ADVANCEMENTS IN TEXTILE THROUGH MICROENCAPSULATON

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ABSTRACT:

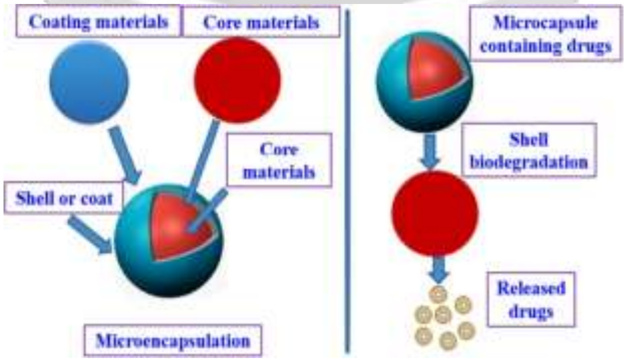
Microencapsulation has revolutionized the textile industry by enhancing functionality and performance. This innovative technique involves enclosing active substances in micro-sized capsules, which are then integrated into fabrics. These capsules release their contents in response to specific triggers, such as friction, temperature, or moisture. Application ranges from moisture-wicking and temperature-regulating fabrics to odor control and skincare textiles. This abstract highlight the transformative impact of microencapsulation on textile properties, opening avenues for smarter, more versatile, and functional textiles.

INTRODUCTION:

Microencapsulation is a process in which tiny particles or droplets are surrounded by a coating to give small capsules. In a relatively simplistic form, a microcapsule is a small sphere with a uniform wall around it. The material inside the microcapsule is referred to as the core, internal phase, or fill, whereas the wall is sometimes called a shell, coating, or membrane. Most microcapsules have diameters between a few micrometers and a few millimeters. The definition has been expanded and includes Foods. Every class of food ingredient has been encapsulated; flavors are the most

Common. The technique of microencapsulation depends on the physical and chemical properties of the material to be encapsulated. These micro-capsules have a number of benefits such as converting liquids to solids, separating reactive compounds, providing environmental protection, and improved

Material handling properties. Active materials are then encapsulated in micron-sized capsules of barrier polymers (gelatin, plastic, wax ...). Many microcapsules, however, bear little resemblance to these simple spheres. The core may be a crystal, a jagged adsorbent particle, an emulsion, a suspension of solids, or a suspension of smaller microcapsules. The microcapsule even may have multiple walls.



MICROENCAPSULATION METHODS

Spray drying

Spray drying is a technique in which a feed solution, which is a mixture of the core material, and the wall material, is atomized and formed into a mist inside a chamber, where hot air is applied to convert the mist into powder. Depending on various factors like the characteristics of the feed solution and operating conditions, powder of varied particle size can be produced. In spray drying, the core material, that is, the material of interest gets trapped in the dried powder. Although spray drying is one of the most extensively used methods for microencapsulation and has many stated advantages also, some studies have portrayed certain drawbacks of the technique. When hot air is used as a drying medium for encapsulation of omega-3 fatty acids, dried powder has particles with highly porous structure, making the powder more prone to oxidation, thus, reducing the shelf life.

Spray cooling

The spray cooling method of encapsulation is remarkably similar to spray drying in operation, the major difference being the use of cold air in it. Here, a mixture of core material and wall material is atomized to form a mist inside a chamber, inside which cold air flows. The low temperature within the chamber results in solidification of the micro droplets, leading to the formation of microencapsulated powder. This technique also has a huge potential in scaling up. Some successful implementations of this technique in encapsulation include microencapsulation of tocopherols within lipid matrix.

Coacervation

Coacervation is a simple technique which involves formation of a homogeneous layer of the polymeric wall material around the core material. This is achieved by altering the physicochemical properties of the wall material by change in temperature, pH, or ionic strength. Here, the core material and the wall material are mixed to form an immiscible solution. Then, phase separation is carried out by changing the ionic strength, pH, or temperature to form coacervates, which are tiny liquid droplets, consisting of polymer-rich dense phase. These coacervates then surround the core material, forming the microcapsules. Electrostatic interaction between two aqueous media is responsible for liquid to gel transition, that is, ionic gelation, hence, leading to the formation of coacervates.

