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Anjum Ayoub
Research Scholar,
Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Monika Sood
Assistant Professor,
Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Jagmohan Singh
Professor, Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Julie D Bandral
Associate, Professor Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Neeraj Gupta
Assistant, Professor, Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Anju Bhat
Professor and Head, Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Correspondence
Anjum Ayoub
Research Scholar,
Division of Food Science and Technology, SKUAST, Chatha, Jammu and Kashmir, India

Microencapsulation and its applications in food industry

Anjum Ayoub, Monika Sood, Jagmohan Singh, Julie D Bandral, Neeraj Gupta and Anju Bhat

Abstract
Microencapsulation is a procedure in which dynamic substances are covered by very little cases that has been broadly utilized in the food and pharmaceutical enterprises. This system can be utilized to decrease the expense of creation, to expand the solidness of mixes, to cover unwanted tastes, and to enhance the discharge properties of mixes in food industries. At present, microcapsules are used in drink, bread kitchen, meat, poultry, and dairy items. In addition, microencapsulation has been utilized to expand soundness, to cover unpleasant taste, to enhance the discharge properties of medications, and to give specific tranquilize conveyance in pharmaceutical enterprises. It is another innovation that has been utilized in the makeup business and also in the pharmaceutical, agrochemical and food industries, being utilized in flavors, acids, oils, nutrients, microorganisms, among others. The accomplishment of this innovation is because of the right decision of the divider material, the center discharge shape and the embodiment strategy. In this review, some important aspects of, for example, the capsules, core, wall material, release, methods of encapsulation and their use in food technology is discussed.

Keywords: Core material, microencapsulation, application, controlled release, wall material

Introduction
Microencapsulation might be defined as the bundling innovation of solids, fluid or vaporous material with thin polymeric coatings, shaping little particles called microcapsules (Gharsallaqui *et al*., 2007) [10]. The polymer goes about as a defensive film, secluding the center and staying away from the impact of its lacking presentation. This film breaks down itself through a specific improvement, discharging the center in the perfect place or at the perfect time (Suave, 2006) [26]. Microencapsulation has various applications in zones, for example, the pharmaceutical, agrarian, restorative and nourishment businesses, being generally utilized in the microencapsulation of basic oils, colorings, flavorings, sugars, microorganisms, among others (Azeredo, 2005) [1]. As of late, the food industry has shown progressively complex definitions: as microorganisms in matured meat; the expansion of polyunsaturated unsaturated fats that are defenseless to auto-oxidation in drain, yogurts or frozen yogurts; and the utilization of flavor intensifies that are very unpredictable in moment nourishments, which frequently must be checked by microencapsulation (Gharsallaoui *et al*., 2012) [9]. Microencapsulation can serve as an effective means of creating foods that are not only a source of nutrients with sensory appeal but also a source of well-being and health for individuals, such as by increasing the level of calcium to prevent osteoporosis, using microorganism-produced lactic acid to decrease cholesterol and adding phenolic compounds to prevent heart problems (Sanguansri and Augustin, 2006) [23].
Miniaturized scale microencapsulation is a procedure in which little particles or beads are encompassed by a covering to give little containers with numerous valuable properties. In a moderately shortsighted frame, a microcapsule is a little circle with a uniform divider around it. The material inside the microcapsule is alluded to as the center, inner stage, or fill, while the divider is at times called a shell, covering, or layer. Most microcapsules have widths between a couple of micrometers and a couple of millimeters. The microencapsulation strategy was right off the bat found by Bungen burg de Jon and Kan in 1931 and which were manage the planning of gelatin circles through a coacervation procedure. Amid the previous decades, there has been an expanding enthusiasm for advancing the proficiency of existing medications using better-planned medication conveyance frameworks. The greater part of these frameworks depend on polymers that contrast in their penetrability, rate of disintegration, level of swelling and erodibility.

