PROFESSOR CARLOS VACA-GARCIA

Closing the loop on sustainable biomass

Professor Carlos Vaca-Garcia heads a well-established and highly successful chemical research facility that partners with agriculture and industry. Thanks to the support and insights of his mentor, the laboratory is engaging in revolutionary studies to produce truly green bioproducts

Could you introduce the French Laboratory of Agro-Industrial Chemistry (LCA)?

Since 1975, we have used physical and chemical methods to transform biomass (mainly from higher-order plants, but also from animals and microalgae) into useful products for different industries. We focus on the use of waste from the food chain and dedicated crops. Our bioproducts and the processes we develop are assessed to ensure minimal impact. This intersection with life cycle sustainability assessment is one of our main strenghts.

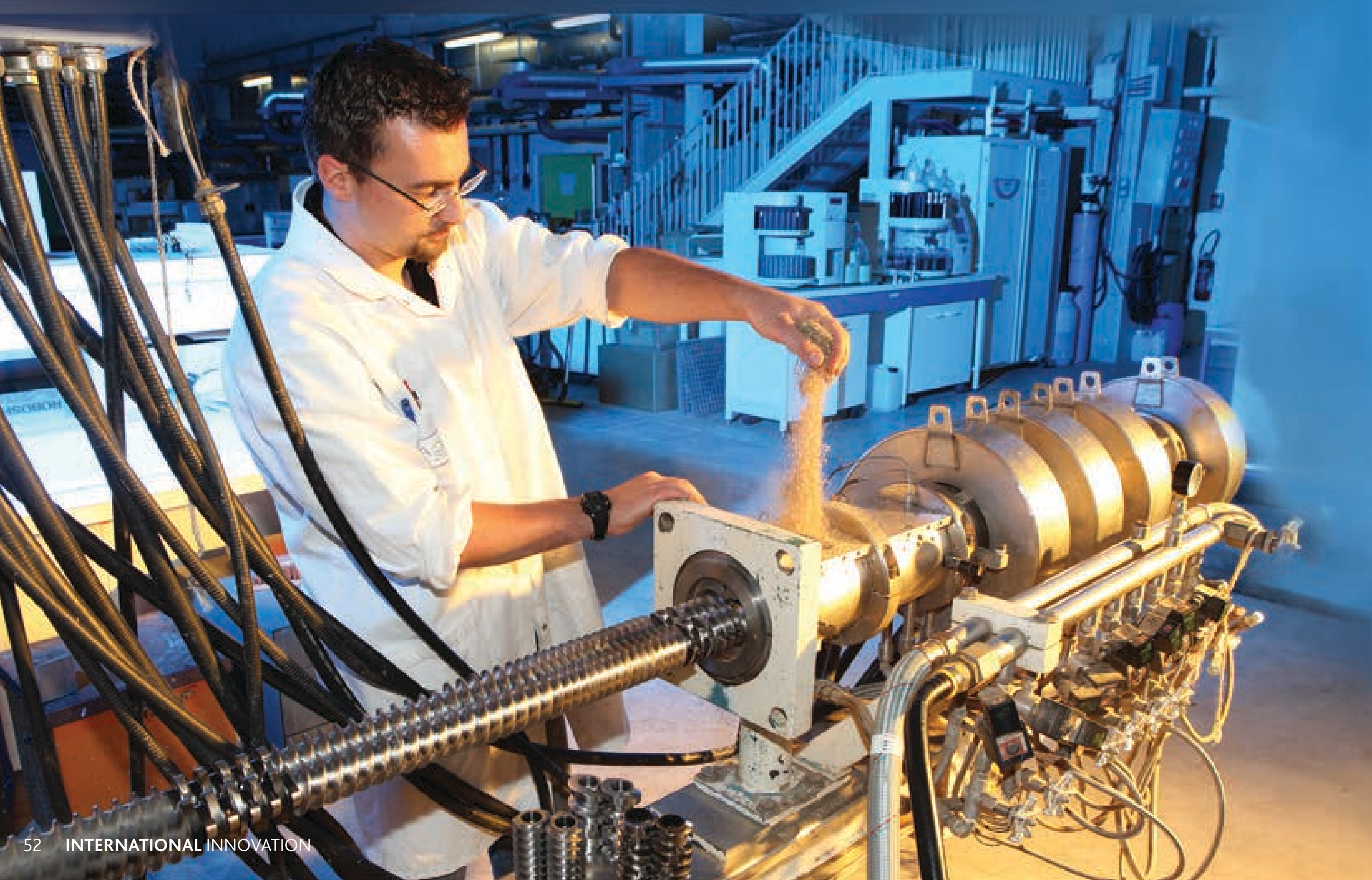
Another key asset is the strong link we maintain with industry, which prompts new ideas and provides financial support to most of our projects. It is wonderful to find that, thanks to this approach, we can develop not only applied but also fundamental research. We are mainly chemists and chemical engineers, so sometimes work in collaboration with biotechnologists to share expertise.

