating".

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- presentation of CIMV
- presentation of DSM

Questions to Michael O'Donohue, deputy manager of CEPIA, an INRA division, and scientific coordinator of the European project BIOCORE :

Why is this milestone important for BIOCORE ?

BIOCORE is an ambitious project that aims to clearly demonstrate the suitability of certain advanced technologies for the industrial transformation of lignocellulosic biomass into useful products such as fuels, chemicals, materials and food ingredients. Today, one of the major hurdles that must be surmounted to achieve this goal is the extreme complexity and resistance of lignocellulosic feedstocks, which makes the extraction of cellulose difficult, if one wishes to avoid the concomitant reduction in the economic potential of the other components (in particular hemicelluloses and lignins).
By reaching this milestone, BIOCORE partners have successfully risen to this challenge, because the extraction of cellulose from wheat straw was accompanied by the production of a pilot scale batch of high quality Bio-lignin™ (lignin from the CIMV process), which can be used for the production of plastics or resins and a similar sized batch of hemicellulose-rich syrup, which after further purification, will be suitable for use as a feedstock for biotechnological processes that will manufacture for example xylitol, an added value food ingredient.
Reaching this milestone is also important because it provides an unambiguous validation of previous laboratory scale R&D work that focused on organosolv refining of biomass and on the development of novel enzymes for cellulose hydrolysis. By testing the different unit process operations at pilot scale, it will now be possible to provide a complete appraisal of the value, from the up-front feedstock conditioning process through to the final distillation and production of ethanol.
Final, the early delivery of this result is highly promising for BIOCORE, because it leaves ample time for Arkema S.A. to pursue its R&D and pilot scale activities, which aim to demonstrate how wheat straw can be converted into PVC, via the production of ethanol, which will serve as a PVC intermediate. Moreover, this serves to underline the fact that BIOCORE is not limited to the production of biofuels, but rather aims to produce a wide range of products from biomass, including many of the polymers that are needed for the manufacture of numerous objects of daily life (e.g. plastic flooring systems, insulating materials etc).

Why is 2nd generation ethanol better than 1st generation ethanol?

Ethanol produced from food commodities, such as sucrose (extracted from sugar beet in Europe) or grain wheat, is often rejected by public opinion, because of the direct competition that it creates with food supply. Moreover, the manufacture of 1st generation biofuels constitutes a sub-optimal use of plants, because only a part of the harvested crop is actually used, and thus precious resources such as energy, water and fertilizers are wasted. Also, it is likely that massive industrialization of 1st generation biofuels at a global scale, using food crops as the feedstock, will lead to high food prices and even food shortages, notably in under-developed countries. For all of these reasons 2nd generation bioethanol represents a major progress, because not only can it be made either from the non-food components of food crops (e.g. wheat straw) or from non-food resources such as wood, but most analyses indicate that 2nd bioethanol procures major reductions in GHG emissions, mainly due to the better use of resources.
As illustrated by the BIOCORE project, INRA's strategy is clearly orientated towards a food and fuel scenario, rather than the food or fuel one, which is to some extent represented by 1st generation biofuels. In BIOCORE, technologies are being developed that will optimize the use of the incoming biomass resources, on one hand, by using unused, residual biomass such as crop residues and, on the other hand, by using woody biomass produced by forests or via the cultivation of energy crops.

BIOCORE has now been running for 18 months. Are there any other results yet?
Obviously, the initial phase of BIOCORE was dedicated to getting things up and running, which is not an easy thing when a project involves 25 partners from 13 different countries! Nevertheless, for several months now a steady flow of results have been working their way along the innovation pipeline and some exciting results are expected in the near future.
Concerning the organosolv process that is under development in CIMV, work performed within the framework of BIOCORE has shown that this technology also performs very well with rice straw, birchwood and short

rotation coppice poplar. Moreover, during the start-up phase of the project, BIOCORE researchers have identified a possible way to introduce resinous wood biomass into the CIMV process. If this novel strategy is confirmed, then the CIMV will acquire extremely wide coverage in terms biomass refining.

