Possibilities for Waste valorisation: the concept of modular biorefineries

http://www.uco.es/~q62alsor/

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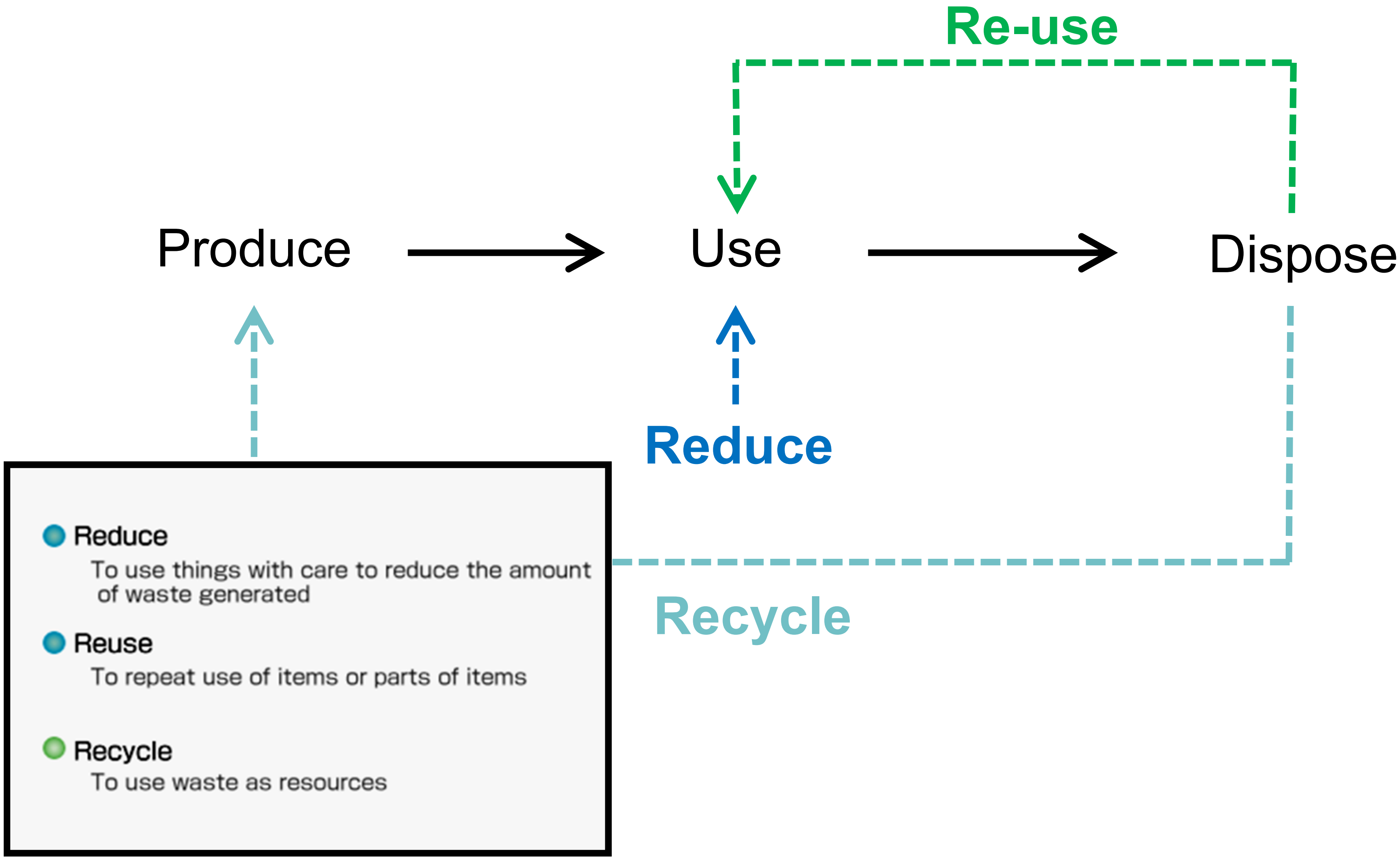
ITS ALWAYS THE SAME THING………

Produce → Use → Dispose

Something wrong with this?



Re-use

Produce → Use → Dispose

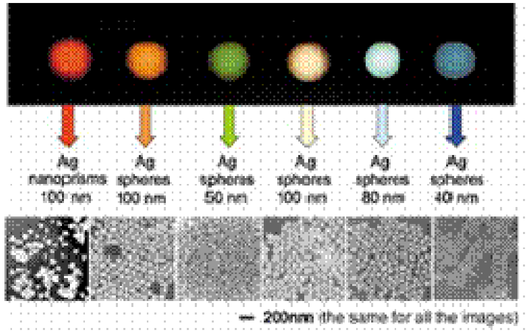
Reduce

Recycle

- **Reduce**
  To use things with care to reduce the amount of waste generated
- **Reuse**
  To repeat use of items or parts of items
- **Recycle**
  To use waste as resources

What do we do?

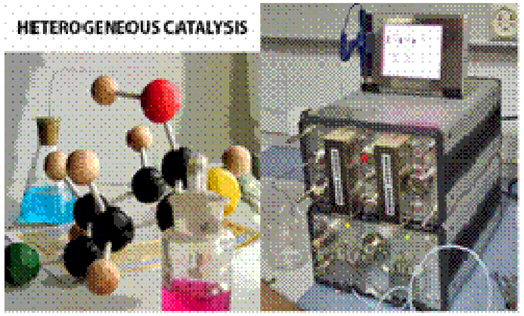
NANOSCALE CHEMISTRY



Supramolecular gels
Nanomaterials
Supported nanoparticles
Microwave nanocatalysis
Mechanochemistry (milling)

Group leader:
Alina M. Balu

HETEROGENEOUS CATALYSIS & FLOW CHEMISTRY



Heterogeneous catalysis (acid-base, redox, C-C y C-heteroatom couplings)
Microwave assisted catalysis
Flow Chemistry