How did you come to develop an interest in chemistry and chemical engineering?

My brother was a professor in Chemical Engineering in Mexico. He gave me a taste for science and rational thinking. Later, working as an engineer in Mexico, I met Professor Antoine Gaset, Founder of LCA, who came to my research centre to give a conference. As a francophone, I acted as his interpreter and interacted closely with him. He invited me to pursue a PhD in Agro-resources Chemistry in his lab and I accepted. The opportunity was great experience and the start of a beautiful relationship with chemistry, Professor Gaset and my Lab.

Can you define a 'bioproduct', and describe their potential impact on humans and the natural environment?

I employ the EC's definition: 'a product obtained mainly or completely from biomass, no matter whether it was obtained by chemical or biochemical methods'. The evident advantage is the substitution of fossil-based raw materials, but we must ensure the use of sustainable transformation processes with minimal impact



to the environment. At present, this is not the case for many bioproducts. In my opinion, they have a negative impact on both the environment and the consciousness of the people who will discover, sooner or later, that making a plant-based bottle has a much larger environmental and social impact than making one from traditional polyethylene terephthalate (PET).

Could you provide a brief outline of LCA's 40-year history?

LCA started with a 20 m^2 lab which has now expanded to 3,600 m^2. The first important shift occurred in 1992 when we built a pilot transfer technology platform that intensified our link to industry. At the same time, a legal independent entity of about 10 people was created to establish a link with local and national SMEs. This structure, known as the Regional Centre of Innovation and Technology Transfer (CRITT), allowed us to create a strong symbiotic link with the regional economic network. Sometimes a small enterprise lacking the capacity to invest in research comes to the CRITT for a short prefeasibility study of an original idea. If the first results are encouraging, the CRITT helps them to find public funding for a long-term applied research project. The CRITT's Centre of Application and Treatment of Agro-resources (CATAR) naturally benefits from LCA's infrastructure, for instance. In the past 18 years, it has obtained and maintained the CRT label, a national quality label awarded by the French Ministry of Higher Education and Research.

A second jump, again thanks to a multi-partner grant, was in 2006, when a demonstration-scale platform called AGROMAT was built. Industrial equipment was installed, so now the French plastic industry can test the whole process of making a complex biomaterial from agricultural residues at real scale and obtain a pre-series of 1,000 pieces a day. I must stress that this spectacular progression is the fruit of Professor Gaset's endeavours.

How do you see LCA evolving over the forthcoming years?

For each solution we propose, we consider its clean industrial implementation. We do not want people in the future to say that we proposed false environmental solutions to our partners. This alignment will be strengthened and consolidated with social impact indicators (such as job creation and wellbeing in industry linked to processes). We want to be the first research laboratory to combine high expertise in biomass transformation with a systemic view of the global impact of our bioproducts.

