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Microencapsulation: Prilling by Vibration

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The present role of microencapsulation
Prilling by Vibration technology opens up new possibilities

Introduction

Microencapsulation, defined as a process which involves the complete envelopment of a material(s) within a porous/impermeable membrane to produce microcapsules, has already provided users with a myriad of applications. These particles have enabled the generation of innovative products in areas such as food, laundry, agricultural, textiles, cosmetics and the pharmaceutical sector [1], as well as helping scientists to develop new treatments against many diseases [2].

There are numerous reasons for encapsulating a product within a membrane and are summarized in Figure 1. The most common is the protection of a product from a harmful environment(s) [1]. Examples include the encapsulation of animal and stem cells for generating artificial implants [3,4] or enabling the obtainment of high density cell cultures to produce larger quantities of medically important drugs [1]. In these cases the encapsulation process protects the cells against immune response in the body and shear stress in the bioreactor.

The food industry has been by far the biggest benefactor of the process. A strategic business report published in 2010 estimates encapsulation processes such as coacervation and spray drying will generate nearly $40 billion in revenue for the food industry by 2015 [5]. Here microcapsules are used to prevent unfavorable reactions with other ingredients, control organoleptic properties, and prevent degradation of expensive bioactive ingredients during processing and packaging [1]. The latter has enabled food manufacturers to add significant value to their products and obtain considerably higher markups.

Microencapsulation has also been employed for sustained, controlled or targeted release of encapsulated products, and has found substantial usage for the delivery of numerous materials such as pharmaceuticals, bioactive ingredients, fragrances, adhesives, vitamins and flavors [1].
Recently the technology has being applied to new fields, which includes environmental applications for the recovery of pollutants from water [6], in fermentations to help purify bio-products [7] and chemical processes to optimize reactions. The technology has also being adopted for technical applications, whereby it has being employed to improve flow and handling (including safety) properties of solids and liquids [1].

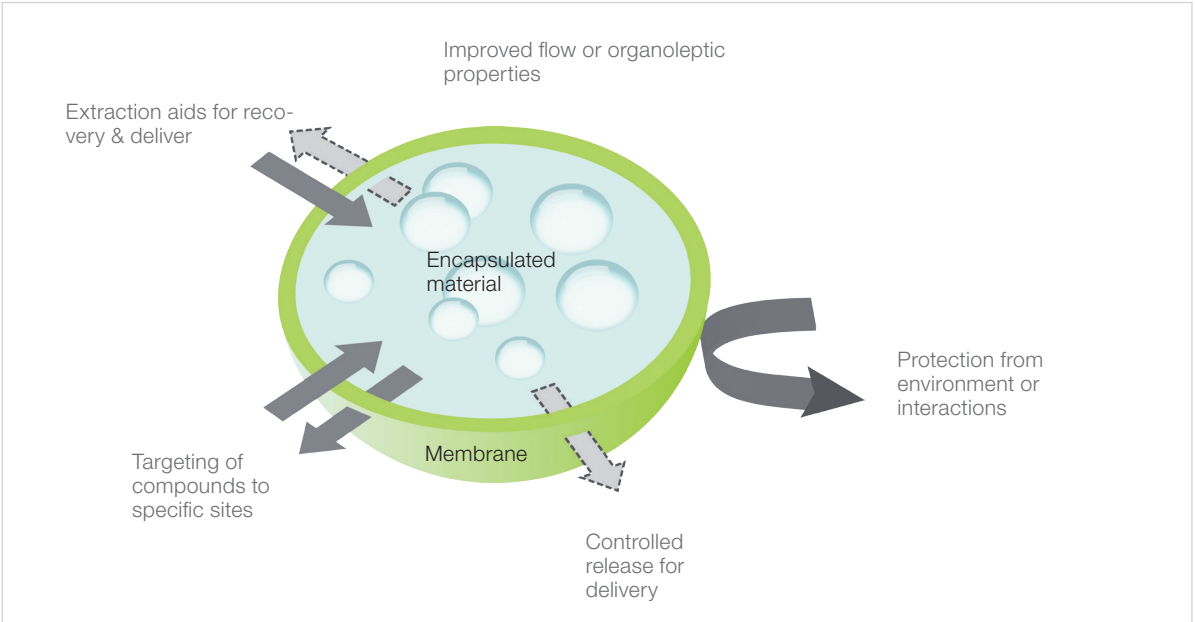

Figure 1: Main reasons why microencapsulation (producing microcapsules) of a product takes place.