Group Leader:
Weiyi Ouyang

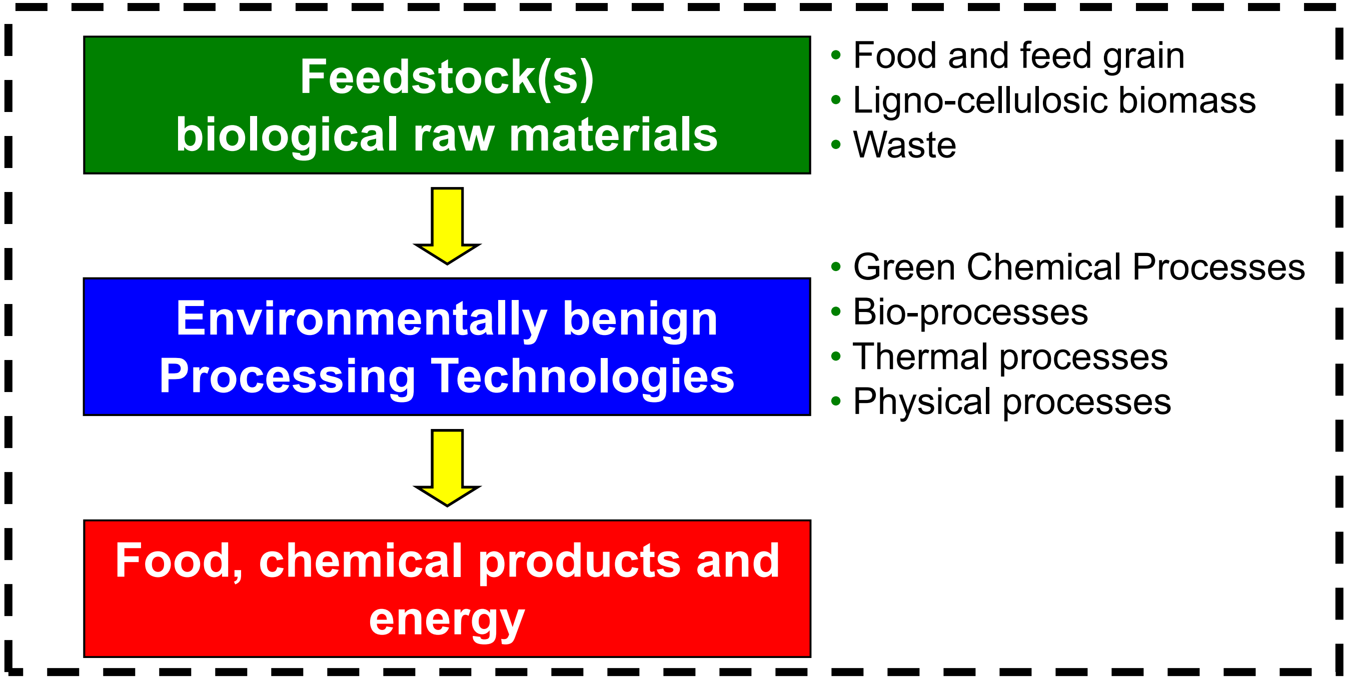
BIOMASS & WASTE VALORISATION

Transformations of platform molecules
Biomass valorisation
Biofuels production
Waste valorisation (biorefineries)

Group Leader:
Sudipta De

BIOREFINERIES

Integrated facilities that can convert a variety of bio-feedstocks into energy, chemicals and other valuable materials **cleanly** and **efficiently** maximising the value of the biomass and minimizing waste



Feedstock(s)
biological raw materials

- Food and feed grain
- Ligno-cellulosic biomass
- Waste

Environmentally benign
Processing Technologies

- Green Chemical Processes
- Bio-processes
- Thermal processes
- Physical processes

Food, chemical products and energy

GREEN APPLIED SOLUTIONS

http://www.cbme.ust.hk/rafaluque.html

WASTE TO WEALTH: FROM RESIDUES TO MARKETABLE PRODUCTS

Green technologies

(e.g. microwaves, extraction, fractionation)

Personal care products

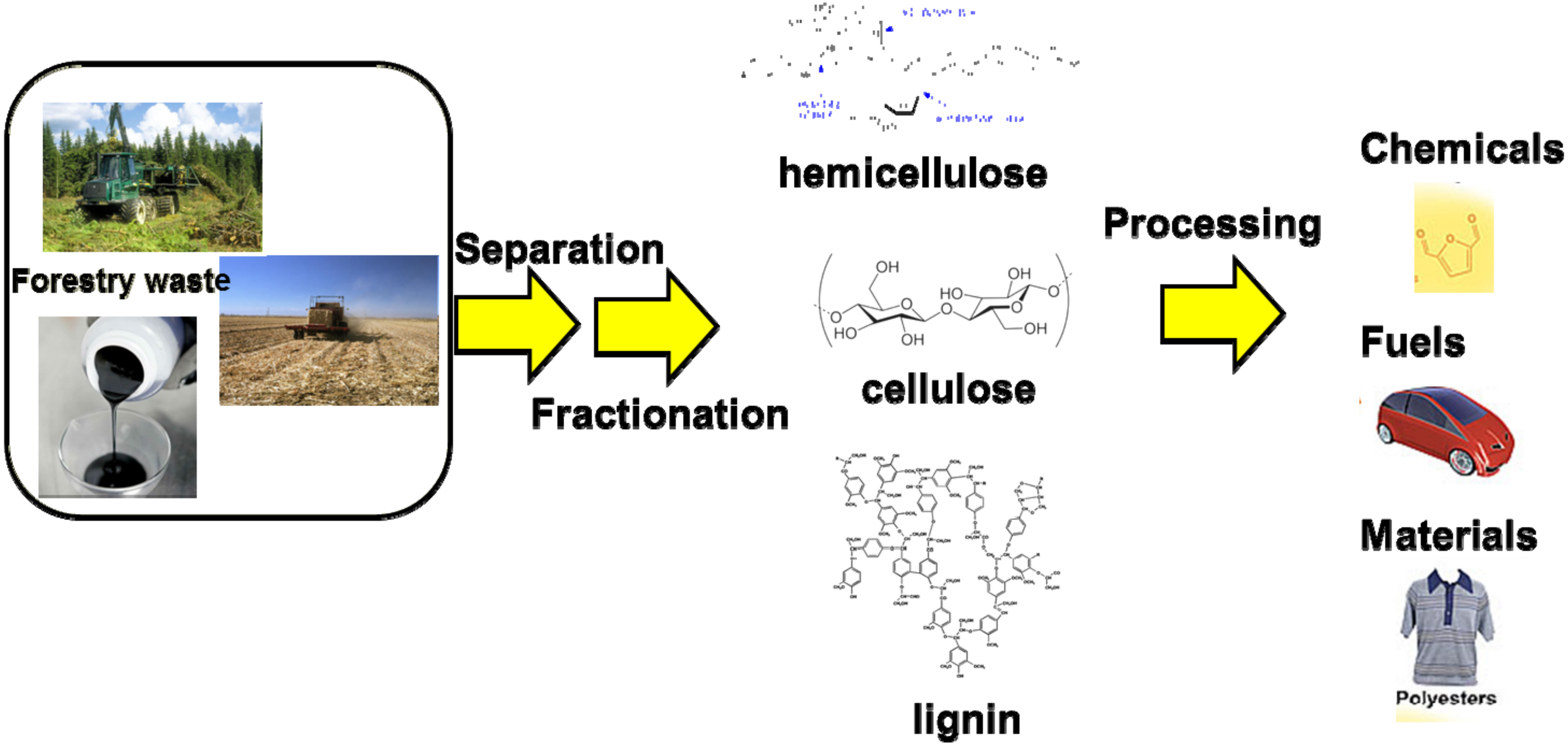
Coatings and unguents

Paint additives

Biodegradable plastics

Other derivatives (chemicals, fuels, etc.)

