INTEGRAL VALORISATION OF BIO-PRODUCTION

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ABSTRACT
Integral valorisation of bio-production including agriculture, forestry and aquaculture for the production of safe food products and renewable production of products, materials and energy is a vital aspect of a rapid expanding bio-based economy.

The organisation of a graduate course on MSc and PhD level in this field is linking the gap between traditional teaching programmes in the field of agriculture and food sciences with the multidisciplinary approach in new developed curricula dealing with a simultaneous conversion of renewable resources for food and non-food uses.

1.0 BIO-BASED ECONOMY AND INTEGRAL VALORISATION OF BIO-PRODUCTS

Bio-production, including agriculture, horticulture, fisheries and forestry is becoming increasingly more market-driven worldwide and there is increasing concern about the effect of these activities on the global environment. During the last decade there has been a significant growing effort to relieve these pressures by focusing on the total agri-production chain involved in the production of safe, quality food and the effective use of the renewable co-products of these activities.

Integral valorisation is an essential part of a bio-based economy using bio-production in agriculture, horticulture, fisheries and forestry as primary resources for food and feed, biomaterials, chemical and pharmaceutical products and bio-fuels (biodiesel, bio-ethanol and biogas).

Bio-based economy is a milestone in the economical evolution. There is a growing tendency to be less dependent on the political situation in the world especially for raw materials and energy resources. In addition there is a limited availability for fossil resources and gas resources.

Another advantage of using renewable resources are the ecological and environmental benefits due to the integration in a closed carbon cycle.

In addition bio-production is very efficient and sustainable in order to provide renewable resources as alternative sources (e.g., waste streams) can be transformed in useful products using emerging technologies. These developments are favoured by their green image and the consumer assessment of sustainable production and clean technologies.

Over the last century consumers have assumed food and energy resources in the western world will continue to be readily available. However, it is now realised that natural resources are extremely limited. A more efficient use of materials, waste minimization and especially integral valorisation must be integrated into bio-system management and biomaterial use. Integral valorisation is the production of safe and healthy food and renewable resources for materials and energy production, with the aim of achieving an efficient and complete use of each bio-product at every step in the agri-bio-chain. Integral valorisation must be the basic concept driving the design of new processes for food, biomaterials and bio-energy production to achieve sustainable development. This will necessitate the optimal utilisation of all co-products and waste streams. The conversion of bio-products into food and non-food materials on the same production site is novel. However, ‘white’ or industrial biotechnology, ‘green’ biotechnology or agricultural biotechnology and the principles of bio-refining, which is the sequential extraction of commercially valuable components have been recently developed.

Bio-refinery can be defined as integrated bio-based industries, using a variety of different technologies to produce food and feed ingredients, chemicals, biomaterials, bio-fuels and power from biomass raw material.

2.0 ECOLOGICAL ECONOMY: FOOD VERSUS NON-FOOD APPLICATION

Integral valorisation of food, biomaterials and bio-energy is based on bio-refining principles that combine agriculture and forestry, bio-production with the use of these materials to produce food, chemicals, materials and energy. However, such use of renewable resources can be accomplished by several approaches. One approach is a self-sustaining model on a local production scale, involving raw material suppliers (agriculture, forestry), decentralised energy producers (power plants, bio-gas) and consumption of locally produced energy. This is a successful approach for food and energy production and optimum use of co-products and waste streams. This sustainable rural development scheme is illustrated by a combination of agricultural-forestry production, biodiesel production, waste management and energy.

An important asset in the production and use of renewable bio-resources is the fact that the products can be used either for food production and for non-food applications. In this way more flexibility towards the market is built into business. In this way the formation of self-sustaining ecological production sites with cyclic utilisation of preferably locally available resources must be favoured. Besides the production of food and non-food preferably on one location attention is given to the valorisation of waste materials from biological processes. Companies are realising that developing a useful outlet for side products and waste streams can contribute to the sustainability and economical and ecological health of their processes. Mostly, waste streams contain valuable products but the separation on processing them has been neglected until now. The integral valorisation of bio-production is illustrated by a number of cases such as corn, vegetable oils and bio-diesel production. As corn crops have a high yield, it may be regarded as a good crop for widespread integral utilisation. The integral valorisation scheme of corn illustrates different possibilities for main- and by-products (in small or large amounts) of equivalent importance from the point of view of total utilisation. Changes in market opportunities can be partially levelled if different outlets are available.

