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Microencapsulation Technology in Food Industry

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A number of microencapsulation technologies for the controlled release of active ingredients have been used in pharmaceutical, agricultural, food, consumer products industry. In the pharmaceutical industry, a variety of microparticulates drug delivery dosage forms are now in the market, while its application in domestic food industry is believed in infancy. The encapsulation of food ingredients such as flavors, nutrients, preservatives, enzymes, and bacteria cells has the following advantages:

- isolation of food ingredients from detrimental environment(water, acid, oxygen)
- stabilization of ingredients from processing
- controlled release
- better processability; change of state, a liquid to a solid for dry application

The main purpose of microencapsulation is to release the food ingredients in a controlled manner; for example, a slow release of volatile flavors, acid, and sweeteners in chewing gums. To achieve the issue of controlled release, the basic release mechanism of encapsulated materials should be understood, and then formulate the microcapsules for its specific purposes.

Table-1. Mechanisms of food ingredients release from microcapsules

Diffusion controlled release	Membrane controlled release
Pressure controlled release	Tearing or peeling release
Solvent activated release	Osmotically controlled release
pH sensitive release	Temperature-sensitive release
Melting activated release	

The encapsulation of food ingredients is normally accomplished by lipids, fats, or hydrophilic natural and synthetic polymers. There have been a number of microencapsulation methods: spraying, extrusion, entrapment, phase separation, crystallization, and polymerization.

Microencapsulation Processes

Physical Processes

Air suspension coating (Wurster coating, fluid bed coating)

A bed of solid particles are suspended in a fluidizing stream of air and "spray painted" with a stream of coating material as the bed is circulated past the spray nozzle. The coating material must be applied as a liquid (a melt or a solution in water or organic solvent). This liquid coating must be solidified before the particle drops out of the air stream and returns to the main bed. Wurster coating is the special subset of air suspension coating which uses a tubular insert that directs the particle flow. This process usually forms a "microcapsule" or an agglomerate.

Spray drying

Standard spray drying can be used with a slurry of particles to be coated and a "wall material" dissolved in some solvent. The solvent is flashed off, leaving behind the wall material and particles. Generally a matrix(dispersion) is formed, rather than a microcapsule.

Prilling

Often known as spray chilling (solidifying small particles from a melt). A solid material is melted and mixed with the particles to be coated. Prills are formed by many techniques (pressure nozzle, air nozzle, spinning disk, etc). A matrix material is formed.

Chemical processes

Simple coacervation

This is the formation of a phase separated layer(usually gelatin) from adding another water insoluble material (usually a salt) to the solution. A true capsule can be formed if the salt is added to the gelatin. A matrix can be formed if this is reversed. The salt is thought of as shocking the gelatin out of the solution.

Complex coacervation

This is the microencapsulation process that forms a (phase separated) "coacervate" layer from the interaction of polycation and a polyanion that deposits on a available droplets. Usually an oil is dispersed in a hot gelatin solution. A solution of a poly-anion(such as gum arabic or polyphosphate) is added. The pH is

adjusted so that the gelatin is positively charged and the polyanion is negatively charged. When the batch is cooled, the coacervate separates as the wall. The wall is frequently crosslinked to make it insoluble.

gelatin-acacia
gelatin-pectin
gelatin-carboxymethylcellulose

Organic phase separation

Sometimes considered as reversed simple coacervation, i. e. a polymer phase separates and deposits on a "core" that is suspended in an organic rather than waster. Separation can be achieved 1) by adding a "nonsolvent" for the polymer, 2) changing the temperature to change solubilities, or 3) adding a second incompatible polymer (referred to as polymer-polymer incompatibility). Ethyl cellulose is a common wall material.

Solvent evaporation

A polymer is dissolved in a volatile solvent(usually water-immiscible). The active ingredient is then suspended in this fluid. This mixture is added to the water carrier, and the solvent is evaporated, precipitating the polymer on the active and forming microspheres.

Interfacial polymerization

Includes a number of processes (in-situ polymerization, interfacial coacervation) in which a wall is formed from monomers at the interface of a core and suspending medium. Monomers may come from the different phases; in other cases they come from the same phase. Usually very thin, impermeable walls can be formed: polyurethanes, urea-formaldehyde, melamine-formaldehyde.