Biorefinery: The big picture



Forestry waste

Separation

Fractionation

hemicellulose

cellulose

lignin

Processing

Chemicals

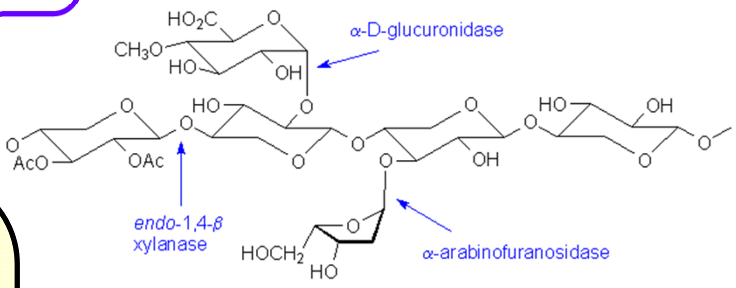
Fuels

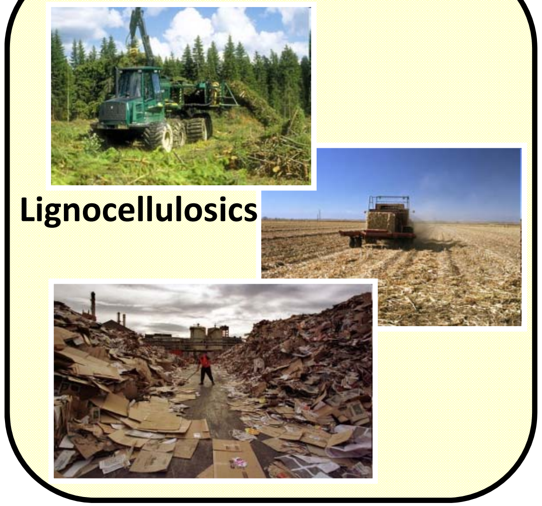
Materials

Polyesters

Knowing chemical composition is the key to success!!!