Prilling by Vibration

Successful application of microencapsulation to a variety of process requires a production technique which is not only flexible and easy to implement, but also has the ability to adhere to stringent production criteria with regard to final product characteristics. One such technique which fits this role is “Prilling by Vibration” (also commonly referred to as vibrating-nozzle), and can be performed on the Encapsulator produced by BÜCHI Labortechnik AG.

The Prilling by Vibration technique works on the principle of controlled breakup of a laminar liquid jet into droplets using mechanical vibrational frequencies (Figures 2 & 3). Extrusion of a polymer liquid (containing the material to be encapsulated) through a nozzle of the BUCHI Encapsulator results in formation of a laminar liquid jet. A controlled vibrational frequency is applied to the liquid jet and causes its breakup into equally sized droplets which are subsequently solidified and converted into the desired beads or capsules by different hardening techniques (Figure 4). The size of the produced beads/capsules is mainly dependent on nozzle size, flow rate and vibrational frequency applied and all parameters can be controlled on the Encapsulator. This enables the operator to pre-determine the size and characteristics of the beads and capsules that are produced.

This production technique has gained significant interest from manufacturers and scientific researchers on account of its ability to produce small, mono-dispersed, homogenous microcapsules and particles with a narrow size distribution. In addition it is easy to set up and operate, has low operating costs and can be integrated into a GMP process if required. For these reasons it is one of the most commonly employed techniques to produce microcapsules at lab-scale [1].
The most important criteria for any microcapsule production technique are the ability to scale-up the process to produce higher quantities of particles, without incurring a significant change in capsule properties. The new BUCHI multi-nozzle Encapsulator which has six separate nozzles achieves such a goal, and further increases in production volumes can be simply achieved by adding more nozzles [1].

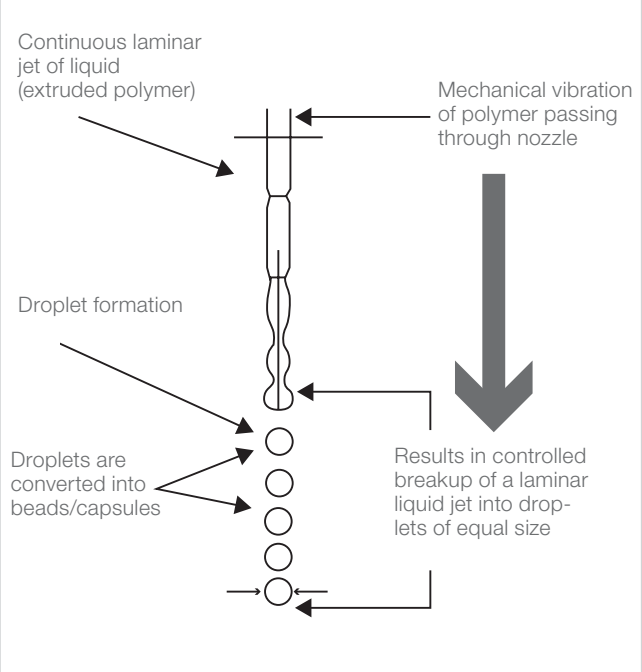

Figure 2: Schematic displaying the operational principle of the BUCHI Encapsulators which uses vibrational frequencies for the controlled breakup of a laminar liquid jet into equally sized droplets [1].