Pioneers in **bioproduct** production

The Laboratory of Agro-industrial Chemistry at the University of Toulouse develops solutions to real-world problems – harnessing natural resources that create safe and sustainable bioproducts

THE CITY OF Toulouse in southwestern France has a rich agricultural tradition, and became internationally known for its production of woad (*Isatis tinctoria*), a flowering plant that has been used to produce blue dye (also known as woad or by the regional name 'pastel'), in the Middle Ages.

Pastel became widely used as a means of colouring fabrics during that time. However, in the late 19th Century, a means of synthetic manufacturing led to the global decline of the woad trade, and it remained static until recent consumer demand for more natural products, including dyes, prompted a resurgence in interest.

POWERFUL PARTNERSHIPS

The Laboratory of Agro-industrial Chemistry (LCA) at the National Polytechnic Institute of Toulouse saw this as a window of opportunity and initiated a programme of research and transfer with local company Bleu Pastel de Lectoure in response. A production platform was built shortly after the partnership began in 2001 to produce a range of different commodities based on woad – leather and textile dyes, car body paint, interior and exterior paints and glazes, cosmetics, gouache paints, watercolours and pencils – for a diversified and sustainable product base. LCA modernised the whole industrial process to improve control and reduce environmental impact, and established rural industrial activity.

LCA's wider mission is to counteract the issue of diminishing stocks of fossil carbon by substituting agro-renewable alternatives in the development of biomass based non-food products – materials, lubricants, fuels, additives, solvents and surfactants – via multidisciplinary partnerships with industry and agriculture. With a large research and transfer facility in Toulouse and an industrial demonstration platform called AGROMAT located in Tarbes, LCA is able to design and assess each and every stage of a bioproduct's life cycle and work across disciplines to validate new processes for manufacturing novel agro-materials or historically valuable plants such as woad.

DEVELOPING THE PHILOSOPHY

The LCA approach, termed 'intensified chemical design', follows the 12 Principles of Green Chemistry set out by Drs Paul Anastas and John Warner in 1998, and led in Europe by Professor James Clark from the University of York, UK, and range from waste prevention to explicitly designing energy efficiency and safety into the manufacturing process. Intensified chemical design simplifies and streamlines the production process while simultaneously minimising the generation of unusable products. Through a variety of chemical processes, the facility is able to break down industrial or agricultural products and bioproducts into their constituent parts, thereby producing high quality raw materials that biodegrade to greater effect and are relatively low in eco-toxicity compared to similar products on the market.

Fractionation of biomass, for instance, which is traditionally used to separate out essential oils, dyes (like woad), tannins, waxes, fats, proteins, sugars, polysaccharides and fibres is based on ecological thermal, chemical and mechanical techniques. Purification is then carried out mostly using solvent-free, water-based systems; destructuring, reassembly and restructuring of complex materials is later undertaken at macro, meso and molecular scales to modify fundamental chemical bonds and interactions. This confers new material properties, which are then adjusted to alter solubility, resistance to thermal stress, affinities with water or lipids and biological activity or biodegradability. Molecular modelling approaches are applied alongside this process to refine available options for substitutions or adjustments, so testing can be targeted and efficient.

A STRONG TEAM

Headed by LCA Director, Professor Carlos Vaca-Garcia, the 100 highly motivated staff include researchers, doctoral students and a support team who together secure competitiveness through leading-edge research and policy change. In 2007 Vaca-Garcia and his team were honoured

Intensified chemical design simplifies and streamlines the production process, while at the same time minimising the generation of unusable products

with France's Pierre Potier Award, a prize for chemistry innovations promoting sustainable development, working with the biggest French wood products company for six years to increase wood durability, using only bio-renewable, non-toxic compounds: "Our solution, applied to local but non-resistant wood, such as pine or beech, produces wood that is infinitely more termite-resistant than teak or other exotic wood for joinery or exterior applications," asserts Vaca-Garcia. "It was a commercial success, because we avoided toxic biocides and the resulting product will also last for at least 120 years without the need for maintenance (varnishing or polishing)." This groundbreaking process, which has the added benefit of reducing deforestation in Africa and Asia, involved chemically modifying sunflower oil.