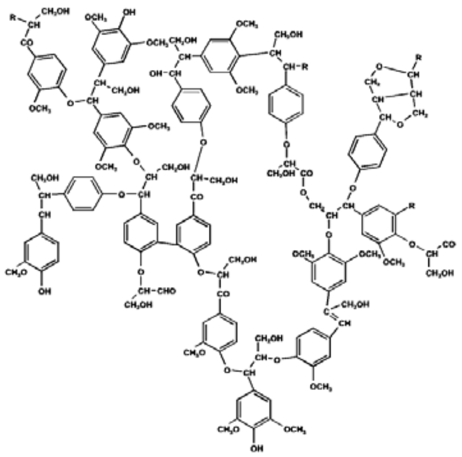
HEMICELLULOSE



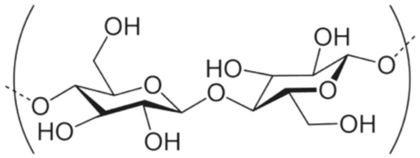


Lignocellulosics

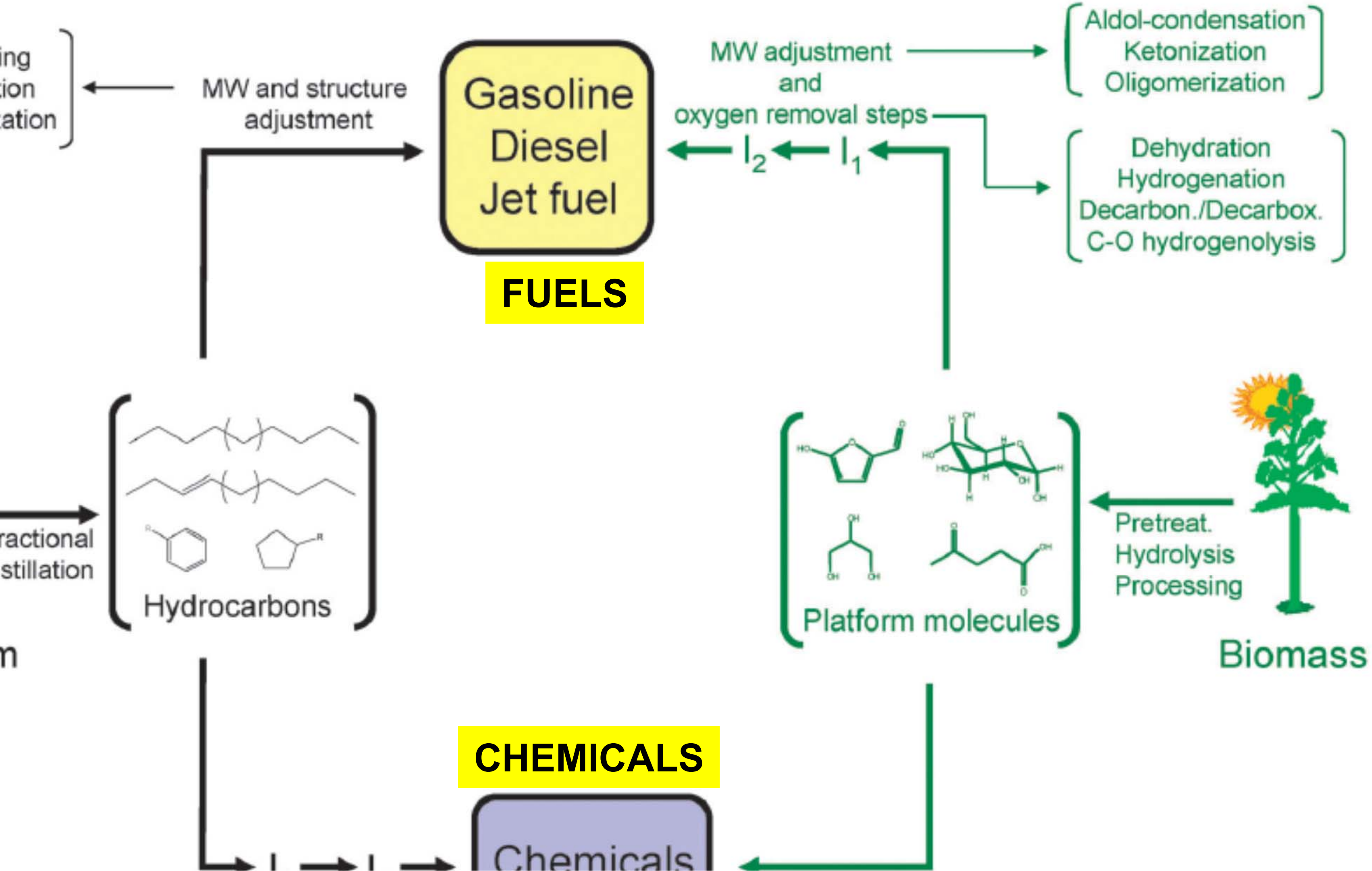
LIGNIN



CELLULOSE



MINOR CONSTITUENTS



FUELS

CHEMICALS

UNIVERSITY of York

Green Chemistry
Centre of Excellence

MANCHESTER
1824
The University of Manchester

heat

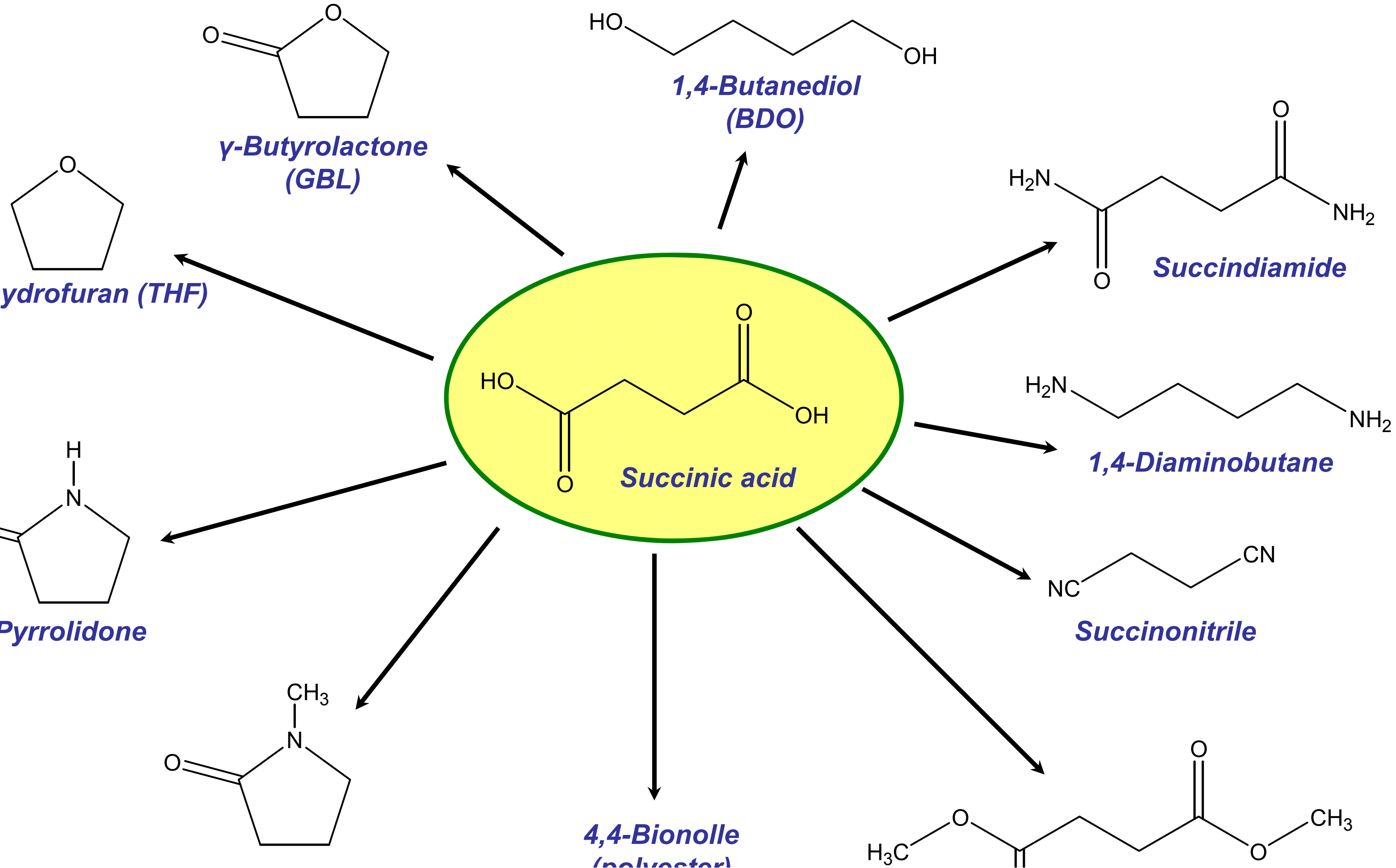
Upstream processing

Bioreaction

Downstream processing

Succinic acid

Succinic acid as a C4 building block



Succinic acid

γ-Butyrolactone (GBL)

1,4-Butanediol (BDO)

Succindiamide

1,4-Diaminobutane

Succinonitrile

ydrofuran (THF)

Pyrrolidone

4,4-Bionolle (polyester)

From Starch to Starbon®

Green Chemistry
Centre of Excellence

e of composites

Ability to functionalise
i.e. acid, basic, metallic

v conductivity

properties

emperature materials stable
ater & organic solvents

soporosity, surface areas

Fuel cells

catalysis

adsorbency

chromatography

applications

With the mighty team at York (UK)

Starbon®
TECHNOLOGIES

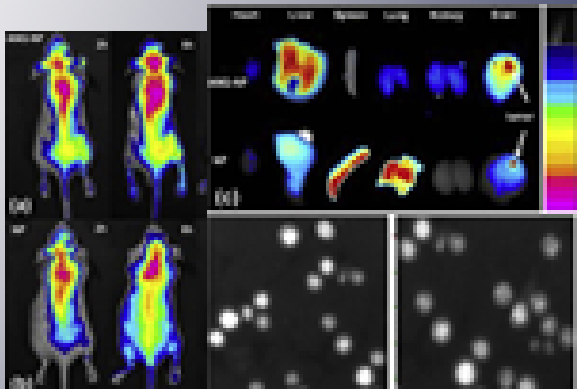
3 x 10^7 joules
The volume of energy released when a kilogramme of coal is burned.

ALGAE VALORISATION: FROM HEALTH PRODUCTS TO BIOPOLYMERS

Extraction of Phytosterols
(cholesterol-reducing agents)

Highly porous and consistent
Antimicrobial foams (Ag NPs)

NP accumulation/migration



AE GROWING
LAGOON IN ITALY

Nanocrystals of

http://www.cbme.ust.hk/rafaluque.html

IOMASS VALORISATION (II)… with NCAR (Oviedo)

MIP concept (EES 2012)

Gracillaria gracilis

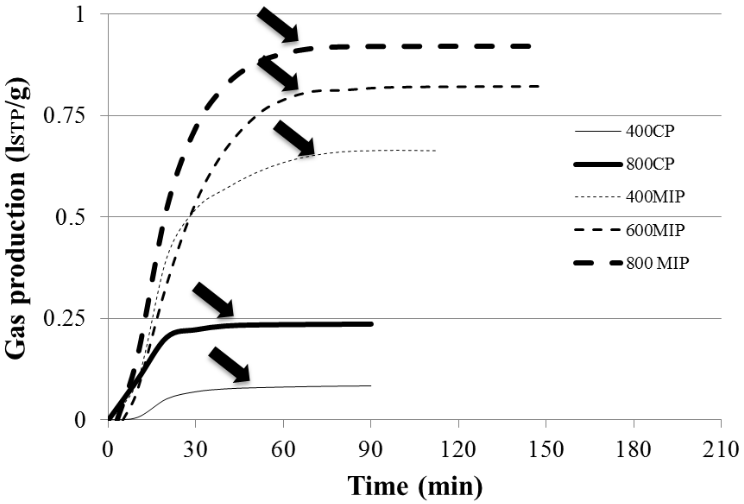


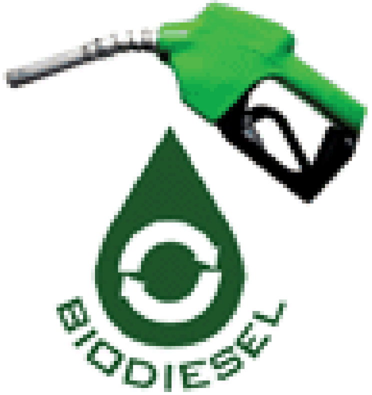
Table 1. Biochemical composition (% d.w.) of *Gracilaria gracilis* sampled in the Lesina lagoon (Italy).