Materials used for microencapsulation

Capsules: By and large, capsules can be classified as per their size: macrocapsules (>5,000µm), microcapsules (0.2 to 5,000µm) and nanocapsules (<0.2µm). As far as their shape and development, capsules can be partitioned into two gatherings: microcapsules and microspheres. Microcapsules are particles comprising of an internal center, significantly focal, containing the dynamic substance, which is secured with a polymer layer establishing the case film. Mononuclear and polynuclear microcapsules can be recognized by whether the center is separated (Favaro-Trindade *et al*., 2008) [7]. Interestingly, microspheres are grid frameworks in which the center is consistently scattered as well as broke up in a polymer arrange. Microspheres might be homogeneous or heterogeneous relying upon whether the center is in the sub-atomic state (broke down) or as particles (suspended), individually (Silva *et al*., 2003) [25].

Wall material: The right decision of the wall material is vital in light of the fact that it infl uences the embodiment efficiency and dependability of the microcapsule. The perfect wall material ought to have the accompanying qualities: not receptive with the center; capacity to seal and keep up the center inside the case; capacity to give greatest insurance deeply against unfriendly conditions; do not have an undesirable preference for the instance of sustenance appropriateness and financial practicality (Nazzaro *et al*., 2012) [17]. As per (Favaro-Trindade *et al*., 2008) [7], most wall materials don't have all the ideal properties; a typical practice includes blending at least two materials. Such materials can be chosen from a wide assortment of normal and engineered polymers, including the accompanying that we feature: sugars: starch, modified starches, dextrins, sucrose, cellulose and chitosan; gums: arabic gum, alginate and carrageenan; lipids: wax, paraffin, monoglycerides and diglycerides, hydrogenated oils and fats; inorganic materials: calcium sulfate and silicates; proteins: gluten, casein, gelatin and egg whites.

Controlled Core Release: As per (Gouin, 2004) [11], exemplification ought to enable the center to be secluded from the outer condition until the point when discharge is wanted. In this way, the discharge at the suitable time and place is a critical property in the epitome procedure, enhancing the adequacy, lessening the required portion of added substances and growing the uses of mixes of intrigue. The principle factors influencing the discharge rates are identified with communications between the divider material and the center. Also, different elements influence the discharge, for example, the unpredictability of the center, proportion between the center and divider material, molecule size and consistency review of the divider material (Roberts and Taylor, 2000) [20]. The principle components associated with the center discharge are dissemination, debasement, utilization of dissolvable, pH, temperature and weight. By and by, a blend of more than one instrument is utilized (Desai and Park, 2005) [6]. Dissemination happens particularly when the microcapsule divider is unblemished; the discharge rate is administered by the substance properties of the center and the divider material and some physical properties of the divider. For instance, a few acids can be discharged amid a procedure step however ensured by another progression. Sometimes, a few additives are required at the item surface, yet their spread to different parts must be controlled (Azeredo, 2005) [1]. As indicated by (Rosen, 2006) [22], debasement discharge happens when compounds, for example, proteases and lipases corrupt proteins or lipids, individually. A model is lessening the time required for the aging of cheddar by half contrasted and the customary aging procedure (Hickey *et al*., 2007) [13]. In contact with a dissolvable, the divider material can break up totally, rapidly discharging the center or begin to grow, favoring discharge. For instance, microencapsulation of espresso flavors enhances the assurance from light, warmth and oxidation when in the dry state, however the center is discharged upon contact with water (Frascareli *et al*., 2012) [8]. The pH discharge happens in light of the fact that pH changes can result in adjustments in the divider material solvency, empowering the arrival of the center. For instance, probiotic microorganisms can be microencapsulated to oppose the corrosive pH of the stomach and just be discharged in the basic pH of the digestive system (Toldra and Reig, 2011) [27]. Changes in temperature can advance center discharge. There are two unique ideas: temperature-delicate discharge, held for materials that extend or crumple when a basic temperature is come to, and combination actuated discharge, which includes dissolving of the divider material because of temperature increment. A model is the fat-epitomized cheddar flavor utilized in microwave popcorn, bringing about the Pressure discharge happens when a weight is connected to the container divider, for example, the arrival of some flavors amid the rumination of biting gum (Wong *et al*., 2009) [30].

