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Biotechnology and the bioeconomy—Towards inclusive and sustainable industrial development

Yvonne Lokko[a,*], Marc Heijde[b], Karl Schebesta[a], Philippe Scholtès[a], Marc Van Montagu[b], Mauro Giacca[c]

[a] Programme for Technical Cooperation, United Nations Industrial Development Organization, Vienna International Centre, P.O. Box 300, 1400 Vienna, Austria
[b] International Plant Biotechnology Outreach (IPBO), Technologiepark 3, 9052 Ghent, Belgium
[c] International Centre for Genetic Engineering and Biotechnology (ICGEB), AREA Science Park, Padriciano 99, 34134 Trieste, Italy

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ABSTRACT

To transform developing and least developing countries into industrialised ones, biotechnology could be deployed along the value chain, to provide support to the development of the bio-based industries in such a way to ensure sustainability of the sector and to reduce negative environmental impacts that might otherwise occur. In agribusiness development, for instance, interventions could start from inputs and agricultural mechanization, modern processing technologies, packaging of perishable products, the promotion of food safety in the processing and regulatory environment; and interventions to improve competitiveness and productivity. Worth over USD 300 billion in revenue, the role of the biotechnology goes beyond industrial growth, since it provides opportunities for progress towards many of the UN sustainable development goals (SDGs). This paper reviews the status of industrial biotechnology as it relates to inclusive and sustainable industrial development.

Contents

Introduction

Key industrial sectors that derive their raw material and/or key components along the value chain from natural resources and biological processes constitute the bio-based economy or bioeconomy. The world faces a number of major environmental, economic and social challenges which have to be properly addressed if future generations are to enjoy a safe, healthy and prosperous future. The solutions we arrive at will change the way we live and work and – if we make the right choices – these changes will generally be for the better. The transition from a dependence on fossil fuels to a situation where agriculture not only will continue to provide food security but also biomass as a renewable raw material for industry will be the basis of the integrated bioeconomy. The bioeconomy is already making substantial contributions to sustainable development and this

* Corresponding author.
E-mail addresses: y.lokko@unido.org (Y. Lokko), marc.heijde@vib-ugent.be (M. Heijde), k.schebesta@unido.og (K. Schebesta), p.scholtes@unido.org (P. Scholtès), marc.vanmontagu@vib-ugent.be (M. Van Montagu), giacca@icgeb.org (M. Giacca).

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contribution will increase in the future: higher quality, renewable raw materials will be produced sustainably, and food security and a healthy environment will continue to be assured. Conversion to a wider range of end products, whether food, feed, fuel, fibre or other healthcare or industrial products, is also sustainable, being efficient, producing little or no waste, and often using biological processing. Developing all sectors of the bioeconomy in concert will provide global food security, improve nutrition and public health, make industrial processing cleaner and more efficient and make a significant contribution to the effort to mitigate climate change. For maximum benefit, the various sectors of the bioeconomy must be properly linked, since they are all interdependent. Concerted action will not only create strong individual sectors, but strong and effective links are needed to create a bioeconomy web. This inter-connectedness means that all sectors must be equally strong; one weak link could significantly reduce the overall effectiveness of the web and limit competitiveness.

In recent years, biotechnology is revolutionizing industrial and agricultural practices by improving quantity and quality of products. In addition, the number of commercial biotechnology products is increasing each year [1]. In the agriculture and agribusiness sector for instance, biotechnology applications play a significant role, from increasing productivity to value addition and product diversification of agriculture produce, while reducing their environmental impact. In the manufacturing sector, biotechnology is used to produce a wide range of bulk and fine chemicals; and the biotechnology derived "*cold water enzymes*" allow effective washing at room temperature. The production of plastics and fuels from biomass is now also well-established globally. Global bioplastics production is estimated to increase from 1.7 million tons in 2014 to approximately 7.8 million tons by 2019 [2].

The economies of many developing countries are based on agriculture and other natural resources. Biotechnology therefore presents unique opportunities for sustainable industrial development. The use of appropriate technology in processing and manufacturing will not only improve efficiency of production and quality of products, but also facilitate trade and international development cooperation.