Total Lipids	1.98
Fatty Acids Methyl Esters	0.47
Proteins	30.93

http://www.uco.es/~q62alsor/

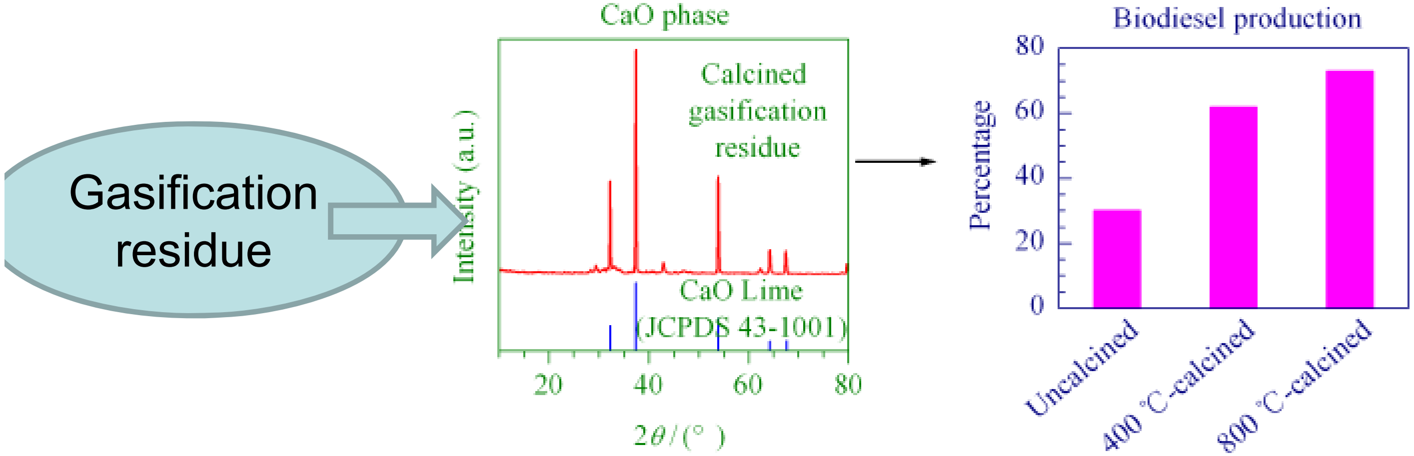
FOOD WASTE VALORISATION (I)… with Rick Arancon (Ateneo Uni)

Green Chem. **2011, 13, 3162**



2 FOOD WASTE RESIDUES:
CORNCOBS, WASTE BREAD, OTHERS
+
WASTE COOKING OILS

2 VALUABLE PRODUCTS:
CARBONACEOUS MATERIAL (CATALYST)
+
BIODIESEL



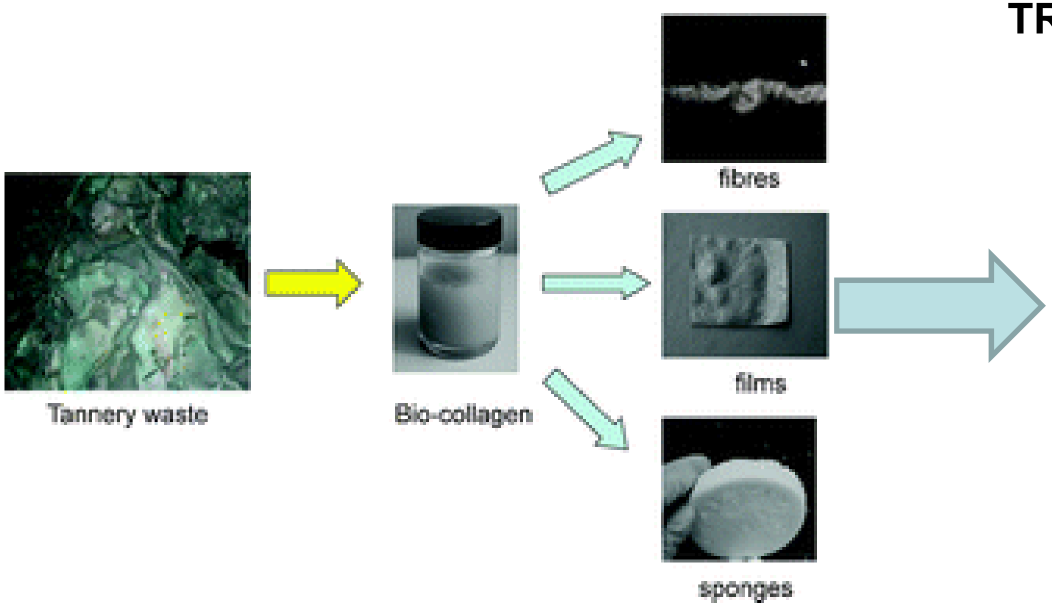
Gasification residue

J. Natural Gas Chem. 2012, 21, 246

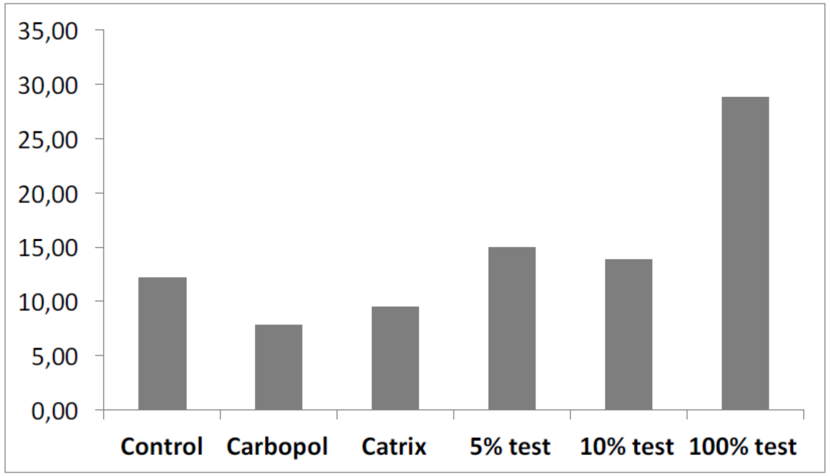
http://www.uco.es/~q62alsor/

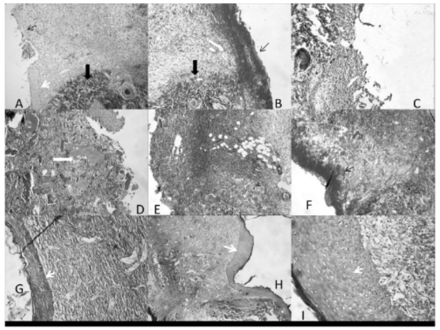
FOOD WASTE VALORISATION (II)… with Jaume Cot (IQAC)

FROM SLAUGHTER WASTE TO BIO-HEALING NATURAL POLYMERS (BIO-COLLAGEN)



