Industrial Symbiosis Using Green Chemistry

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ABSTRACT

The twin problems of resource depletion and growing amounts of waste can be solved through the valorization of waste into chemical, fuel and material products. While future “closed-loop” manufacturing should reduce waste through in-house use of by-products and products designed for end-of-life utilization of the components, we also need to find ways to capture valuable substances from existing waste streams and landfill sites. These waste valorization technologies must themselves be green so as not to add a substantial environmental footprint to new waste-derived products. Suitable green chemical technologies include bio-chemical processing (eg fermentation of food waste), thermo-chemical including microwave processing (eg conversion of paper waste to chemical intermediates), and benign solvent extraction (eg supercritical carbon dioxide extraction of waxes from cereal straws). One exciting new case study is on orange peel waste that is widely available in large quantities and rich in chemicals such as D-limonene and materials such as pectin: these and other valuable products can be simultaneously extracted in a novel microwave biorefinery process.

Keywords: Green chemistry, industrial symbiosis, waste valorization.

1 GREEN CHEMISTRY AND TECHNOLOGIES

Traditional chemical manufacturing is resource demanding and wasteful, and often involves the use of hazardous substances while products have often been manufactured without proper knowledge of their human and environmental impacts. Resources are used throughout the production and including the treatment of waste streams and emissions (Figure 1).

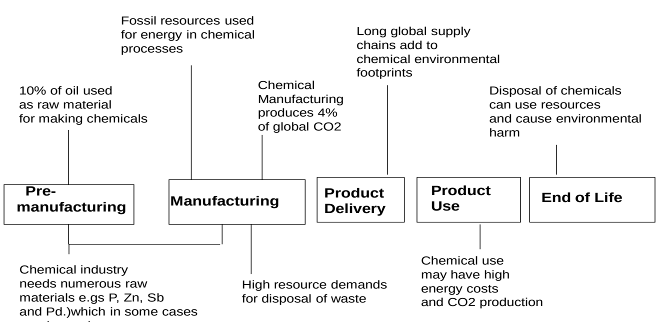

Figure 1: Resource demands of traditional chemical manufacturing

Green chemistry focuses on resource efficiency and on the design of chemical products and processes that are more environmentally benign. If green chemistry is used in a process it should be made simpler, the inputs and outputs should be safer and more sustainable, the energy consumption should be reduced and costs should be less as the overall efficiency is greater and increasingly expensive hazardous waste disposal is minimized [1]. Green chemistry moves us towards new, clean technologies such as alternative reaction media, flow-reactors and microwave reactors, as well as clean synthesis methods including heterogeneous catalysis [2].

Today there is more emphasis on the use of renewable feedstocks [3] and on the design of safer products including an increasing trend for recovering resources or “closed loop manufacturing”. Green chemistry research and application encompasses the use of biomass as a source of organic carbon as well as other low value or waste feedstocks, and the design of new greener products to replace existing products that are unacceptable in the light of new legislation such as the European chemical legislation, REACH.

The ideals of green chemical synthetic design are described Figure 2.

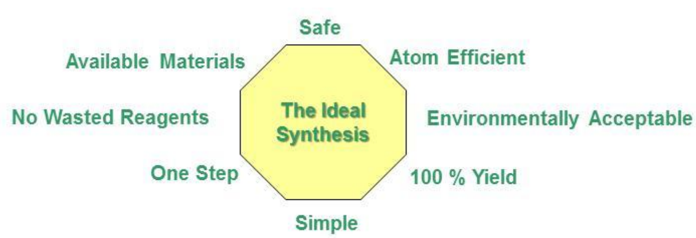

Figure 2: The eight parts of an ideal synthesis

2 FOOD SUPPLY CHAIN WASTE

Food supply chain waste (FSCW) is a major issue in modern society and alternatives to its economically and environmentally costly disposal practises (e.g. landfill, incineration) need to be developed. At the same time society faces a huge looming crisis of resources. Europe and North America especially dependent on importing oil and minerals to feed its industries yet they have the highest consumption of raw materials per capita in the world. As these traditional resources become scarcer their availability will become more politically controlled leaving the West vulnerable to highly politicised negotiations and pricing. First generation FSCW re-use (e.g. anaerobic digestion, composting, animal feed) only have marginal economic value. However FSCW valorisation to produce products including sustainable and bio-derived materials, fuels and chemicals represents one of the most promising research avenues from both environmental and economic standpoints. The disposal of FSCW could in principle be replaced by strategies which have a lower environmental impact and which allow the recovery of valuable products for existing and new markets (Figure 3). Moving towards 'closed loop manufacturing' will both help the West resist future geo-political issues over resources, reduce pressures on landfill sites, helping it to move towards a technology-leading and a resource intelligent economy. Increasingly western countries recognise that, in order to sustain our demands in energy, chemicals and food, while addressing environmental issues, we need to substantially reduce our dependence on oil by establishing a bio-based economy. Future European and American standards on bio-based content along with preferred purchasing policies will encourage greater use of bio-feedstocks. Other major drivers for this topic include: increasing compliance costs to meet regulations for existing substances (e.g. REACH), favouring investment into economically and environmentally sound alternative feedstocks, and growing public awareness towards environmental issues and cradle-to-grave concerns leading to industry's increasing concern over their 'green credentials'.

3 ORANGE PEEL EXPLOITATION

Orange peel waste (WOP) is one of the most geographically diverse bio-waste residues on the planet. After extraction of the juice the residual peel accounts for 50 wt. % of the fruit. However, with high volumes of citrus production (up to 94.8 million tonnes globally) and with processing activities accounting for over 25% of harvested fruits in major citrus producing countries for example, there is a real opportunity to utilise this resource. Major components of wet WOP are water (80%), soluble sugars, cellulose and hemicellulose, pectin and D-limonene. Current applications and uses of WOP are only marginally profitable, and in cases where it is used as animal feed, it is economically unfavourable due to the low protein content (around 6%) and expensive drying cost. Mitigation of expensive drying processes, the design of a sustainable and integrated process for WOP, including the separation and production of marketable bio-chemicals and materials is necessary to allow companies to reduce waste management costs, increase competitiveness and generate additional profits.

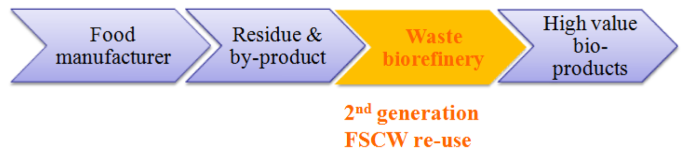

Figure 3: From food waste to bio-products

Low temperature microwave hydrothermal processing of orange peel not only enables the separation of the major components but also adds further value through the production of other higher value products: pectin and D-limonene together with a rare form of mesoporous cellulose are produced in a single step, without use of added acid. A process temperature change enables the conversion of D-limonene to α-terpineol, making the process tunable.

4 CONCLUSIONS

Green chemistry offers a solution to the problems of resource depletion and waste increase. By using green chemical technologies we can hope to create green and sustainable products using waste including food waste as a feedstock.

REFERENCES

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