References

1. R. Baker,; Controlled Release of Biologically Active Agents, John- Wiley & Sons, New York, 1986

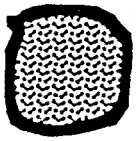
2. S. J. Risch and G. A. Reineccius, Encapsulation and Controlled Release of Food Ingredients, ACS Symposium Series 590, ACS, Washington DC, 1995

DEFINITIONS

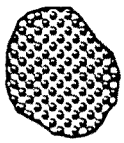
Generally controlled delivery technology (sometimes called encapsulation) is used to provide some sort of protective wall for an ingredient to control its delivery in use, to increase its safety or convenience, to protect it from other materials or the environment, or increase its lifetime.

Controlled delivery products can take many forms. There can be a discrete wall surrounding a core of active (a microcapsule). The active can be dispersed uniformly throughout the wall (a micromatrix). A matrix particle can have a protective wall put around it (microcapsule aggregate). A particle of inert wall can have the active dissolved in it as a molecular dispersion (microsphere). Any of these can be combined, such as agglomerating microcapsules, imbedding them in a micromatrix, and adding a wall around the particle.

Microcapsule
Continuous core & shell



Microcapsule Agglomerate
Dispersion of core surrounded by continuous shell



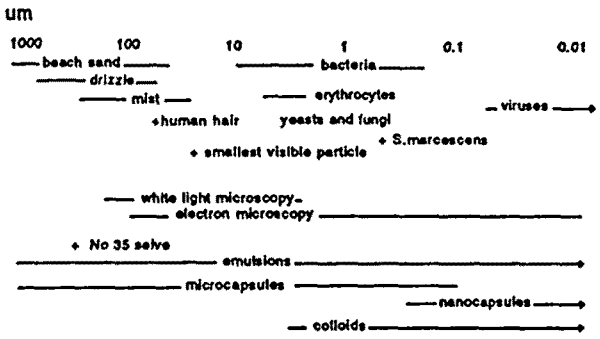
Micromatrix
Particles dispersed uniformly in a matrix

Microsphere
Molecular dispersion in a matrix

Why microencapsulate?

to: isolate active from environment
separate incompatible actives
control release of actives
mask taste
modify flow properties

RELATIVE SIZE OF SMALL PARTICLES



General Preparation


disperse


reduce free energy


solidify:
chemical
physical


continuous phase


actives, core


coating polymer

SIMPLE COACERVATION

desolvation and precipitation of one colloid by

change in: temperature

pH

addition of: miscible non-solvent

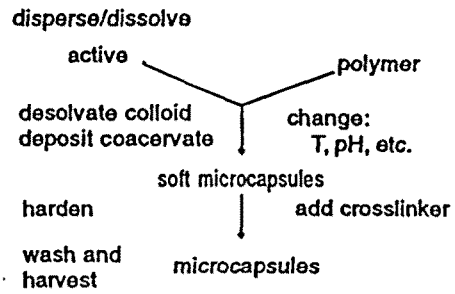
competitive solutes

around dispersed core material either

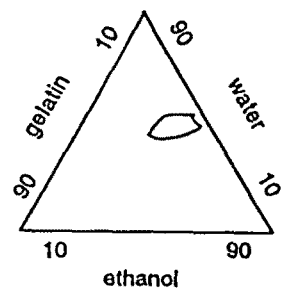
in suspension

in emulsion

FLOW CHART FOR SIMPLE COACERVATION



PHASE DIAGRAM FOR SIMPLE COACERVATION



COMPLEX COACERVATION

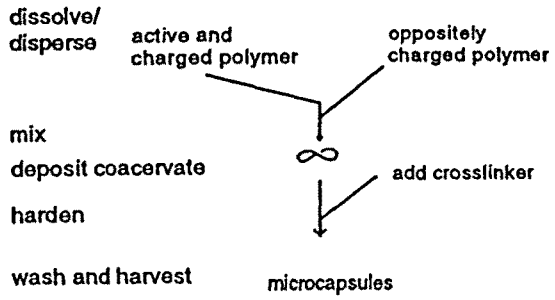
mutual precipitation of charged colloids
by charge neutralization

and

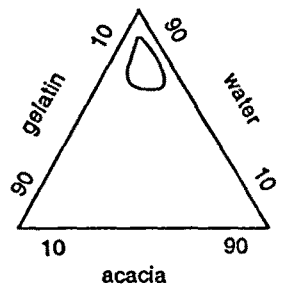
coalescence around dispersed core
insoluble particles/emulsion droplets