TREATMENT OF WOUND HEALING IN RATS





Materials 2013, 6, 1599
Materials 2013, 6, 4641

Green Chem. 2012, 14, 308

PCT Patent 2013

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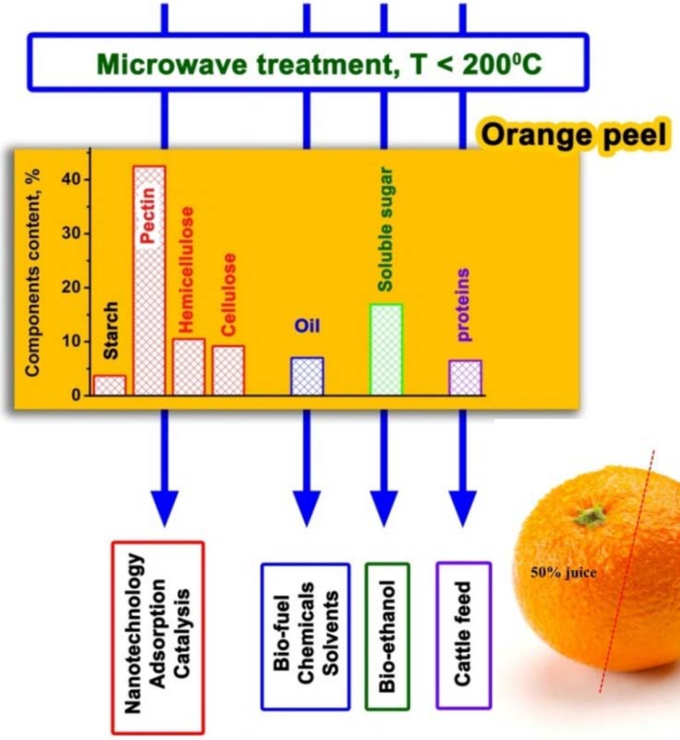
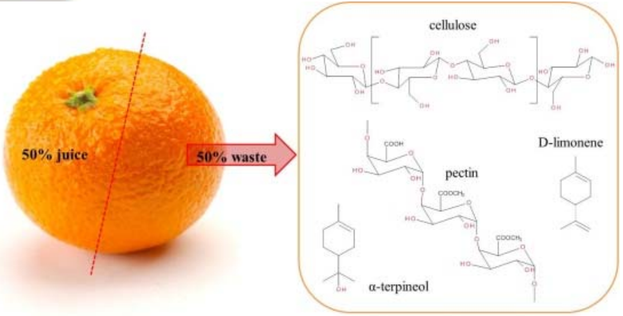
FOOD WASTE VALORISATION (III):

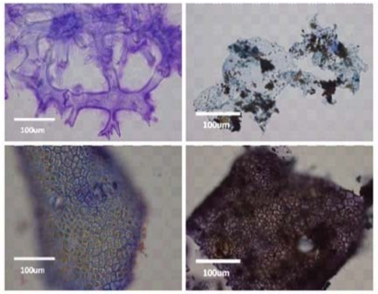
ChemSusChem, **2012**; Energy Env. Sci. **2013**

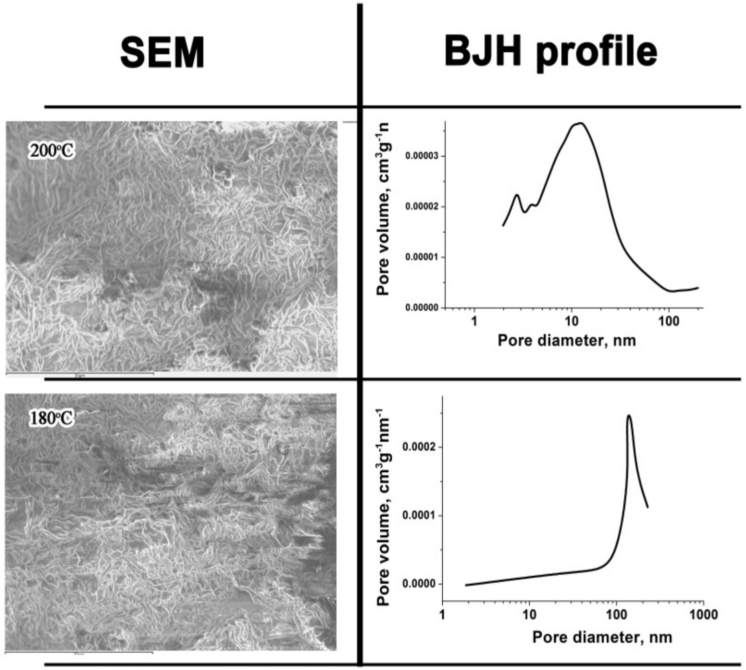


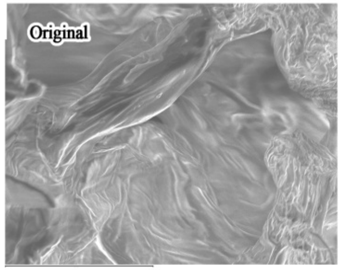
Microwave-assisted extraction:
- simple
- rapid (5-10 min)
- efficient



Unique form of mesoporous cellulose

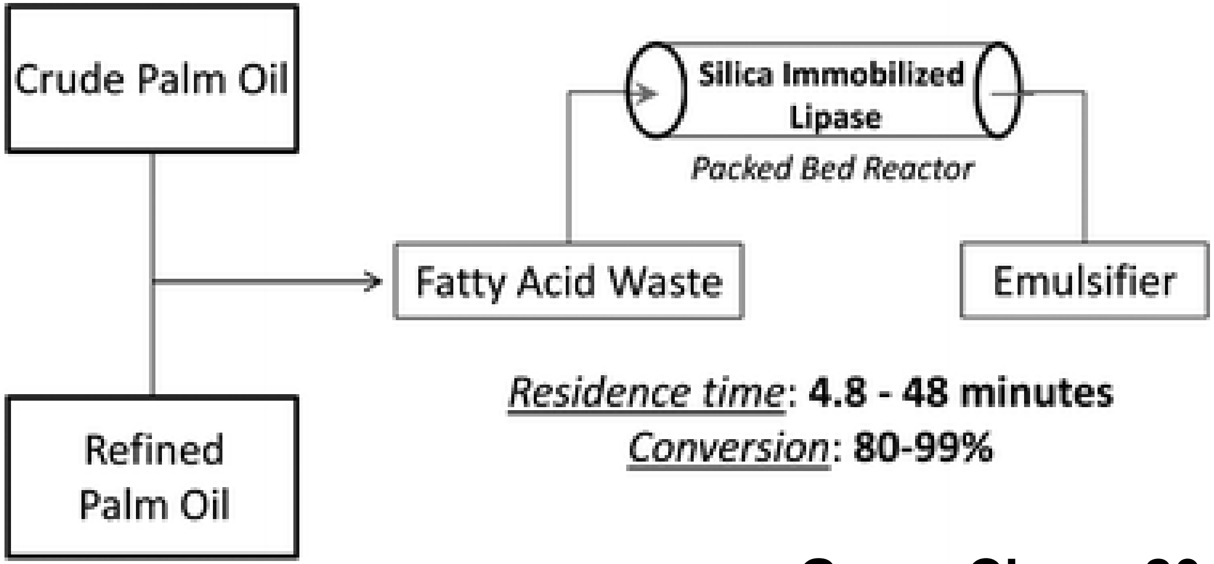






Sample	Surface area (m^2g^{-1})	Pore volume ($ml\ g^{-1}$)	Pore size (nm)
MW-150ºC	2	0.01	35
MW-180ºC	6	0.68	88
MW-200ºC	26	0.38	19

