Encapsulation

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Encapsulation is a process of enclosing or entrapping a core material (liquid, gas, solid particles, cells, dissolved active ingredients, etc.) inside a solid shell or within a solid or liquid matrix for the purpose of controlled or triggered release, immobilization, isolation or protection of the core material. The material being encapsulated is called the core material and the carrier material used for envelopment or entrapment is called the shell material. Typical examples of core materials being encapsulated are ink or dye for carbonless copy papers, liquid crystals for microparticle-based displays, phase change material for smart textiles, high molecular weight gases for ultrasound contrast imaging, genetic material for *in vitro* compartmentalization, active food ingredients for functional food products, enzymes for biocatalytic reactors, drugs, pesticides, fragrances, anti-microbial agents, etc.

Encapsulation efficiency (EE) is defined as the percentage of core material incorporated into the microcapsules relative to the total amount of the core material added during encapsulation process: EE = $(m_E/m_T)100\%$, where m_E is the mass of the core material incorporated and m_E is the total mass of the core material added. Loading capacity refers to the percentage of core material incorporated within the microcapsules relative to the total mass of the microcapsules (i.e. core + shell material).

Two main types of capsules can be distinguished, core/shell (reservoir) type and matrix type. In the core/shell capsule (Fig. 1a), the shell material completely surrounds and contains an internal core material (the internal phase). The strategies used for formation of shell are complex coacervation, polymer precipitation by internal phase separation, interfacial reaction that may include polycondensation or cross-linking, and layer-by-layer polyelectrolyte deposition (Yow and Routh 2006). The core material can be released from core/shell capsules by simple molecular diffusion through the shell, or by deliberately compromising the integrity of the shell, e.g., by exposing the microcapsule to environmental stresses such as mechanical forces, change of pH, temperature or ionic strength, or by chemical or biochemical degradation of the shell. A special class of core/shell capsules are micelles and vesicles (liposomes, polymersomes, and colloidosomes), formed by self-assembly of amphiphilic molecules (phospholipids and diblock copolymers) or particles (Dinsmore et al 2002). Micelles are formed spontaneously when amphiphiles are dispersed in a polar solvent at concentrations that exceed a critical level, known as the "critical micelle concentration" (CMC). Micelles containing solubilized materials are referred to as microemulsions or swollen micelles. A difference between micelles and vesicles is that vesicles are not a thermodynamically stable state of amphiphiles and do not form spontaneously, e.g. without input of external energy (Tadros, 1993).

In the matrix-type capsule (Fig. 1b) the core material is distributed uniformly throughout a matrix of shell material. The most common release pattern from matrix-type capsules is first-order in which the release rate decreases exponentially with time until the active ingredient is exhausted. Typical matrix-type capsules are multiple emulsions, hydrogel particles, solid lipid particles, polymeric particles, etc. Hybrid structures consisting of a number of hierarchically assembled homogenous phases may be engineered that allow for even finer control over the functionality of microcapsules (Fig. 1 c-d).

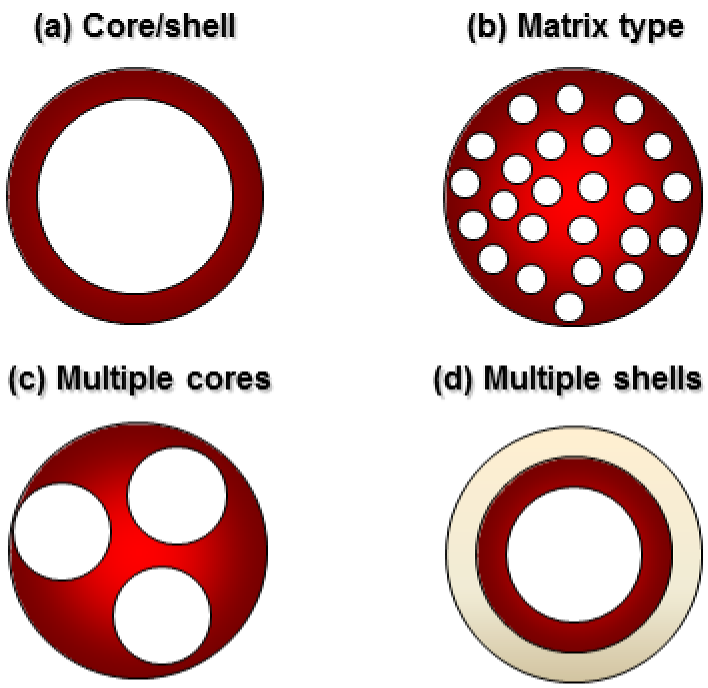

Figure 1. Schematic diagrams of capsules with different morphologies.

References

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