Numerous activities have been focused on the Bio-lignin™ fraction, obtained after biomass refining, and results are highly encouraging. Despite the fact that lignins are generally considered to be difficult to valorize, in BIOCORE we have shown that Bio-lignin™ can be used to manufacture several types of products including polyurethane foams, which can be used as insulating material, or polyurethane elastomers that can be used for electrical cabling. Indeed, Synpo (Czech republic) has shown that the incorporation Bio-lignin™ into a conventional polyurethane elastomeric formulation provides a new material whose tensile strength, hardness and surface resistance are increased by factors of 2.5, 3.5 and 1.5 respectively.
Also working on Bio-lignin™, the company Chimar Hellas (Greece) has shown that these molecules can be incorporated into phenol-formaldehyde glues used to manufacture wood panels. The result is commercial grade wood panels that display excellent mechanical properties, use less fossil resources and contain less formaldehyde.
Finally, researchers in the Catholic University of Leuven (Belgium) have developed a ‘one-pot’ reaction that converts CIMV cellulose into polyols, molecules derived from sugars, which are widely used in both the food industry and for the manufacture of polymers. The process involves a bifunctional catalyst and operates at very yield and productivity, producing sorbitol as the major product.

BIOCORE (« BIOCOmmodity REfinery ») in brief

Today, concerns linked to climate change and Europe's excessive dependency on fossil resources are providing the necessary impetus for Society's transition towards a new economy that will use biomass as its primary source of carbon and energy. In this respect, biomass (plant and animal-derived resources alike) and is completely unique, because it is the only naturally renewable energy source that can also supply carbon for the production of the chemicals and products that are vital for our daily life.

The EU project BIOCORE, managed by INRA, has been built to conceive and analyze the industrial feasibility of a biorefinery concept that will allow the conversion of cereal by-products (straws etc), forestry products and short rotation woody crops into 2nd generation biofuels, chemical intermediates, polymers and materials.

The first challenge for BIOCORE is to demonstrate the feasibility of an advanced biorefinery operation that uses diverse biomass feedstocks. To achieve this, activities in BIOCORE are focusing on important areas, such as feedstock supply, using a case study approach, which accounts for variations in biomass type and annual availability, and transport logistics. Case studies are currently underway in several European regions and in India.

From a technical point of view, BIOCORE is developing and optimizing a series of technologies to perform the different stages of lignocellulosic biomass refining and to extract maximum value and products from available resource. Regarding the initial extraction of the biomass components: cellulose hemicellulose and lignin, BIOCORE is using patented technology developed by a French company (CIMV S.A.), which supplies the three fractions as refined platform intermediates. To further transform these into useful products BIOCORE partners are focusing on a variety of chemical, thermochemical and biotechnological processes that will lead to the production of a wide range of products including 2nd generation ethanol and other chemicals that can be used to make polymers (bio-PVC, bio-polyolefins, polyurethane, polyesters etc), detergents, food ingredients and wood panels.

Beyond the development of individual processes and technologies, BIOCORE is also in the business of demonstrating feasibility of value chains. Focusing on a certain number of mature technology that form part of the BIOCORE portfolio, pilot scale testing is being used to further establish industrial feasibility in conditions that are close to the market. Additionally, process engineering is being used to model the whole BIOCORE biorefinery process and to scope for process optimization, notably through unit operation integration, the reduction of energy consumption and the reduction and/or recycling of waste streams.

Finally, beyond the performance of unit operations and manufacturing efficiency, tomorrow's biorefineries will have to conform to all of the criteria of sustainability, which take into account environmental, economic and sociopolitical impacts.

Therefore, BIOCORE researchers are analyzing the whole of the biorefinery process, from the production of the feedstock through to the ultimate use of the biorefinery products, using a variety of assessment methods in order to ensure that a comprehensive appraisal of the benefits of the BIOCORE concept will be available at the end of the project.