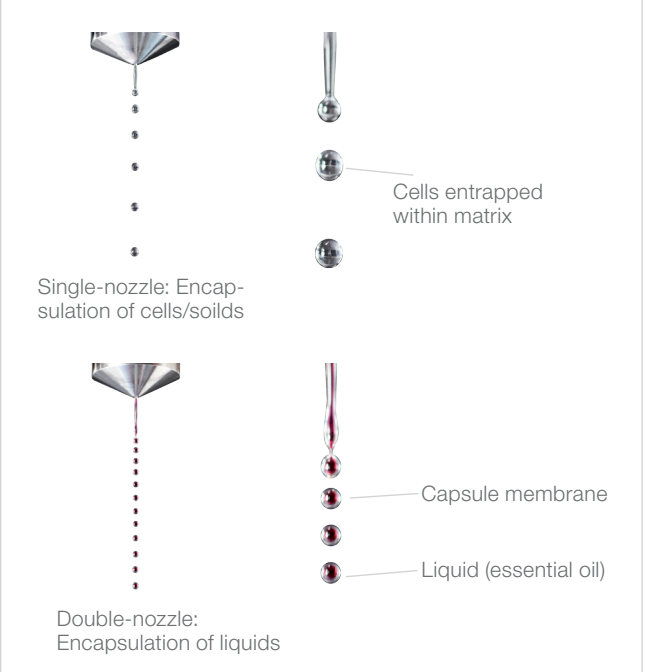

Figure 3: Real-time image of droplets being produced on the BUCHI Encapsulator using prilling by vibration technology. The produced droplets are converted into beads/capsules using different hardening techniques.

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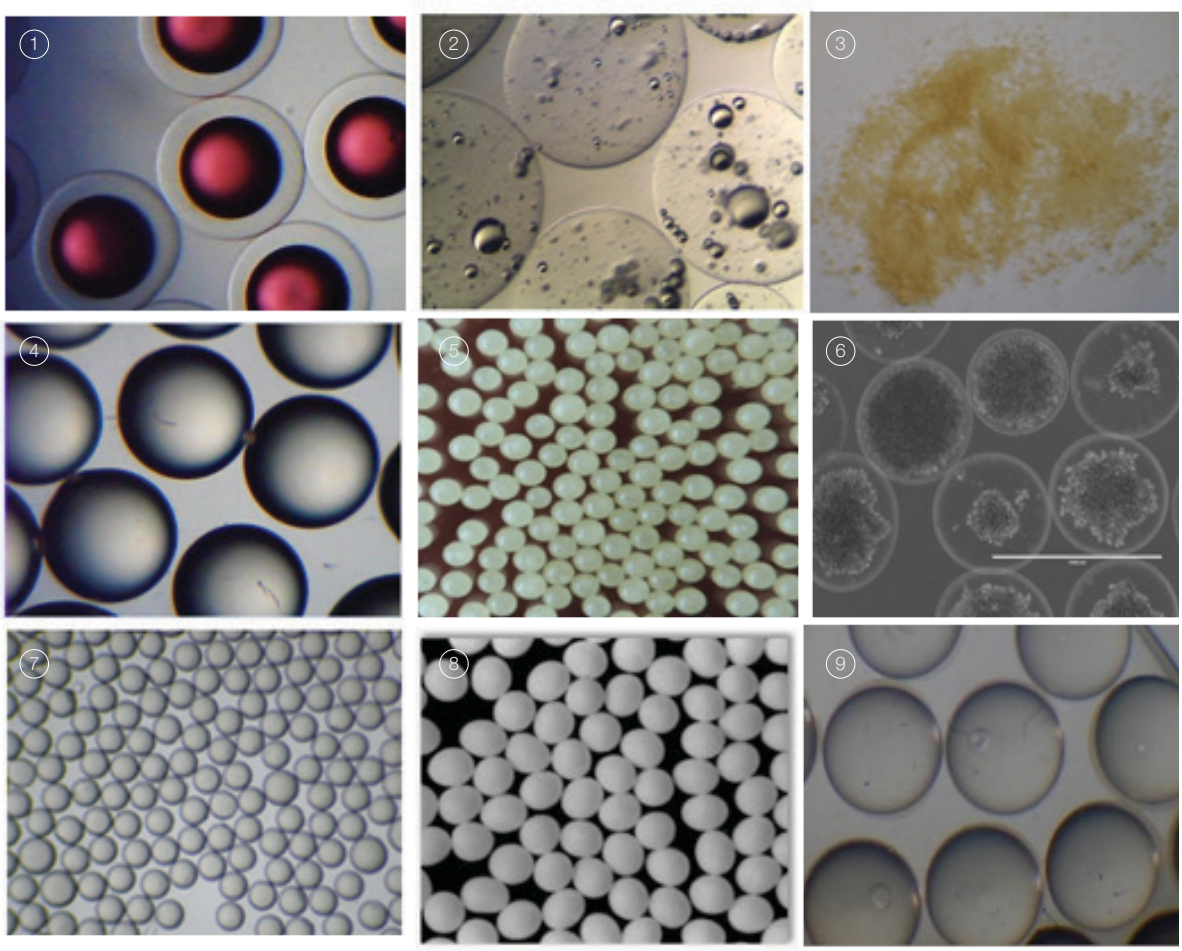

Figure 4: The many different types of beads and capsules which can be produced by the BUCHI Encapsulators and can be used for numerous applications in different industries (see application table).

