Green and economically viable extraction of natural products: from lab to marketplace

BIOMATERIALS & NANOMATERIALS

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Driven by large and increasing demand of natural compounds (lipids, alkaloids, terpenes, proteins, phenolics and glycosides) in medical, nutraceutical, pest and disease control, cosmetic, food supplement, perfumery and aromatherapy products, conventional extraction methods widely relying on distillation using oil-derived organic solvents are being replaced by green methods (1). Informed customers in the digital age do not wish to buy natural products obtained with petroleum derivatives.

This trend, in brief, caused accelerated technical progress which in turn resulted in technologies such as supercritical fluid (SCF) and microwave-assisted extraction (MAE) to exit niche applications and leave academic laboratories to finally enter the marketplace. The few companies using $scCO_2$ in place of CH_2Cl_2 to decaffainate coffee are no longer alone. Today numerous firms across the world rely on advanced SCF extraction processes, including advanced supercritical fluid chromatography for the enrichment of omega-3 polyunsaturated fatty acids (2).

For decades, as suggested by Pereira and co-workers, little information about SCF industrial costs was disclosed (3). Today, flexible, natural ingredient manufacturers use supercritical CO_2 to extract a wide variety of ingredients in multi-product platform plants of medium-capacity and high profitability.

Similarly, MAE is a technically and economically feasible process eventually being used at commercial scale (4). The technology enables quick, pressure-driven extraction of natural compounds from various plant matrices replacing the organic solvent with water such as in the elegant microwave extraction combining hydrodiffusion and gravity (MHG) (5).

MICROWAVE-ASSISTED EXTRACTION: SOLVING THE HURDLES POSED BY SCALE-UP

To achieve reproducible extraction, which is a critical aspect in the commercial production of standardized natural product, a number of advances were necessary for MAE to go commercial. For example, rotation of the drum in the extractor in Figure 1, ensures a homogeneous microwave distribution through the botanical matrix, whereas vapor and liquid smoothly cross the perforated drum circumference.

Figure 1. Pilot scale MAE extractor equipped with four magnetrons (4 × 1500 W). The 150 L stainless steel microwave cavity contains a removable drum that allows up to 75 L of plant material to be loaded. (Photograph of Milestone srl, reproduced with kind permission).

The system automatically adjusts the power delivered if the microwave absorption, controlled by sensors, is too low. The botanical sample to be extracted is comprised of parts of 2 cm maximum thickness, because microwaves at 2.45 GHz frequency have relatively low ability to penetrate the sample.
Several other new generation extraction technologies will emerge, especially those using water as extracting medium and requiring little energy input such as, for example, controlled hydrocavation (CHC) (6), as well as those requiring no other energy besides freely available solar energy (7), particularly abundant in developing countries where a large fraction of the population relies on medicinal plants for primary health care. For example, the extraction of essential oils from medicinal plants can be carried out using parabolic solar dish concentrator for deriving the necessary energy for heating a collecting vessel placed at the focus of the concentrator (Figure 2).

Figure 2. Solar distillation unit jointly developed at University of Agriculture Faisalabad, Pakistan, and University of Kassel, Germany. The system can provide 300-400 °C temperature (Image courtesy of Dr W. Amjad, Reproduced from Ref.7, with kind permission).

SOLAR-DRIVEN DISTILLERY FOR ESSENTIAL OIL EXTRACTION FROM MEDICINAL PLANTS

Different kinds of medicinal and aromatic plants including melissa, peppermint, rosemary, cumin, cloves, oregano, rosemary, lavender, fennel anise, lemon, orange, cedar wood, sandalwood generally can be processed successfully by using solar distillation system charged with the leaves, but also seeds and buds. In detail, with the system shown in Figure 2, about 10 kg fresh plant material can be processed in 4-5 batches each day (8).
In a progress identical to that occurring with distributed energy generation with solar panels, the solar-driven distillation technology enables the replacement of large and capital-intensive distillation units powered with fossil fuel energy, with a distributed network of smaller distillation units for local extraction of essential oils whose economic value is so high that it can well become a source of income for farmers and farming companies.

Whatever the green extraction method of choice, in the path from research to economic opportunities, education in the new green methodologies will play a key role (9).

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