List of BIOCORE partners

N°	Organisation name	Short name	Country	Organisation type
1.	Institut National de la Recherche Agronomique	INRA	France	Res
2.	Valtion teknillinen tutkimuskeskus	VTT	Finland	Res
3.	Energy research Centre of the Netherlands	ECN	The Netherlands	Res
4.	Compagnie Industrielle de la Matière Végétale	CIMV	France	SME
5.	Chimar Hellas AE	Chimar	Greece	SME/end-user
6.	Arkema SA	Arkema	France	MNI/end-user
7.	National Technical University of Athens	NTUA	Greece	HE
8.	Institute for Energy and Environmental Research Heidelberg	IFEU	Germany	Res
9.	Katholieke Universiteit Leuven	KULeuven	Belgium	HE
10.	Syral SAS	Syral	France	MNI/end-user
11.	SYNPO, akciová společnost	Synpo	Czech Republic	Res
12.	Stichting Dienst Landbouwkundig Onderzoek	DLO	The Netherlands	Res
13.	Chalmers Tekniska Hoegskola AB	Chalmers	Sweden	HE
14.	Latvian State Institute of Wood Chemistry	IWC	Latvia	Res
15.	INRA Transfert	IT	France	Other
16.	The Energy and Resources Institute	TERI	India	Res
17.	CAPAX environmental services	CAPAX	Belgium	SME
18.	nova-Institut *GmbH*	NOVA	Germany	SME
19.	Royal DSM N.V	DSM	The Netherlands	MNI/end-user
20.	Institut für Umweltstudien - Weibel & Ness GmbH	IUS	Germany	SME
21.	Imperial College London	Imperial	United Kingdom	HE
22.	Solagro Association	SOLAGRO	France	NGO
23.	Szent Istvan University	SZIE	Hungary	HE
24.	Tarkett SA	Tarkett	Luxemburg	MNI/end-user
25.	DSM Bio-based Products & Services B.V.	DBPS	The Netherlands	MNI/end-user

CIMV, a specialist of lignocellulosic biomass

Created in 1998, CIMV S.A. has used oil refining as a paradigm to develop a technology for the refining of lignocellulosic biomass. The CIMV process cleanly separates biomass into its major component parts and provides three platform intermediates for industry: Biolignin^{TM}, cellulose (C_6) and hemicellulose syrup (C_5). These intermediates, which can be considered as commodities, can be used to develop a variety of marketable products, thus replacing petrochemical commodities in many products of day to day life.

From the outset, CIMV has implemented a clear strategy that consists of IP protection, filing a total of 7 patents to date, and collaboration with academia and industry, in order to develop the potential of its IP portfolio. CIMV's participation in BIOCORE is coherent with this policy and provides CIMV with the possibility to place its biomass fractionation technology at the heart of an ambitious and comprehensive biorefining concept. In the BIOCORE project, CIMV technology constitutes the front-end process of a biorefinery scheme, which develops a large number of innovative value chains. Using both chemistry and biotechnology, BIOCORE partners are aiming to provide routes to a wide range of products for different market sectors.

CIMV : disruptive technology for lignin production and valorization

A pioneer in biorefining, CIMV is presently the only company that is able to extract the three major biomass components in an environmentally-friendly manner, and without degradation of the products (i.e. cellulose, hemicelluloses and lignin)

Importantly, a unique aspect of the CIMV process is the extraction of pure, sulphur-free lignin, whose structure and properties make it ideal for the replacement of numerous petro-based chemicals. CIMV's Biolignin™ can be used as a basic component for the formulation of numerous polymers and materials that are currently obtained using petrochemistry. The structure of Biolignin™ can be simply described as oligomeric phenol, but its properties are exceptional, allowing it to be used by BIOCORE researchers to create novel, added-value products. The consequences of the scientific and technical progress that is being made in BIOCORE will be considerable, because lignin represents approximately 20% of terrestrial biomass and has the potential to become the world's top-ranked biomass-derived commodity. Indeed, the industrial scale production of Biolignin™ will allow the manufacture of:

New wood glues for particle boards, plywood, and other 'zero formaldehyde emission' wood-based materials.
Phenolic resin substitutes for plastics and elastomers
Reactive, reinforcing phase that can be used to substitute for carbon black in plastic and elastomeric materials
New polyurethanes, polyesters et epoxy resins, whose property will be identical or superior to their petrochemical equivalents

Regarding CIMV cellulose, this can used as pulp to manufacture paper whose quality is equivalent to commercial hardwood pulp. Nevertheless, CIMV cellulose can also be used to manufacture industrial and food-grade glucose, which will be a key commodity for industrial biotechnology, notably for the production of 2nd generation ethanol, a process that has been demonstrated by our partner DSM.

Finally, CIMV hemicellulose syrup can be used as a source of xylose, which is also set to become a major industrial commodity that can be used as a feedstock for the production of xylitol, furfural, and derivatives thereof, and 2nd generation bioethanol.

An industrial project

Over 50 pilot runs have now been successfully completed using the CIMV's pilot unit, located in Pomacle (France). These have allowed us to achieve preindustrial validation. For the future, CIMV has charged the TECNIP group with the responsibility of industrialization, and two projects are currently under study, one in France in a cereal production zone and the second in the USA, in collaboration with industrial leaders of the sector.

Biomass valorization

Today, the development of bio-fuels and green plastics using agricultural commodities is in direct competition with the food supply chain and has already led to steep price increases in food commodities.

In contrast, the feedstocks used in the CIMV process are non-food biomass, being either co-products of cereal crops (straws, bagasse, cobs etc), forestry products or energy crops (e.g. short rotation poplar, hemp, Miscanthus etc). Therefore, the CIMV process will contribute to a more efficient use of agricultural resources and a more optimized use of available land.

For more information: www.cimv.fr

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DSM Bio-based Products & Services, a solution provider for sustainable production of biofuels and biobased platform chemicals

DSM - Bright Science. Brighter Living.(TM)
Royal DSM N.V. is a global science-based company active in health, nutrition and materials. By connecting its unique competences in Life Sciences and Materials Sciences DSM is driving economic prosperity, environmental progress and social advances to create sustainable value for all stakeholders. DSM delivers innovative solutions that nourish, protect and improve performance in global markets such as food and dietary supplements, personal care, feed, pharmaceuticals, medical devices, automotive, paints, electrical and electronics, life protection, alternative energy and bio-based materials. DSM's 22,000 employees deliver annual net sales of around € 9 billion. The company is listed on NYSE Euronext. More information can be found at www.dsm.com.

DSM has a unique position in the development of second generation bioenergy and bio-based chemicals and materials (derived from agricultural residues and non-edible crops). DSM is the only company capable of offering both enzyme and yeast fermentation technologies to increase conversion rates to make the technology commercially viable.
Microorganisms such as yeast are essential to the biofuel production process as they are needed to convert the fermentable sugars generated by enzymes from biomass into ethanol. There are two primary classes of fermentable sugars that are liberated from cellulosic biomass during hydrolysis, six carbon sugars (C6) and five carbon sugars (C5). Typically yeasts only consume C6 sugars, but DSM's advanced yeast technology is capable of converting both C6 and C5 sugars to ethanol. DSM is the technology provider for the second generation biorefineries, providing thermostable enzymes to convert the biomass efficiently into a sugar mix and advanced yeast to convert the C6 sugars as well as the C5 sugars. DSM is convinced this will be a winning combination.
Within Biocore, DSM is bringing its expertise in the enzymatic hydrolysis of C6 / C5 (hemi)cellulose and conversion technology of C6- and C5-sugars into bioethanol. Also demonstration of enzymatic hydrolysis and fermentation tests at pilot scale are performed at the pilot plant of the DSM Biotechnology Center in Delft, the Netherlands.

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