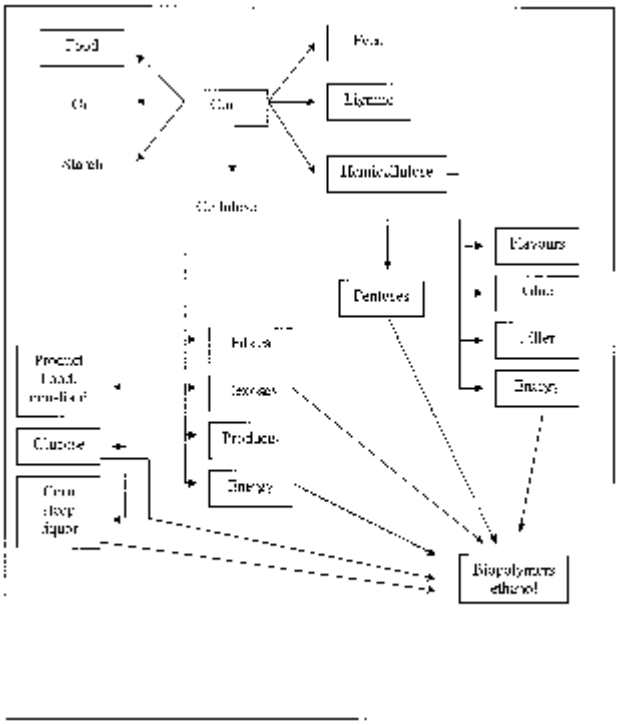

Figure 1: Integral valorisation of corn

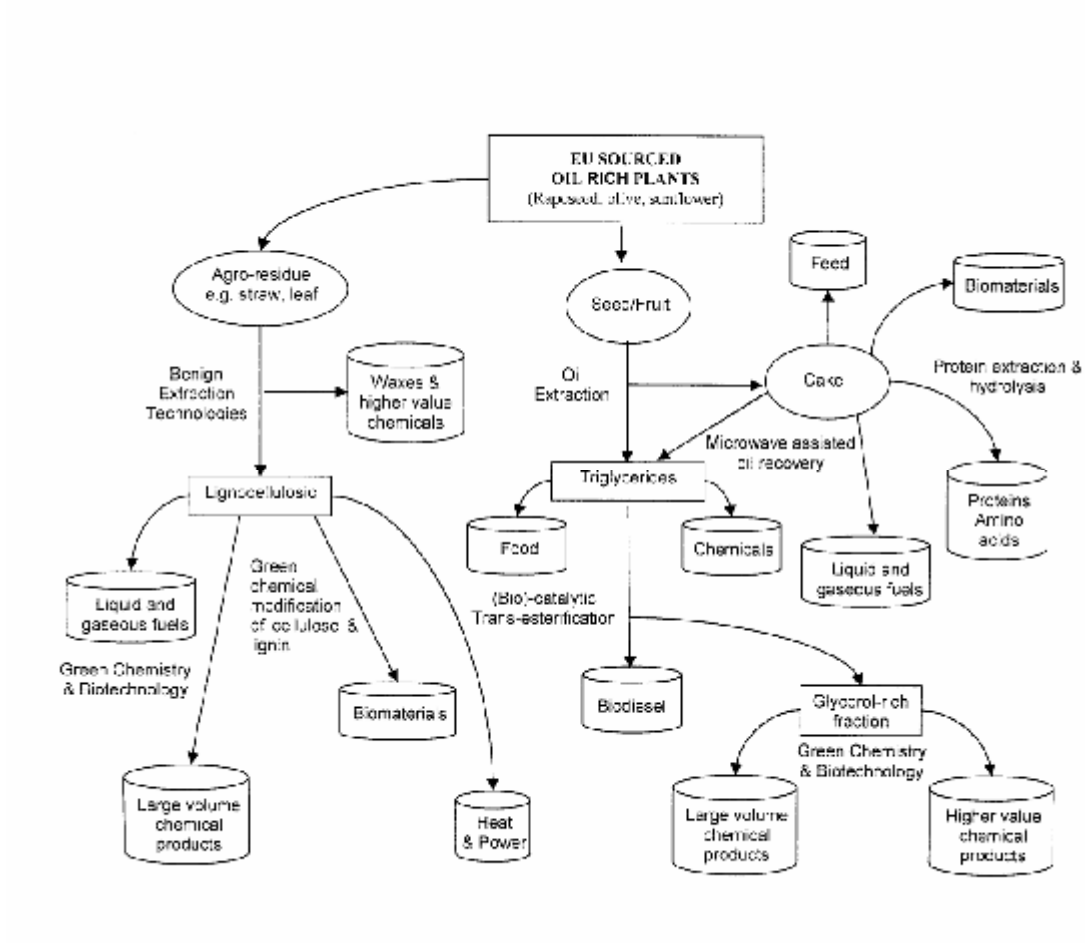

Figure 2: The oilseed bio-refinery

A very important aspect is that the technology for use of renewable resources for non-food applications need to exist and preferably similar to the technology for fossil-derived products. For example the production of biopolymers can only be successful if they can be produced with the equipment which is used in the chemical industry.

Another example of this concept is an oil mill for bio-diesel production, combined with power plants (electricity, heat: CHP), using waste from bio-diesel production, used cooking and frying oils, with wood residues and biogas also partially supplied by waste from the diesel production.

Processing of locally grown rapeseeds provides biodiesel and protein-rich feedstock. The feedstock is redistributed in aliquots to the farmers. Any surplus is sold or utilised in the energy power plant. In order to increase the biodiesel capacity, used frying oils are collected and transformed in biodiesel. The glycerine (by-product) of biodiesel production can be used in two ways. It can be mixed with wood waste and sawdust to produce power of in biogas production combined with agricultural and food waste and manure.

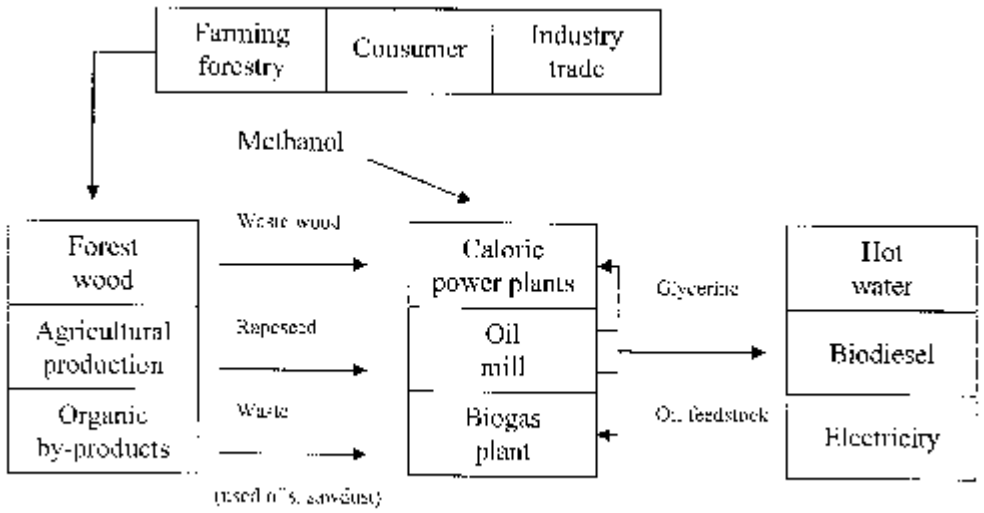

Figure 3: Integral valorisation of bio-products

The principle of integral valorisation of bio-production has been applied on an industrial scale at Ghent. A consortium Ghent Bio-Energy Valley Ghent has been created by the City of Ghent, Harbour of Ghent, Ghent University and various industrial partners with the aim to produce on one location, which was originally a food plant, food, feed and bio-fuels. On this site soy or rapeseed are extracted and refined to produce edible oil which is used either for food or the production of biodiesel. The cake is used for feed, power or biogas. At the same site corn and wheat are processed for food and for bio-ethanol via fermentation and distillation. The residual waste products are sold as feed or transformed into biogas. Also the blending of bio-fuels with the fossil fuel are performed on the same location.

