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EPOBIO – Realising the economic potential of sustainable resources – bioproducts from non-food crops

EPOBIO WORKSHOP 2: Products from Plants – from crops and forests to zero-waste biorefineries

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Title of paper: CROP PLATFORMS FOR CELL WALL BIOREFINING - LIGNOCELLULOSE FEEDSTOCKS

EPOBIO Flagship: Plant Cell Walls

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Introduction

EPOBIO is an international project to realise the economic potential of plant-derived raw materials by designing new generations of bio-based products that will reach the marketplace 10-15 years from now.

EPOBIO is a "science-to-support-policy" project funded by the Framework 6 programme of the European Commission (EC). Partners from the European Union (EU) and United States (US), from academic research institutions and from industry, work together with an International Advisory Board of researchers, industrialists and policymakers. The aim is to ensure a robust and holistic evidence-base is established to inform future national and international decision-making. This "EPOBIO process" considers new science-led projects and products within a wider context of their environmental impact, economics, regulatory framework, social acceptability and expectations of the public and policymakers. This holistic process underpins strategic recommendations that constitute the major outputs of EPOBIO.

The security and cost of supply of fossil reserves, together with the environmental impacts of climate change, are driving the search for sustainable alternatives. A key issue that is emerging is the potential availability of very considerable energy resources locked in lignocellulose. The means to hydrolyse this lignocellulose in a cost-effective way is a major research focus globally that will underpin mass production of cellulosic bio-ethanol as well as the development of other bio-based manufacturing processes.

In terms of biorefinery technology, it will become increasingly essential to maintain the utility of other value products in the feedstocks from agriculture, forestry and marine biomass. In this way, integrated biorefineries with multiple output streams will open up many opportunities for sustainable development.

Lignin and cellulose are components of plant cell walls. The EPOBIO report “Crop platforms for cell wall biorefining – lignocellulose feedstocks” considers crop platforms in the context of the crops providing lignocellulose biomass in their cell walls for biorefining. The report complements "cell wall saccharification" prepared by EPOBIO in 2006 and available at www.epobio.net.

Executive Summary

Four sources of biomass of relevance to Member States of the EU are considered as case studies. These are poplar and willow, *Miscanthus* and wheat straw. These four potential industrial crop platforms for lignocellulose biorefining have been chosen as representative of woody species, grass and a co-product from arable crop cultivation.

For each of the crop platforms, the current state-of-the-art is reviewed with a detailed bibliography. The research and development (R&D) needs are identified in terms of the work that will need to be undertaken to achieve an optimised platform for large-scale cultivation/use in 10/15 - 20 years. It is anticipated that these crops will be used in the first instance for liquid biofuels, although in due course, the improved saccharification of lignocellulose biomass should lead to use of these feedstocks for production of platform chemicals.

Poplar: The use of poplar as an industrial crop platform has significant advantages due to the exceptionally strong supporting science-base. The genome is sequenced, the genetics are well characterised and a transformation system is available. This information and associated technologies will underpin rapid development of poplar, addressing many of the outstanding issues that need to be optimised. For example, our understanding of cell wall biosynthesis in woody species is limited but through elucidation of these synthetic pathways and metabolic flux control it is highly probable that poplar with cell walls more suitable for bioconversions can become available. In terms of weaknesses, there are only moderate yields of biomass in short rotation coppice and this could readily be addressed by identifying varieties with better coppicing ability. Susceptibility to rust infection is also an issue that requires addressing by increased R&D. Unfortunately breeding cycles for poplar are relatively lengthy, hindering rapid improvement of selected traits.

A significant issue facing all perennial crops is the timescales required to recover investment costs, as well as costs associated with recovery of the land if replaced by arable crop production. Whilst poplar undoubtedly has considerable potential to become

a biomass feedstock platform in Member States of the EU, the market will determine uptake relative to other biomass crops and land use competition with food crops.

Willow: Willow and poplar are very similar woody species, with the consequence that scientific understanding of poplar will automatically benefit understanding of willow. Classical breeding programmes to increase biomass yield and disease resistance are already in progress and should be further enhanced by the use of molecular tools and greater understanding of gene function gained from studies on poplar.

In terms of R&D needs, willow, as poplar, is extremely susceptible to rust. This risk to plantations needs to be addressed both by research and plantation management. The high water requirement of willow plantations is undoubtedly a weakness for cultivation in many low rainfall areas of the EU and may constitute a strategic issue in terms of changing climates.

Large-scale commercialisation of willow short rotation coppice is already practised with considerable experience already in place of plantation management. Willow short rotation coppice, particularly in the northern regions of the EU, presents a major opportunity to become a biomass crop.

Miscanthus: The perennial grass, *Miscanthus*, has substantial strengths in terms of yield potential and ability to grow successfully under low inputs of fertiliser and pesticides. *Miscanthus* is already recognised to present a considerable opportunity for bioenergy production, given parameters such as biomass yield and low inputs. However, its use for bioenergy is currently severely limited because the grass is not developed as yet as a crop for widespread cultivation.

Research needs are those associated with any plant species that is undeveloped as an agricultural crop. There are urgent needs to improve our understanding of the genetics of *Miscanthus*, to establish a robust breeding programme and to develop molecular tools for fast-track breeding. Research is also required to establish a robust genetic transformation system for *Miscanthus*. In this context, parameters for successful tissue culture systems need to be optimised for regeneration purposes.