(1) Capsules with a core of sunflower oil (with a red dye) and an alginate shell.
(2) Beads containing sunflower oil.
(3) Dried alginate beads containing yeast.
(4) Wet gelatin beads containing vitamin C.
(5) Dried gelatin beads.
(6) Encapsulated CHO cells in alginate-PLL-alginate microcapsules.
(7) PLGA beads encapsulating Ibuprofen.
(8) Wax-based beads and
(9) Core-shell capsules containing olive oil.

Applications for Prilling by Vibration Technology

The Prilling by Vibration technique has being used for over 2 decades by scientists to develop new innovative products. The table below highlights some of this work performed on the BUCHI Encapsulator* and also explains the benefits of encapsulating a selected material for application in a particular segment.

Industries	Encapsulated material	Benefit (application)	Ref.
Food & Beverage Feed	Sunflower oil	Control bioavailability of lipids in food	8
	Folic acid	Improve stability during freeze drying & storage	9
	Probiotics (*Lactobacillus acidophilus*)	Protection of bacteria in gastric conditions	10
	Probiotics (*Lactobacillus fermentum*)	Oral and controlled delivery	11
	Probiotics (*Lactobacillus casei*)	Controlled release (Gastrointesinal (GI) Tract of pigs)	12
	Flavourzyme	Encapsulation of enzyme to improve acceleration of cheese ripening	13
	Avocado oil	Improve storage stability	14
	Olive oil	Improve storage stability	15
	Canola oil	Improve storage stability	16
	Essential oils	Improve storage stability (prevent evaporation)	17
	Iron	Controlled release in the GI Tract	18
	Carvacrol (essential oil)	Controlled delivery (GI Tract of pigs)	19
Pharma	Celecoxib	Controlled release	20
	Furosemide	Enhanced solubility & permeability	21
	Thalidomide	Controlled delivery (Crohn's disease)	22
	Methotrexate	Controlled release	23
	Salicylic acid, propranolol & insulin growth factor I	Controlled release	24
Bio-Pharma	Bacteriophage (Felix O1)	Oral delivery	25
	Sperm (bovine)	Storage and controlled release (artificial insemination)	26
	Vaccine (*Brucella*)	Controlled release	27
	Vaccine (*B. melitensis* vjbR::Tn5 mutant)	Controlled release (treatment of Brucellosis)	28
	Stem cells (human adipose)	Transplantation in vivo for production of growth factors	29
	Mesenchymal stem cells (Whartons Jelly)	In vivo applications	30
	Carbon nanotubes	Controlled delivery	31
	Therapeutic proteins	Targeted and controlled delivery	32

*The BUCHI Encapsulator technology is the successor model to the Inotech and EncapBioSystems devices.

Conclusion

The simplistic nature of the BUCHI Encapsulator should help further improve and expand the applications of microencapsulation technology in many fields. To-date this hasn't always been possible due to the unavailability of suitable production techniques to produce the required microcapsules with the desired characteristics. For manufactures this will lead to the establishment of new products, improvement of existing ones (by delivering new functionality), or in some cases completely redefine the role of a commodity.

Delivering new product functionality is seen by many as the most important feature of the technology as it will help extend a products life-cycle as well as increasing market share – all without having to develop a completely new product.

Furthermore as expressed by many international experts in medicine and biotechnology, further developments in microencapsulation also has the potential to help scientists to make breakthroughs in treating and preventing many incurable diseases.

Due to its many existing and potential applications in many diverse areas, microencapsulation has already received much attention from both academic and commercial bodies. For the future its further development is seen as a major interest both from an economic and scientific point of view.

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