Methods used for microencapsulation:

1. Air suspension
2. Coacervation phase separation
3. Centrifugal Extrusion process
4. Spray drying and congealing
5. Pan coating
6. Solvent evaporation techniques
7. Polymerization

Air suspension

Air-suspension covering of particles by arrangements or melts gives better control and adaptability. The particles are covered while suspended in an upward-moving air stream. They are upheld by a punctured plate having diverse examples of gaps inside and outside a tube shaped embed. Simply adequate air is allowed to ascend through the external annular space to fluidize the settling particles. The vast majority of the rising air (generally warmed) streams inside the barrel, making the particles rise quickly. At the best, as the air stream separates and moderates, they settle back onto the external bed and move descending to rehash the cycle. The particles go through the inward barrel ordinarily in almost no time techniques. The air suspension process offers a wide assortment of covering materials possibility for microencapsulation. The procedure has the ability of applying coatings as dissolvable arrangements, watery arrangement, emulsions, scatterings or hot melts in hardware going in limits from one pound to 990 pounds. Center materials contained micron or submicron particles can be adequately typified via air suspension systems, yet agglomeration of the particles to some bigger size is typically accomplished (Bansode *et al*., 2010) [2].

Coacervation phase separation

The general outline of the procedures comprises of three stages completed under constant disturbance.

a) Arrangement of three immiscible compound stages: A fluid assembling vehicle stage, a center material stage, and a

covering material stage. To shape the three stages, the center material scattered in an answer of the covering polymer, the dissolvable for the polymer being the fluid assembling vehicle stage. The covering material stage, an immiscible polymer in a fluid state, is framed by using one of the techniques for the strategies for stage division coacervation, i.e., by changing the temperature of the polymer arrangement; or by including a salt, nonsolvent, or contrary polymer to the polymer arrangement; or by inciting a polymer-polymer association.

b) Deposition of the coating: It comprises of saving the fluid polymer covering upon the center material. This is practiced by controlled, physical blending of the material in the assembling vehicle. Statement if the fluid polymer covering around the center material happens if the polymer is adsorbed at the interface shaped between the center material and the fluid vehicle stage, and this adsorption marvel is an essential to compelling covering. The proceeded with affidavit of the covering material is advanced by a decrease in the aggregate free interfacial vitality of the framework, achieved by the decline of the covering material surface territory amid blend of the fluid polymer beads.

c) Rigidization of the coating: It includes rigidizing the covering, as a rule by warm, cross-connecting, or desolvation methods, to frame a self-continuing microcapsules. (Lehman *et al*., 1976) [16].

Centrifugal extrusion

Fluids are encapsulated utilizing a pivoting expulsion head containing concentric spouts. In this procedure, a fly of center fluid is encompassed by a sheath of divider arrangement or liquefy. As the fly travels through the air it breaks, inferable from Rayleigh shakiness, into beads of center, each covered with the divider arrangement. While the beads are in flight, a liquid divider might be solidified or a dissolvable might be vanished from the divider arrangement. Since the vast majority of the beads are inside ± 10% of the mean width, they arrive in a tight ring around the splash spout. Subsequently, if necessary, the containers can be solidified after development by getting them in a ring-molded solidifying shower. This procedure is fantastic for shaping particles 400– 2,000µm (16– 79 mils) in distance across. Since the drops are framed by the separation of a fluid fly, the procedure is reasonable for fluid or slurry. A high creation rate can be accomplished, i.e., up to 22.5 kg (50 lb) of microcapsules can be delivered per spout every hour per head. Heads containing 16 spouts are available. (Bansode *et al*., 2010) [2].

Spray drying and Congealing

Splash drying fills in as a microencapsulation procedure when a functioning material is broken down or suspended in a liquefy or polymer arrangement and ends up caught in the dried molecule. The primary points of interest is the capacity to deal with labile materials in view of the short contact time in the dryer, what's more, the task is temperate. In current splash dryers the thickness of the answers for be showered can be as high as 300mPas.