Porous materials



Residence time: **4.8 - 48 minutes**

Conversion: **80-99%**

Green Chem. 2013

ChemSusChem 2013

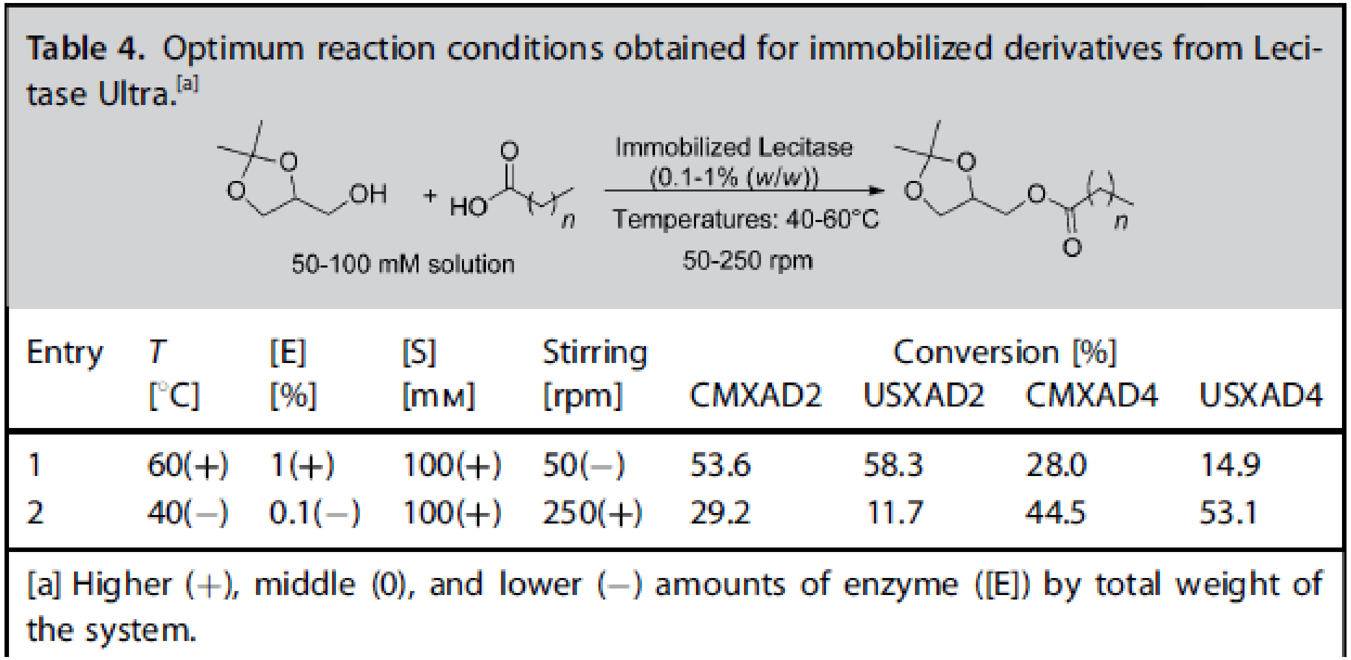
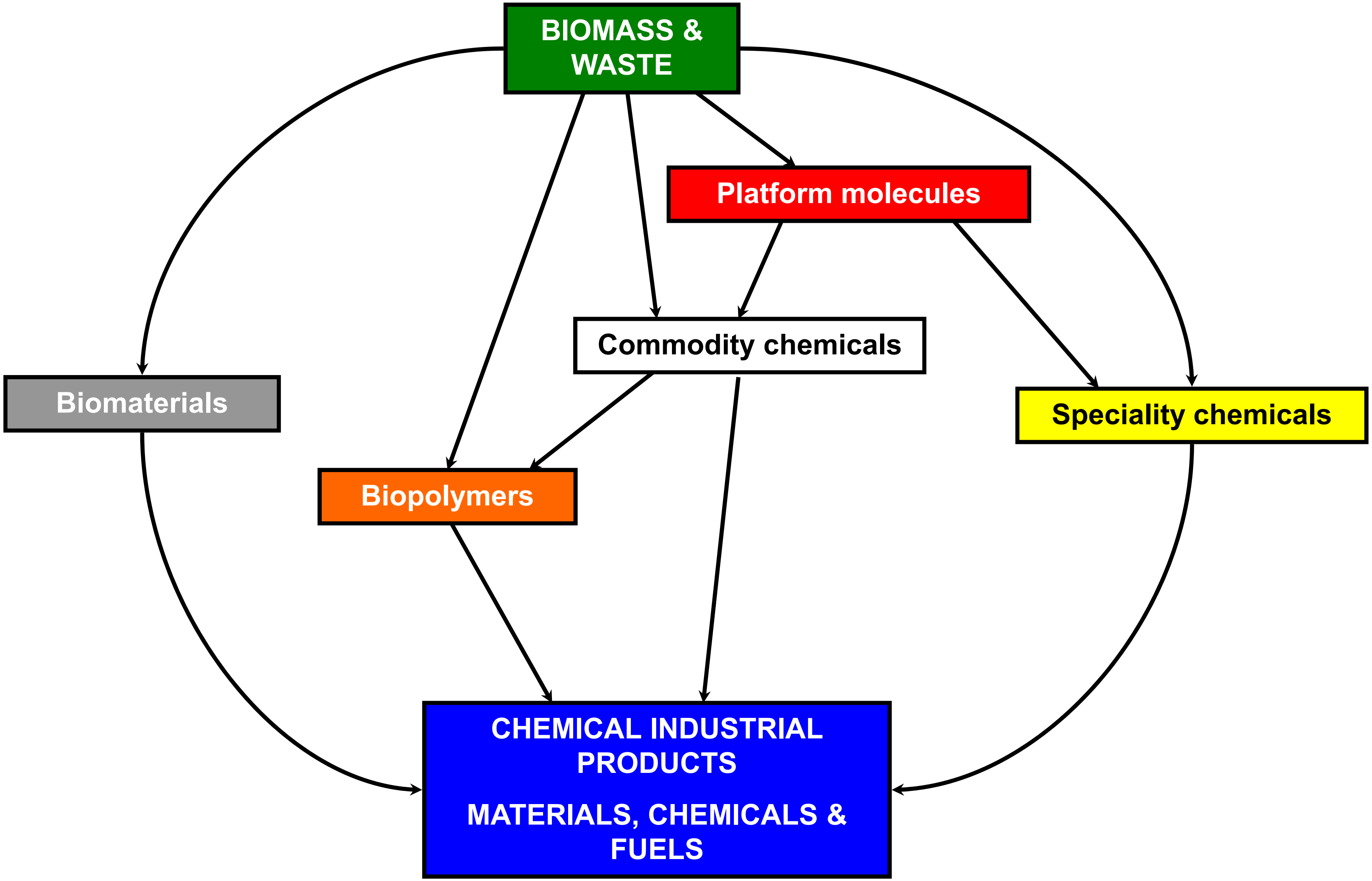


Table 4. Optimum reaction conditions obtained for immobilized derivatives from Lecitase Ultra.[a]

Entry	T [°C]	[E] [%]	[S] [mM]	Stirring [rpm]	Conversion [%] CMXAD2	USXAD2	CMXAD4	USXAD4
1	60(+)	1(+)	100(+)	50(−)	53.6	58.3	28.0	14.9
2	40(−)	0.1(−)	100(+)	250(+)	29.2	11.7	44.5	53.1

[a] Higher (+), middle (0), and lower (−) amounts of enzyme ([E]) by total weight of the system.