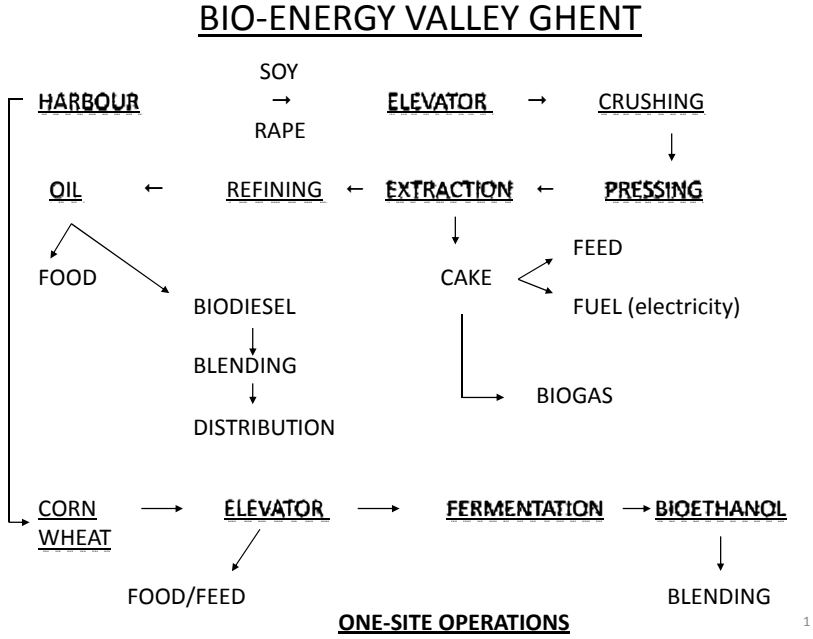

Figure 4: Bio-energy valley Ghent

Taking into account the experiences mentioned "integral valorisation of bio-production" is a successful development applying the following conditions:

(i) Self-sustaining model on local production scale.
(ii) Simultaneous production of food and energy.
(iii) Integration of the total bio-production chain from raw material to final product.
(iv) Optimal use of co-products and waste streams.
(v) Combination of bio-production, bio-refinery, waste management, clean technology and energy.

3.0 SPECIFIC ASPECTS OF BIO-PRODUCTION

The change of attitudes in production processes involving integral valorisation and sustainability is giving rise to new developments in the economical organisation.

Using agricultural and natural materials has some disadvantages compared to production schemes using fossil resources. Especially the changing quality of resources due to agricultural production conditions can be harmful for food production and non-food applications. Therefore quality control of products from crops, animals is an essential condition. This has been illustrated by problems with BSE, PCBs and dioxins.

Using renewable resources for food and non-food applications will need quality control in order to product a constant quality. Mixing of resources is a solution very well known in food production but is more difficult to perform for non-food applications in addition to a stable and reliable availability.

Another drawback is that bio-production is limited to a certain period of the year so that the yearly consumption has to be produced and downstreamed in a short period.

This is leading to a production capacity which is bigger than in the case of fossil raw materials.

Essential is the stability of the intermediate during storage. This is very well known in food industry and these processes are also used in non-food applications stressing the complimentary of both applications.

The use of preservation techniques (e.g., anti-microbial, anti-fungal) and additives (e.g., anti-oxidants) are applied both for food and non-food applications.

Therefore the search for stable intermediates from bio-production which can serve as basic products is one of the highlights of the bio-refinery. The production of methanol, ethanol, acetic acid are being promoted to mimic the position of ethylene in the petrochemistry.

4.0 INTEGRAL USE OF RENEWABLE, AN INTERESTING CONCEPT FOR DEVELOPING COUNTRIES

During the last century, the western countries shifted progressively from agriculture and moved to petrochemistry (petroleum, natural gas) as a source for materials and industrial products. This tendency is one of the main reasons for the economical and social gap between North and South. The increased interest in the Western world of utilising renewable resources for food and non-food can be an important signal to similar sustainable technologies for developing countries.

Food production will be the main concern but the application of the integral use and processing of bio-production will be a stimulus for regional developments and for regional developments and especially valuable for small communities. It can increase the number and the qualification of jobs and the societies become less dependent on imported goods. A good example was the production of biodiesel (4000 l/day) on palm oil refineries in Ivory Coast and Cameroon. These communities became less dependence from important diesel oil without disturbing the food supply due to the use of palm oil fractions less suitable for human consumption.

There is no doubt that integral valorisation for food and non-food products will generate more jobs with higher qualifications and reduce the tendency to move to cities and reduce the need for import of expensive Western products.