Fluidized bed coating

Fluidized bed coating is an encapsulation method in which coating material is sprayed onto the fluidized core material. Here, the core material is fluidized by application of air, onto which a coating material is sprayed. Different fluidized bed coating methods are: (a) Top spray (b) bottom spray, and (c) tangential spray. In this method of encapsulation, coating efficiency of the wall material is dependent on various parameters like feed rate of the wall material, atomization pressure of the nozzle, inlet air temperature, and velocity,

Etc. Encapsulated spray dried beta carotene with hydroxypropyl cellulose using fluidized bed coating.

Extrusion

Extrusion technology for microencapsulation can be used for producing highly dense microcapsules. To use this method, the core and the wall material should be immiscible. Here, the core and the wall materials are passed in such a way that the wall material surrounds the core and they are passed through concentric nozzles, thus, forming droplets

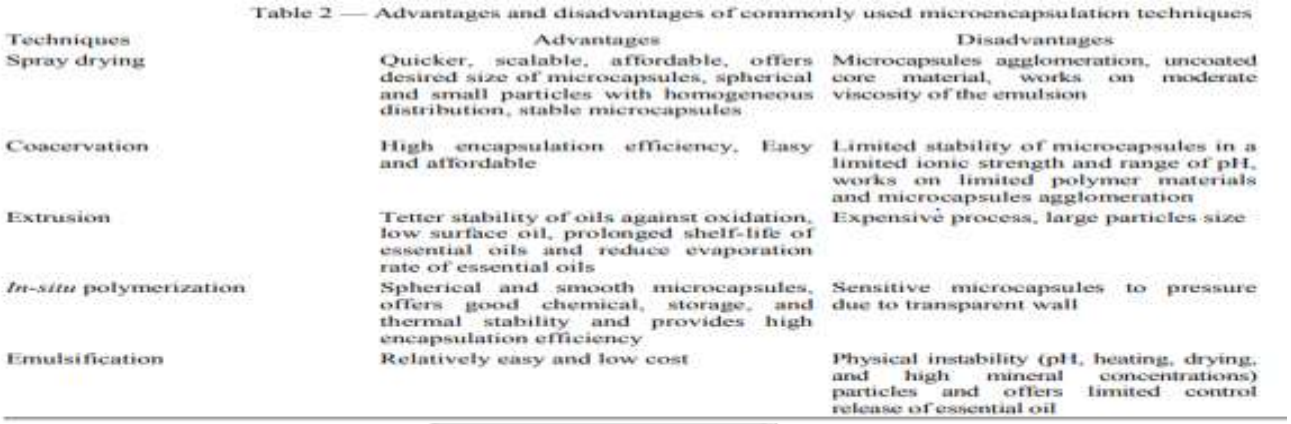


Table 2 — Advantages and disadvantages of commonly used microencapsulation techniques

Techniques	Advantages	Disadvantages
Spray drying	Quicker, scalable, affordable, offers desired size of microcapsules, spherical and small particles with homogeneous distribution, stable microcapsules	Microcapsules agglomeration, uncoated core material, works on moderate viscosity of the emulsion
Coacervation	High encapsulation efficiency, Easy and affordable	Limited stability of microcapsules in a limited ionic strength and range of pH, works on limited polymer materials and microcapsules agglomeration
Extrusion	Tetter stability of oils against oxidation, low surface oil, prolonged shelf-life of essential oils and reduce evaporation rate of essential oils	Expensive process, large particles size
In-situ polymerization	Spherical and smooth microcapsules, offers good chemical, storage, and thermal stability and provides high encapsulation efficiency	Sensitive microcapsules to pressure due to transparent wall
Emulsification	Relatively easy and low cost	Physical instability (pH, heating, drying, and high mineral concentrations) particles and offers limited control release of essential oil

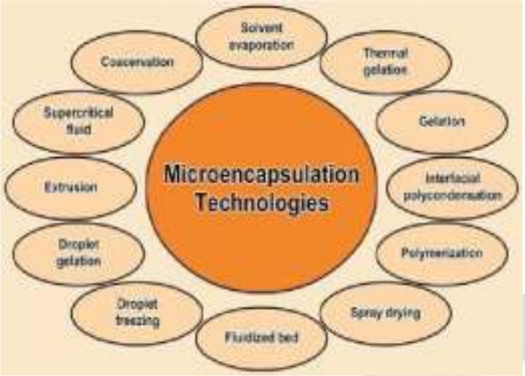
Containing the core surrounded by the wall material. Then solidification is done either by cooling or using an appropriate gelling bath wherein the droplets fall and solidify due to formation of complex. The encapsulates formed using this method are relatively larger in size than formed using any other method and also, this technology is useful with limited wall materials.