The group later investigated the potential for oil cake – a bioproduct of sunflower oil, normally used for domestic animal feed – as a green product. Through physico-chemical transformation of the cake, they found it displayed plastic-like properties while retaining its potentialy valuable nutrients. The result was a biodegradable plant pot capable of nourishing both plant and soil.


Food waste used to make bioproducts.

SCALING UP THE BENEFITS

Vaca-Garcia attributes the achievements of LCA and its growing international reputation to the many successes achieved through synergies between pure and applied research: "Industry come to us with problems to solve, with research challenges to work on and with funding to allocate to projects in need". As a consequence, LCA projects typically explore the optimal transformation of biomass for a specific purpose to ensure associated fabrication processes are 'green'; evaluate the short- and long-term impacts of the final bioproducts; and determine the impact manufacturing processes have on human health, the environment, natural resources and economic sustainability. Each focal area is designed to transfer skills, knowledge and techniques from LCA to their industrial or agricultural partners.

Currently, European research projects are underway in Germany, Greece, Italy, Lithuania, Romania, Spain, Sweden, Switzerland and the UK, along with ongoing collaborations in Africa, Cuba, Mexico and the US. Training in biomass conversion and related topics is also provided to many national and foreign students. SMEs and large companies across the world are benefitting from this framework, including the high performance materials manufacturer Saint-Gobain, the vegetables processor Bonduelle and the chemical company Solvay.

HOLISTIC GREEN MANUFACTURING

When biofuel production began, biomass was used as a 'first-generation' source for conversion. However, this rapidly led to a food versus fuel debate and diversion of investment into more promising second or third generation alternatives. BABETHANOL, which aimed to develop a new process for obtaining energy ethanol from a wide range of sustainable second-generation materials, has been the LCA's contribution. Known as Hydrol, it can generate fuel from materials such as blue agave bagasse (a fibrous residue from tequila production), palm oil residues, corn cobs or barley straw, as well as any other lignocellulose material. The project was a partnership between the Lab, seven European organisations and six Latin American organisations.

Work at LCA continues to refine existing agricultural resources and uncover the potential of often underutilised or potentially harmful feedstock. Environmentally friendly products are key to long-term sustainability, but without the critique and expertise of facilities like LCA, the green credentials of biomass could be misunderstood and therefore used without completely understanding their chemical make-up. Vaca-Garcia concludes that teamwork without boundaries underpins the Lab's continuing success: "Research is, de facto, multidisciplinary and international. I never limit any international collaboration of my researchers; on the contrary I exhort them to intensify efforts and let natural affinities operate".

INTELLIGENCE

LABORATORY OF AGRO-INDUSTRIAL CHEMISTRY

OBJECTIVES

To generate knowledge in chemistry, chemical engineering and analytical engineering in order to develop transformation processes for renewable biomass leading to sustainable industrial bioproducts with reduced impacts on humans and the environment.

PARTNERS

National Polytechnic Institute of Toulouse (INPT), France

National Institute for Agronomic Research (INRA), France

FUNDING

Systematic funding from INPT and INRA provides 4 per cent of our operational budget corresponding to 35 per cent of LCA's consolidated budget (with salaries). The rest (€3-4 million) comes from competitive grants (public, semi-public and industrial).

CONTACT

Professor Carlos Vaca-Garcia
Director

Dr Gérard Vilarem
Deputy Director

Laboratoire de Chimie Agro-industrielle
UMR 1010 INRA / INP-ENSIACET
4, allée Emile Monso - BP 44362
31030 Toulouse Cedex 4
France

T +33 534 323 500
E lca@ensiacet.fr

www.chimieagroindustrielle.fr

CARLOS VACA-GARCIA is Full Professor at INPT, France, and Director of the Laboratory of Agro-industrial Chemistry. He completed his PhD at INPT and was a postdoctoral fellow at Kyoto University, Japan. His research activities focus on Chemistry and Chemical Engineering for the industrial transformation of different types of biomass.