In terms of agronomy, *Miscanthus* is not completely frost-tolerant, with particular issues in the first winter following establishment. Improvements to the crop are required to increase frost hardiness which in turn would greatly expand the cultivation areas suitable for *Miscanthus* across Europe. Whilst the grass has considerable yield potential, productivity under low input conditions is another target for improvement. Current practice is the use of rhizomes to establish *Miscanthus*. This is labour-intensive and new approaches, such as seed sowing, need to be optimised.

In terms of bioconversion, very much more work needs to be undertaken on understanding *Miscanthus* cell walls and the properties that determine ease of susceptibility to saccharification. Whilst clearly less developed than poplar and willow, *Miscanthus* undoubtedly offers opportunities in the 15-20 year timeframe to become a widespread biomass crop and it will be essential to undertake underpinning R&D in the near term to enable a successful outcome in the long term.

Wheat straw: Whilst wheat is a major developed grain crop throughout the world, R&D has focussed to date on its development as a food crop. There has been no breeding programme dedicated to its use as a bioenergy crop, nor to improvement of the wheat straw as a useful co-product for biorefineries. Since there is an excellent knowledge base globally available on wheat genetics, genomics and breeding, the platform is in place to develop alternative varieties with a view to optimising its use as an energy crop in entirety, and/or its use as a provider of wheat straw co-product for energy biorefineries. There are opportunities for the farmer in terms of added value of the crop if wheat straw does become a feedstock for cell wall biorefineries.

Strategic recommendations – science

Recommendations within this theme of industrial crop platforms must be viewed from the perspective of underpinning work that needs to be undertaken to ensure success in the market place in a 10/15 - 20 year time period. The energy efficient and effective hydrolysis of plant cell walls is key to realising the potential of biomass crops for biorefineries since new bioconversion methods will open up major opportunities for gaining additional value, beyond energy, from the biomass feedstock.

The science base of poplar and the fact that its genome sequence is known, provides an excellent foundation for the development of woody species for biorefining. Together with willow, short rotation coppicing of poplar offers many opportunities for the agricultural sector providing initial investment costs and the timeline to investment recovery are acceptable. Information on the synthesis and organisation of cell walls in these species with targeted studies to define properties of direct relevance to ease of hydrolysis would be highly beneficial as these crops are developed in the longer term.

Miscanthus undoubtedly holds great promise as a bioenergy crop for the future but studies are only beginning both to understand the molecular features of the grass, its cell walls and its optimisation for large-scale commercial cultivation. The decision to undertake the very considerable amount of R&D needed to bring *Miscanthus* up to speed, must be a strategic commitment to perennial grasses as an industrial crop platform in the EU.

Agricultural co-products as a feedstock for biorefining have the advantages of adding value to the main use of the crop. Thus the use of co-products from food crops – such as wheat straw, and in the US, maize stover – holds considerable commercial advantages. In examples of well-established global food crops the science base, genetics and breeding are highly advanced. The disadvantage is that it may well be problematic to improve the functionality of the co-product for biorefining whilst maintaining the high quality bred into the crop as a food feedstock over many generations. It will be a strategic decision, in terms of development of new feedstocks for energy and chemicals biorefining whether to disadvantage use and yield of crops for food production.

Strategic recommendations – policy

Our strategic recommendations on policy encompass six specific elements to ensure take up of the bio-based economy.

Policies must be coherent, integrated and coordinated. Integration in Brussels and Member States is essential to develop a policy framework that will support the bioeconomy. As the bioeconomy represents a potentially huge strategic development consideration should be given to applying a ‘bioeconomy test’ to policies in development, in the same way that policies are assessed for their sustainable development impacts.

Innovation in plant and industrial biotechnology should be supported. Clear research objectives and a framework to achieve them are essential. An adequate level of targeted funding, selecting those novel and innovative processes and products likely to achieve success in the market place and deliver environmental benefit, should be an element of this.

Policies should support development of the whole supply chain. This will need to consider feedstock supply, processing and the production of bioproducts. There is a need to both stimulate the market side and build on the foundation of the Common Agricultural Policy which has moved from production subsidy to market-orientated developments. Financing along the supply chain needs to be considered as one aspect of feedstock supply.

A communication strategy is essential. The acute lack of awareness of the bioeconomy and the potential of biotechnology at all levels in society must be addressed by a strategic communications campaign designed to raise awareness and create an informed acceptance of bioproducts. This will need to explain the benefits of the processes and products delivered by the bioeconomy.

Pilot projects have a role to play. The establishment of proof of concept and testing under industrial conditions is a key step in moving research into product development. Scale-up during the research phase can develop and test industrial processes and also help to develop stronger co-operation between industrialists and academics.

Measurable sustainability indicators should be developed. The absence of validated techniques for the measurement of sustainability benefits needs to be addressed. This is important as these gains need be evidenced to enable all stakeholders to understand the rationale for the development of the bioeconomy.

In addition, Common Agricultural Policy support for perennial crops is currently focused on the energy market with the single farm payment available if the energy crops payment is also claimed. In the future, the development of non-energy products from biorefining will be a major component of the bioeconomy. Permanent crops used as feedstocks for non-energy products would not, under current rules, be eligible for the single farm payment. This is an issue for urgent consideration by the European Commission.

Conclusion

The report has analysed woody species, a perennial grass and an agricultural co-product. Each of these alternatives have strengths and weaknesses and all will benefit from R&D development work in the immediate term to ensure a foundation for gaining maximum advantages from cell wall biorefineries in the mid to long term.

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