Hydrodynamic cavitation: the enabling technology of the bioeconomy

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Mario Pagliaro is a chemistry and energy scholar based at Italy’s Research Council in Palermo, Italy, where he leads a research group focusing on nanotechnology, solar energy and the bioeconomy. Co-author of 22 books and of 250 research articles, he ranks amongst Italy’s most cited scientists in nanotechnology, materials science and organic chemistry. Dr Pagliaro serves on the advisory and editorial boards of several internationally recognized journals, including Chemical Society Reviews.

In manufacturing, including chemical manufacturing, a technology is said to be enabling when it allows the rapid creation of usable products in large abundance. Controlled hydrodynamic cavitation -- the controlled formation, growth, and implosion of vapor bubbles in water releasing in milliseconds on the nanoscale huge amounts of energy -- applied to abundant, and virtually free, biological resources such as agriculture, agrofood industry and forest leftovers and by-products is the enabling technology of the bioeconomy (1).

In chemistry, cavitation is increasingly used for the intensification of chemical and physical processes in the chemical process industry (2), in wastewater remediation (3), and to recover valued bioproducts from biological resources that would otherwise undergo landfilling, incineration or composting and anaerobic digestion (4).

Cavitation based on the use of the Venturi tube, and no longer on barely scalable acoustic waves or costly and critical arrangements based on moving parts, can now be applied, among other things, to convert malt into beer (eliminating malt dry milling and wort boiling) of enhanced biophenolic (5) and much lower gluten (6) content, or to extract pectin, essential oil, natural dyes, cellulose and biophenols from waste citrus peel obtained from the citrus juice industry (7).

Hydrocavitation (HC) is generated by forcing the fluid to pass through a constriction channel in a conduit (Venturi tube). Hence, an hydrocavitation reactor is comprised of metal parts only and exclusively uses electrical energy to power the pump that drives the cavitation process. No organic solvent, acid or base is required to separate different valued bioproducts present in the biological matrix. In general, the use of HC for the extraction of natural products meets all six principles of Green Extraction: (8)

1. Use of renewable, plentiful plant resources
2. Solvent free: water is the only solvent.
3. Reduce energy consumption: lower process temperature, greater heating efficiency, simplification of process steps, and intrinsic pretreatment (e.g., grinding) of raw materials, higher efficiency in the extraction, and reduction in processing time.
4. Co-products instead of waste: Residual fraction of the original raw material, separated from the aqueous solution, could be reused (anaerobic digestion, biochar) by the bio- and agro-refining industry.
5. Reduce unit operations and favor safe, robust and controlled processes: only two operations (i.e., HC processing, and mechanical separation), equipment generally simple, safe, robust, scalable and easily controllable.
6. Aim for a non-denatured and biodegradable extract without contaminants: absence of additives, water and raw materials can be the only ingredients. HC process does not denaturate the antioxidant compounds.

For instance, applied to waste orange or lemon peel, HC affords bioproducts of largely superior quality at a fraction of the cost of competing extraction technologies, either consolidated or newer ones (6).

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In closer detail, the pectic polymer does not degrade, the terpenes comprising the essential oil are not oxidized, pure defibrillated cellulose microfibrils are obtained and all valued phenolic substances are recovered including citrus bioflavonoids that today are used to produce for example oral antibacterials. Accordingly, lemon pectin obtained using this new process and aptly called “IntegroPectin” shows exceptional antioxidant activity and a complete lack of cytotoxicity (9), as well as superior antibacterial activity (10).

As put it by Meneguzzo, founder of the HCT Agrifood Lab at Italy’s Research Council in Florence, a key advantage of the technology is its ability to support the marketability of the resulting higher value added bioproducts, while improving the overall sustainability (conservation of biological resources) and public health profile of natural product extraction based on hydrocavitation (Figure 1).

In the framework of the emerging bioeconomy, for bioproducts replacing competing oil-derived products on the market, it is necessary to reach the cost parity, and this explains why the HC technology with its low capital and operational cost will be readily adopted by the natural product, food, beverage and chemical industries.

REFERENCES

6. L. Albanese, R. Ciriminna, F. Meneguzzo, M. Pagliaro, Gluten reduction in beer by hydrodynamic cavitation assisted brewing of barley malts, LWT - Food Science and Technology 82 (2017) 342-353.

GREEN MANUFACTURE OF ACTIVE PHARMACEUTICAL INGREDIENTS

Uniqsis has recently installed a 4-channel FlowSyn™ flow chemistry system in the Riley Research Group Laboratories at the University of Pretoria (South Africa).

The Riley Research Group (www.rileygroup.co.za) is well known for its development of novel pharmaceuticals using flow synthesis, reaction engineering and the development of new chemical reactors. Currently the Riley group medicinal chemistry team is focusing on lead discovery and computational modelling aimed at the identification and development of new anti-Alzheimer’s agents.

Dr Darren Riley, head of the group commented “My team is actively involved in flow chemistry process development for economic and green manufacture of active pharmaceutical ingredients for the South African market”. He added “Flow chemistry in microreactors has many advantages over batch processing including better reproducibility and scalability, improved yields and fewer problems with unstable intermediates or exothermic reactions. We chose a FlowSyn™ flow chemistry system from Uniqsis as they are widely proven to handle everything from homogeneous single reactions to complex, multi-reactant reactions. We also factored into our choice the knowledgeable technical and applications support provided by the staff at Uniqsis to my team of chemists”.

For further information on the FlowSyn flow chemistry system please visit http://www.uniqsis.com/paProductsDetail.aspx?ID=FLW_SYN or contact Uniqsis on +44-845-864-7747 / info@uniqsis.com.

Since 2007, Uniqsis has specialised in the design and supply of mesoscale continuous flow chemistry systems for a wide range of applications in chemical and pharmaceutical research. The company’s aim is to make flow chemistry easily accessible to both novices and experienced users.

Riley Group chemists with their FlowSyn Flow Chemistry System