5.0 CURRICULUM DEVELOPMENT: INTEGRAL VALORISATION OF BIO-PRODUCTION

Integral valorisation of bio-products from agriculture, horticulture, forestry, fisheries and aquaculture for food and non-food uses is a new and innovative area for curriculum development in graduate courses leading to MSc and PhD degrees. At this moment the majority of western study programmes in agriculture, biotechnology, chemistry, chemical engineering and food science and technology cover only a fraction of the relevant current knowledge and is not making connection and link between the food production and non-food application neither in the primary raw materials and in the final products. This is due to the traditional specialisation either for food science or non-food renewable bio-resources. Consequently study programmes that combine these expertise do not exist, despite the fact that both fields using the same raw materials and similar processing, technologies, logistics and management. In addition this study field is applying the same

basic sciences (mathematics, physics, chemistry, biology and engineering). With the increasing use of agricultural food products and non-food renewable materials and energy, there is an urgent need in the industrial world for graduates and experts combining knowledge of both food and non-food biomaterial processing and management.

The objectives and aims of the curriculum development of graduate courses in "integral valorisation" are:

(i) To train critically reflective experts in new developments in the bio-production chain, providing technical and scientific education for the implementation of integral food, non-food and energy production.
(ii) To enable students to a critical evaluation of the introduction and acceptance of interdisciplinary technologies, new products and evaluation of the environmental impact.
(iii) To train bio-experts to understand and to analyse the variation in quality and safety of production and technologies.
(iv) To ensure students of the importance of global environment, sustainable production and technologies, consumer perception and ethics.

The curriculum of "integral valorisation of bio-production" involves a multi- and interdisciplinary approach applying the principle of the "total production chain". The following fields are the subject of the curriculum:

(i) Primary production of renewable bio-resources from plant, animal, forestry and biomass.
(ii) Technologies and processing of renewable bio-production for food and non-food products.
(iii) Food technology and engineering.
(iv) Biotechnology.
(v) Quality and safety of bio-products.
(vi) Bio-economics and management.

The idea of "integral valorisation of bio-production" has been realised in the framework of the EU-US exchange programme Atlantis in which 3 EU universities (Ghent University Belgium; INP Toulouse, France and Karl-Franzen University Graz, Austria) together with 3 US universities (University of Arkansas, Fayetteville, Iowa State University, Ames and Kansas State University, Manhattan) have taken the initiative to develop a graduate degree course together with a student and staff mobility programme, organisation of short (2 weeks) intensive programme (in 2009: 2 organisations: Ames and Graz) and the preparation of teaching material.

A model for a graduate course in "integral valorisation of bio-production" should involve modules dealing with:

(i) Primary production of renewable bio-resources, plant, animal, forestry.
(ii) Technology and engineering of renewable bio-production for food and non-food applications.
(iii) Principles of food science and technology.
(iv) Quality and safety of bio-products.
(v) Renewable biomaterials from carbohydrates and wood: fibres, biopolymers.

(vi) Renewable biomaterials from lipids and proteins: e.g. biopolymers, detergents, lubricants.
(vii) Production of bio-fuel: bio-ethanol, biodiesel, bio-gas, pyrolysis of biomass.
(viii) Production of high value-added products: e.g., herbs, pharmaceuticals, perfumes/flavours, bio-colorants.
(ix) Principle of bio-refining.
(x) Waste prevention and conversion of waste-streams.
(xi) Clean technologies in food and industrial engineering.
(xii) Life cycle analyses and exergy.
(xiii) Principles of bio-economy and management.
(xiv) Bio-ethics: conflict food versus non-food.

The course will clearly emphasise the importance of a simultaneous conversion and/or modification of raw bio-resources for food and non-food applications.

The course is representing a unique opportunity to create a multidisciplinary approach for students from various disciplines and orientations to use food and non-food technologies and products and it will also allow the development of graduates with unique skills which are not currently available.

Industry is actively searching for such employees who are experts in these new innovative and expanding fields.

It also will provide opportunities for academic staff to create multidisciplinary teaching programmes and modules by simultaneous integration of various disciplines while also involving multiple teaching and research institutions.

6.0 CONCLUSION

The concept of a bio-based economy and integral valorisation of bio-production is creating a unique opportunity for the integration of various educational disciplines emphasising the importance and added values of a simultaneous conversion and/or modification of renewable bio-resources into food products and non-food applications. The development of new curricula in these fields will create new opportunities for institutions of life sciences and new openings for students in a rapid expanding and innovative bio-economy.