Emulsification

Encapsulation using emulsification technique is done by dispersing the core in an organic solvent, containing the wall material. The dispersion is then emulsified in the oil or water, to which emulsion stabilizer is added. Encapsulation of the core occurs by formation of a compact polymer layer around it, by evaporation of the organic solvent. This is one of the frequently used techniques of encapsulation as the procedures involved are very simple. This technique is widely used for encapsulating enzymes and microorganisms. Song et al. (2013) reported encapsulation of probiotics in alginate-chitosan using emulsification and demonstrated better resistance of the probiotics under stimulated gastrointestinal conditions.

Cyclodextrin inclusion

Cyclodextrins are cyclic oligosaccharides, capable of forming inclusion complexes with many organic compounds. Cyclodextrins have an internal nonpolar cavity and hydroxyl groups on the surface. Formation of inclusion complexes of cylodextrins with the hydrophobic compounds mainly takes place by the hydrophobic interaction between the cyclodextrin surface and the guest compounds. However, other forces, such as dipole-dipole interactions and van der walls forces may also be involved in the formation of the complexes (Rakmai et al., 2018). There are several methods for obtaining inclusion complexes with cyclodextrin. Some of them are: (a) Coprecipitation method, which is used for the nonwater-soluble substances. In this method, the compound to be encapsulated is dissolved in organic solvents like benzene, chloroform, diethyl ether, etc. and to this solution; cyclodextrin dissolved in water is added in appropriate amount with proper agitation.



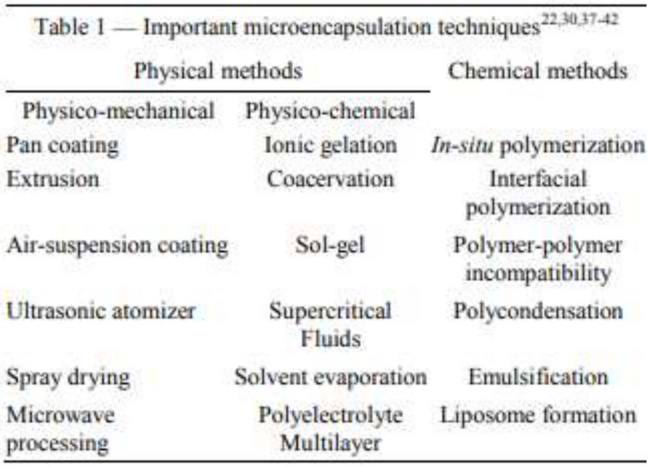


Table 1 — Important microencapsulation techniques[22,30,37-42]

Physical methods		Chemical methods
Physico-mechanical	Physico-chemical	
Pan coating	Ionic gelation	*In-situ* polymerization
Extrusion	Coacervation	Interfacial polymerization
Air-suspension coating	Sol-gel	Polymer-polymer incompatibility
Ultrasonic atomizer	Supercritical Fluids	Polycondensation
Spray drying	Solvent evaporation	Emulsification
Microwave processing	Polyelectrolyte Multilayer	Liposome formation