Agricultural biotechnology in industrial value chains

Underlying all human societies is the need for food security. The modern bioeconomy has its roots in providing both food and non-food products from managed agricultural, aquaculture and forestry ecosystems. Based as it is on continuously renewable resources, it provides an ideal platform from which to tackle 21 st Century challenges. Major issues such as water usage, land management, efficient use of nutrients like nitrogen and phosphorus, maintaining carbon sinks and socio-economic development must be tackled in a systematic and holistic way across all the interconnected sectors. Managing natural resources sustainably is a vital start, but the whole supply chain must also be sustainable, to ensure food security, supply sufficient quantities of renewable raw materials and energy, reduce environmental footprints and promote a healthy and viable rural economy. Beyond this, it is also important to avoid unnecessary waste and to recycle unavoidable waste in useful and efficient ways. The ideal is to have closed loop systems of production and by-product reuse. The bioeconomy already does this adequately, but the ambition is always to use by-products from one sector in another part of the web if they cannot be used directly.

Biotechnology as applied in agriculture, offers a wide variety of scientific approaches to improve plants, animals and micro-organisms aiming at developing solutions to agriculture productivity and sustainability. These scientific tools are very diverse and include for example tissue culture, molecular breeding, genetic engineering, molecular diagnostic tools. They assist breeders in delivering high quality new varieties, assist the farmers to detect diseases or serve the industry to produce molecules of high added value for food or health improvement.

The uptake of these technologies has been very fast in agriculture and numerous crop varieties have been ameliorated or engineered with the help of biotechnology, being it conventional or genetically engineered varieties. Thus, several millions hectares of agriculture land over the globe today have been in hands of biotechnology to ensure their quality and success in the field. However, only some parts of the world have benefited from the availability of these technologies and the poorest parts of the world often have only limited access to such technology.

For the propagation and conservation of most important crops and especially those with a vegetative way of propagation, tissue culture (TC) is the biotechnological tool of choices since many decades. Tissue culture (TC) is the cultivation of plant cells, tissues, or organs on specially formulated nutrient media [3]. Commercial plant tissue culture is now a key component of the horticulture and seed industries, as well as in management of forest resources. The transfer of TC to the private sector mainly through development of SME's has permitted to farmers to get access to clean planting material which is a key element for a good harvest whereas farmers traditionally propagated themselves in the field under uncontrolled growth conditions. In India, for example, 93 commercial TC production units have been recognized by the Department of Biotechnology, Govt. of India under the National Certification System for Tissue Culture Raised Plants [4].

The production of biological products for plant growth-promotion and disease suppression is another important aspect of biotechnology in the agribusiness sector. This includes: 1) biopesticides which fight against stresses caused by pests and diseases through predatory, parasitic, or chemical relationships, soil improvers; 2) biofertilizers which are substances that contain living microorganisms which, when applied to seeds, plant surfaces, or soil, colonizes the rhizosphere or the interior of the plant and promotes growth by increasing the supply or availability of primary nutrients to the host plant; and 3) biostimulants [5]. Biostimulants/biofertilizers include the nitrogen fixers, phosphorus solubilizers, phosphorus mobilizers, micro-nutrient (Silicate and Zinc) solubilizes and plant growth promoting Rhizo bacteria (PGPR) [6].

The worldwide turnover of biopesticides is approximately USD 1.8 billion and the market availability of different types of microbial cultures and inoculants has increased rapidly in the past decade due to improved biotechnological production schemes. Nitrogen fixing biofertilizers were the most widely used biofertilizers accounting for over 78% of the global demand in 2012, followed by phosphate solubilizing biofertilizers, with 14.6% of the market share.

The biofertilizers market in 2015 was valued at USD 946.6 million and it is expected to grow at a CAGR of 14.08% from 2016 to 2022. With the increasing pressure on global food production, the demand for fertilizers is expected to increase, which in turn would enhance the growth of the biofertilizers market [7].

The rapid progress made in molecular genetics, bioinformatics and molecular biology has broadened the panel of tools available for making high quality conventional breeding and in addition has allowed the development of new genetically engineered crop varieties with agronomic traits that are important for the farmer, the consumer and the environment.

Since 1996, nine GM crops have been grown commercially worldwide including soybean, maize, cotton and canola which support several industries including food, feed, textile and health. The direct global benefit from GM crops is estimated at USD 18.8 billion [8] and socioeconomic studies have revealed that it is also