Conclusions



BIOMASS & WASTE

Platform molecules

Commodity chemicals

Biomaterials

Speciality chemicals

Biopolymers

CHEMICAL INDUSTRIAL PRODUCTS

MATERIALS, CHEMICALS & FUELS

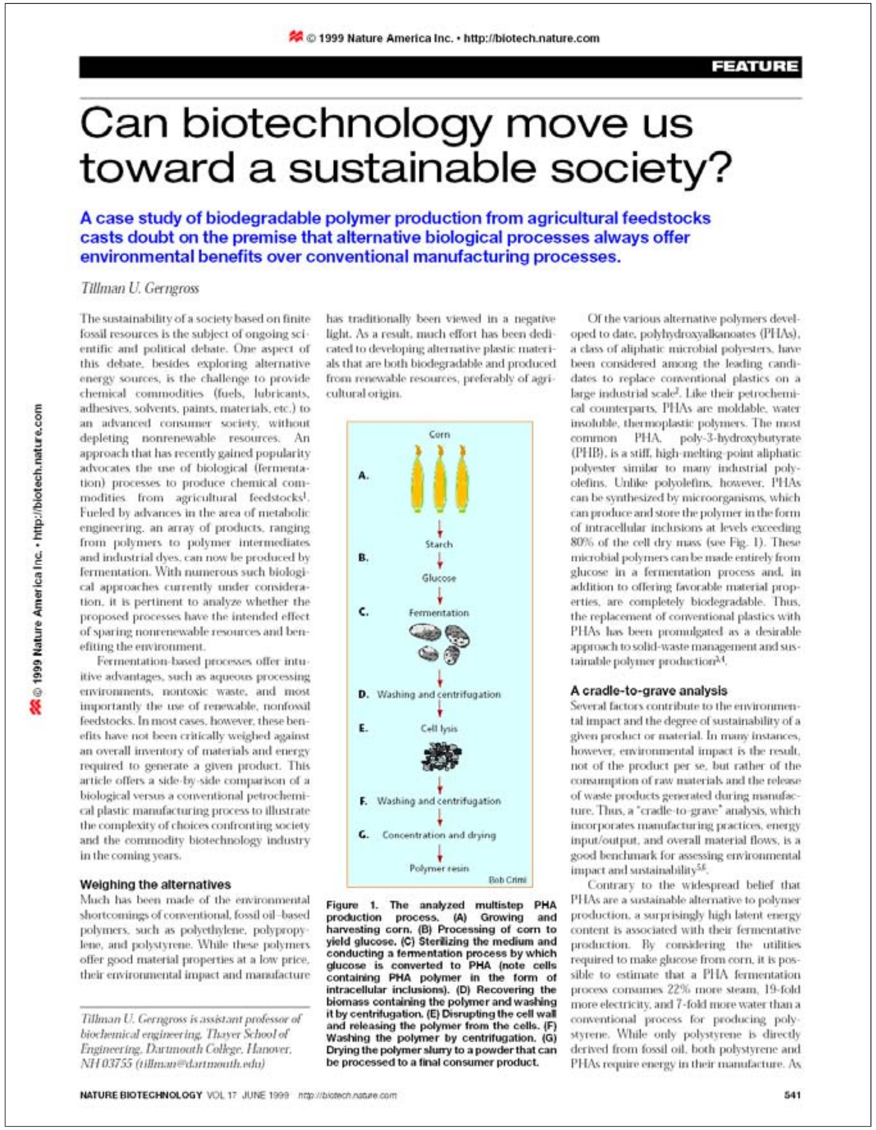
Some food for thought….

- ***The synthesis of 1 kg of polystyrene requires a total of 2.26 kg of fossil oil (1 kg to generate electricity and 1.26 kg to serve as feedstocks for polymer production).***

- ***The production of 1 kg of PHAs requires 2.39 kg of fossil resources.***

Simply deriving chemical products from renewable resources is NOT ENOUGH!

Real environmental benefit?
Biodegradability?
Toxicity?
SAFETY!!!



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FEATURE

Can biotechnology move us toward a sustainable society?

A case study of biodegradable polymer production from agricultural feedstocks casts doubt on the premise that alternative biological processes always offer environmental benefits over conventional manufacturing processes.

Tillman U. Gerngross

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The sustainability of a society based on finite fossil resources is the subject of ongoing scientific and political debate. One aspect of this debate, besides exploring alternative energy sources, is the challenge to provide chemical commodities (fuels, lubricants, adhesives, solvents, paints, materials, etc.) to an advanced consumer society, without depleting nonrenewable resources. An approach that has recently gained popularity advocates the use of biological (fermentation) processes to produce chemical commodities from agricultural feedstocks[1]. Fueled by advances in the area of metabolic engineering, an array of products, ranging from polymers to polymer intermediates and industrial dyes, can now be produced by fermentation. With numerous such biological approaches currently under consideration, it is pertinent to analyze whether the proposed processes have the intended effect of sparing nonrenewable resources and benefiting the environment.

Fermentation-based processes offer intuitive advantages, such as aqueous processing environments, nontoxic waste, and most importantly the use of renewable, nonfossil feedstocks. In most cases, however, these benefits have not been critically weighed against an overall inventory of materials and energy required to generate a given product. This article offers a side-by-side comparison of a biological versus a conventional petrochemical plastic manufacturing process to illustrate the complexity of choices confronting society and the commodity biotechnology industry in the coming years.

Weighing the alternatives

Much has been made of the environmental shortcomings of conventional, fossil oil–based polymers, such as polyethylene, polypropylene, and polystyrene. While these polymers offer good material properties at a low price, their environmental impact and manufacture has traditionally been viewed in a negative light. As a result, much effort has been dedicated to developing alternative plastic materials that are both biodegradable and produced from renewable resources, preferably of agricultural origin.

Figure 1. The analyzed multistep PHA production process. (A) Growing and harvesting corn. (B) Processing of corn to yield glucose. (C) Sterilizing the medium and conducting a fermentation process by which glucose is converted to PHA (note cells containing PHA polymer in the form of intracellular inclusions). (D) Recovering the biomass containing the polymer and washing it by centrifugation. (E) Disrupting the cell wall and releasing the polymer from the cells. (F) Washing the polymer by centrifugation. (G) Drying the polymer slurry to a powder that can be processed to a final consumer product.

Of the various alternative polymers developed to date, polyhydroxyalkanoates (PHAs), a class of aliphatic microbial polyesters, have been considered among the leading candidates to replace conventional plastics on a large industrial scale[2]. Like their petrochemical counterparts, PHAs are moldable, water insoluble, thermoplastic polymers. The most common PHA, poly-3-hydroxybutyrate (PHB), is a stiff, high-melting-point aliphatic polyester similar to many industrial polyolefins. Unlike polyolefins, however, PHAs can be synthesized by microorganisms, which can produce and store the polymer in the form of intracellular inclusions at levels exceeding 80% of the cell dry mass (see Fig. 1). These microbial polymers can be made entirely from glucose in a fermentation process and, in addition to offering favorable material properties, are completely biodegradable. Thus, the replacement of conventional plastics with PHAs has been promulgated as a desirable approach to solid-waste management and sustainable polymer production[3,4].

A cradle-to-grave analysis

Several factors contribute to the environmental impact and the degree of sustainability of a given product or material. In many instances, however, environmental impact is the result, not of the product per se, but rather of the consumption of raw materials and the release of waste products generated during manufacture. Thus, a "cradle-to-grave" analysis, which incorporates manufacturing practices, energy input/output, and overall material flows, is a good benchmark for assessing environmental impact and sustainability[5,6].

Contrary to the widespread belief that PHAs are a sustainable alternative to polymer production, a surprisingly high latent energy content is associated with their fermentative production. By considering the utilities required to make glucose from corn, it is possible to estimate that a PHA fermentation process consumes 22% more steam, 19-fold more electricity, and 7-fold more water than a conventional process for producing polystyrene. While only polystyrene is directly derived from fossil oil, both polystyrene and PHAs require energy in their manufacture. As

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📖 ***T. U. Gerngross, Nature Biotechnology, 17, (1999), 541 - 544***

Many thanks for your attention!!