Use of Microencapsulation Textiles

Phase-change substances

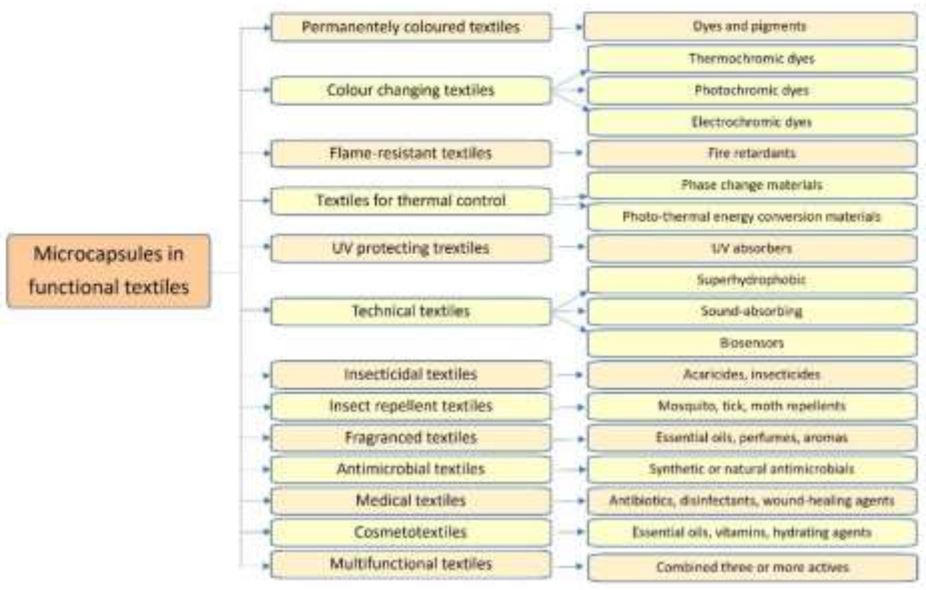
Phase-change materials have the ability to convert an aggregation from a solid to a liquid within a specific temperature range. Extreme temperature changes are reduced using phase-change material microcapsules. This makes it easier for clothes to regulate its own temperature and maintain a steady temperature. Different fabrics, such as vests, parkas, snowsuits, blankets, mattresses, and duvets, are used with these sorts of microcapsules.

Fragrance finishes

Despite numerous instances of fragrance finishes being directly applied to fibers and fabrics, the aroma does not persist for more than two wash cycles. When applied to textiles, the process of microencapsulating perfumes prolongs the impact. This method is frequently employed in aromatherapy, where microcapsules may include flavors from essential oils like lavender, rosemary, pine, etc.This is done to relieve sleeplessness, headaches, and to stop unpleasant odor.

Fire retardant

To solve the issue of diminished softness brought on by the direct application of fire-retardant chemicals, microcapsules with a fire-retardant core were created. They are employed on materials for military purposes, such as tentage.



Microcapsules that are thermochromic and polychromic (color-changing technology)

The thermochromatic color-changing system changes color in reaction to temperature, and the photo-chromatic color changing system changes color in response to UV radiation. Polychromic and thermochromic microcapsules are used in textiles for product labeling, security, and medicinal purposes. There are microencapsulated thermochromatic dyes that, in reaction to human touch, change color at a particular temperatures.

Antimicrobials

Bacteria frequently induce the microbiological degradation of textiles, which results in the loss of a variety of valuable qualities. Anti-microbial coatings, which may be applied with the aid of microencapsulation, can be used to prevent this issue. This finish is specifically for technical and medical fabrics.

Counterfeiting

Microencapsulation can be used to combat the imitation of high-end fabrics, branded items, and designer goods. A color former or an activator is included in microcapsules affixed on labels. Microcapsules rupture under the influence of UV light or a solvent, releasing their contents and allowing for the development of color, which allows for identification.

Release Mechanism of Microcapsules

To release microencapsulated active components from microcapsule cores, numerous ways of release mechanisms have been invented and applied in added-value textile products , such as:

- The mechanism of external pressure, which breaks the microcapsule wall and releases the core, was the first developed and is still widely used, for instance in antimicrobial agents for socks and textile shoe inserts (mechanical pressure caused by walking), fragranced textiles, such as t-shirts, ties, handkerchiefs, pillows and linen (release by pressure and rubbing), and pressure-sensitive multicomponent adhesives for textile bonding (activation in a mechanical press).

- In some applications, microcapsule wall breaks because of inner pressure. This happens if the core contains substances which, under special conditions (e.g. UV light), decompose into gaseous components. The effect is used in blowing agents in the production of light synthetic leather.

- The core substance can be released by abrasion of the microcapsule wall, e.g. in antistatics and fragrances in textile washing and drying.

- In many applications, core materials are released by heat that causes melting of microcapsule wall at a specifically designed temperature. Examples include components in cosmetic and medical textiles (release at body temperature), and textile softeners and fragrances in formulations for dryers (release by heat).

- Microencapsulated fire retardants or extinguishers, released by burning, are used in fire-proof textile materials for carpets, curtains, fire-protecting clothes, and car interiors.

- Microcapsules in photographic and light-sensitive textile printing processes are decomposed or hardened by light.

- In textile washing/cleaning compositions, microcapsules with active ingredients dissolve in a specific solvent (most often water), sometimes only at a selected pH value of the washing cycle.