B.F Green & L.Schelcher,
U.S. Patents 2,730,456 & 2,730,457
10 January 1956

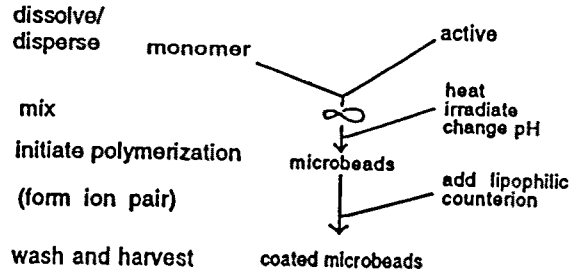
FLOW CHART FOR COMPLEX COACERVATION



PHASE DIAGRAM FOR COMPLEX COACERVATION



FLOW CHART EMULSION/SUSPENSION POLYMERIZATION



P.Couvreur et al. J. Pharm.Sci. 68:1521-4 (1979)
C.Chavany, et al. Pharm.Res.9:441-9 (1992)

INTERFACIAL POLYMERIZATION

two or more monomers
separately dissolved in immiscible solvents
when emulsified
react at droplet interface
to form film surrounding droplets.

active dissolved/dispersed in dispersed phase

E.L.Whitbecker and P.W.Morgan, J.Polym.Sci. 40:289-97 (1959)
T.M.S.Chang Science 146:524-5 (1964)

POLYMERIZATION; SUSPENSION, EMULSION AND MICELLE

polymerization or copolymerization of monomers
initiate with:
chemical catalyst
irradiation
active component
entrapped during
adsorbed after

S.C.Khama, T.Jecklin, and P.Speiser
J.Pharm.Sci. 59:614-18 (1970)

CAPABILITIES OF ENCAPSULATION PROCESSES

"CONVENTIONAL" PROCESSES

PROCESS	CORE	SUSPENDING MEDIUM	SIZES -μ	LOAD %	COMMENTS
1. Wurster	S	Air	75-5000	50-99	Batch process, walls applied as liquid, some breakage in collisions, long contact time, 46" largest unit.
2. Centrifugal nozzle (SwRI)	L	Air	125-2000	10-60	Continuous process, short contact time, low capacity.
3. Stationary nozzle (SwRI)	L	Liquid	1000-3000	10-60	Continuous, low capacity.
4. Spray dry	L, S	Air	10-1000	10-40	Continuous, low cost, many applications, poor particle control, matrix form generally, usually poor protection, loss of volatiles.
5. Prilling	L, S	Air	10-2000	10-60	Continuous, matrix formation, usually poor protection, incomplete coverage, generally long contact time.
6. Spinning disk (WUTA)	S, L	Disk	30-1500	10-95	Continuous, liquid applied walls, gentle process, once through, few commercial examples.
7. Pan coating	S	Pan	500-5000	50-90	Batch, large particles, can be very smooth coat, food-grade, expensive, equipment.
8. Microsponge	S, L	Liquid	5-2000	10-50	Batch, usually polymerize in place, open structure, generally poor protection.
9. Extrudates	S, L	Air, liquid	500-5000	10-40	Continuous, matrix formation, generally poor protection, low cost.
10 Complex coacervation	L, S	Water	25-1000	10-95	Batch, insoluble solids or oil soluble core, agglomeration often, long contact time, aldehyde cross-linking, low capital.
11 Simple coacervation	L, S	Water	50-1000	10-80	Batch, insoluble solids or oil soluble core, agglomeration often,long contact time, generally lower protection, low capital.
12 Organic phase coacervation	L, S	Organic liq	100-5000	10-80	Batch, water soluble cores, expensive solvent system, agglomeration often.
13 Solvent evaporation	S	Liquid	10-1000	10-50	Batch, wide range of application, expensive solvent systems, few commercial examples.
14 "Interfacial polymerization"	S	Organic liq	5-1000	10-95	Batch, thin walls possible, reactants often have safety issues.

* L = liquid, S = solid