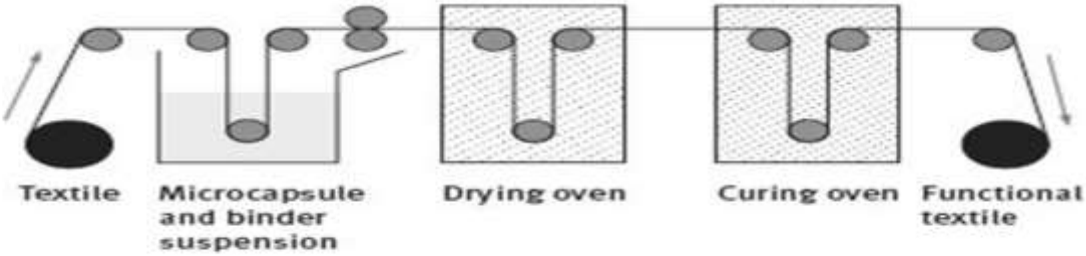
- In textile processing formulations, selected reagents may be released by enzymatic degradation of target microcapsules.

- In specific applications, permanent enclosure of the core material within the resistant microcapsules is essential. Examples include microencapsulated phase change materials (PCMs) for active thermal control, where microcapsules hold the PCM solid-liquid transitions, and for liquid crystals in reversible color changing textiles.

PROCESS OF APPLYING MICROCAPSULES TO TEXTILES

Different techniques can be used for applications of microcapsules to textiles. Patents describe incorporation of microencapsulated compounds onto or into textiles by:

- coating with an air knife or rod coater;
- impregnation or immersion;
- printing techniques, such as screen-,photographic-, electrostatic-, pressure-transfer, thermal transfer and inkjet printing;
- spraying on the surface of textiles;
- inclusion of microcapsules into the textile fibers during the spinning process, such as polyester, nylon or modacryl fiber material;
- Incorporation into polymer foams, coatings and multilayer composites that are placed or inserted into selected parts of textile clothing or footwear.



CHARACTERIZATION OF CAPSULES:

Particle size analysis is an essential aspect of microencapsulation, as it can affect various properties of the encapsulated material, such as release kinetics, stability, and bioavailability. Here are some common methods for particle size analysis in microencapsulation:

Dynamic Light Scattering (DLS):

DLS is a non-invasive technique that measures the Brownian motion of particles in a suspension to determine their size.

It is suitable for measuring particle sizes in the nanometer to sub-micrometer range.

Laser Diffraction:

Laser diffraction measures the angle-dependent intensity pattern produced when a laser beam passes through a dispersed particle system.

This technique is versatile and covers a wide range of particle sizes, making it suitable for both small and large particles.

Scanning Electron Microscopy (SEM):

SEM provides high-resolution images of the surface of particles. It is not a direct size measurement method but can give qualitative information about particle size and morphology.

Sample preparation is required, and the technique is often used in conjunction with other methods.

Transmission Electron Microscopy (TEM):

Similar to SEM, TEM provides high-resolution images, but it involves transmitting electrons through the sample.

TEM can provide detailed information about particle morphology and size at the nanoscale.

Microscopy Techniques:

Optical microscopy and fluorescence microscopy can be used for qualitative assessments of particle size and distribution.

These techniques may not be as precise as some other methods but can provide valuable information.

Coulter Counter:

The Coulter Counter measures changes in electrical impedance as particles pass through an aperture. This change in impedance is directly proportional to the particle volume.

It is effective for measuring the size distribution of particles in a liquid suspension.

Nuclear Magnetic Resonance (NMR):

NMR can be used to analyze the size and distribution of particles in a sample.

This method is particularly useful for studying the encapsulation of materials in various environments.

CONCLUSION

Microencapsulation has proven as one of the most effective ways of incorporating desirable qualities to textile materials. It is fascinating that our clothing is now able to actively moisturize, heal and even can release fragrances to reduce anxiety. The growing health awareness among consumers is further propelling researchers to try and test all possible ingredients to deliver expected performance. New materials are being explored and a major shift is towards the use of organic compounds both in sheath and core. There is no doubt that this technology has a promising future, however, one aspect that seems critical is the intended delivery of the encapsulated core on particular external stimulus. There is a need to optimize the methods of producing microcapsules and extend the shelf life of treated materials to achieve large scale industrial production for each specific application.

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