Splash drying and shower coagulating forms are comparable in that both include scattering the center material in a melted covering substance and splashing or presenting the center - covering blend into some natural condition, whereby, moderately quick cementing (and development) of the covering is influenced. The main distinction between the two strategies is the methods by which covering hardening is practiced. Covering cementing on account of shower drying is influenced by quick dissipation of a dissolvable in which the covering material is broken down. Covering cementing in shower coagulating strategies, be that as it may, is cultivated by thermally hardening a liquid covering material or by setting a disintegrated covering by presenting the covering - center material blend into a nonsolvent. Expulsion of the nonsolvent or dissolvable from the covered item is then practiced by sorption, extraction, or vanishing systems.

Practically speaking, microencapsulation by shower drying is led by scattering a center material in a covering arrangement, in which the covering substance is broken up and in which the center material is insoluble, and afterward by atomizing the blend into air stream. The air, generally warmed, supplies the inert warmth of vaporization required to expel the dissolvable from the covering material, along these lines framing the microencapsulated item. The hardware segments of a standard splash dryer incorporate an air radiator, atomizer, fundamental shower chamber, blower or fan, twister and item gatherer.

Microencapsulation by splash coagulating can be practiced with shower drying gear when the defensive covering is connected as a soften. General process factors and conditions are very like those officially portrayed, then again, actually the center material is scattered in a covering material soften as opposed to a covering arrangement. Covering cementing (and microencapsulation) is cultivated by splashing the hot blend into a cool air stream. Waxes, unsaturated fats and alcohols, polymers and sugars, which are solids at room temperature yet soften at sensible temperatures, are material to splash solidifying strategies. Ordinarily, the molecule size of shower solidified items can be precisely controlled when splash drying hardware is utilized, and has been observed to be a component of the feed rate, the atomizing wheel speed, scattering of feed material thickness, and variables. (Lehman *et al*., 1976) [16].

Pan coating

The pan covering process, broadly utilized in the pharmaceutical business, is among the most seasoned modern methods for shaping little, covered particles or tablets. The particles are tumbled in a dish or other gadget while the covering material is connected gradually. The container covering process, broadly utilized in the pharmaceutical business, is among the most seasoned modern methods for shaping little, covered particles or tablets. The particles are tumbled in a dish or other gadget while the covering material is connected gradually as for microencapsulation, strong particles more noteworthy than 600 microns in size are commonly viewed as basic for successful covering, and the procedure has been widely utilized for the arrangement of controlled - discharge dots. Medicaments are typically covered onto different round substrates, for example, quintessence sugar seeds, and after that covered with defensive layers of different polymers.

By and by, the covering is connected as an answer, or as an atomized shower, to the ideal strong center material in the covering skillet. More often than not, to evacuate the covering dissolvable, warm air is disregarded the covered materials as the coatings are being connected in the covering container. At times, last dissolvable evacuation is practiced in a drying oven**.** (Bansode *et al*., 2010) [2].

Solvent Evaporation Techniques

Dissolvable vanishing systems are performed in a fluid assembling vehicle (O/W emulsion) which is shaped by fomentation of two immiscible fluids. In this procedure microcapsule covering (polymer) is broken down in an unstable dissolvable, which is immiscible with the fluid assembling vehicle stage. A center material to be microencapsulated is scattered in the covering polymer arrangement (Nokhodchi *et al*., 2002) [18]. To acquire the microcapsule of proper size the center and covering material blend is scattered in the fluid assembling vehicle stage with unsettling. The unsettling of framework is steady till the dissolvable parcels into the watery stage and fluid stage is expelled by evaporation.Various process factors that could influence the procedure of microencapsulation (Trinade *et al*., 2000) [28].

Incorporate strategies for shaping scatterings, vanishing rate of the dissolvable for the covering polymer, temperature cycles and fomentation rates. Critical variables that must be viewed as while getting ready microcapsules by dissolvable vanishing strategies incorporate decision of vehicle stage and dissolvable for the polymer covering, as these decisions incredibly impact microcapsule properties and the decision of dissolvable recuperation systems. This strategy to deliver microcapsules is appropriate to fluid and strong center material. Water dissolvable or water insoluble materials are utilized as center materials. An assortment of film framing polymers can be utilized as covering materials. (Lehman *et al*., 1976) [16].

Polymerization

1. Interfacial polymer

In Interfacial polymerization, the two reactants in a polycondensation meet at an interface and respond quickly. The premise of this strategy is the traditional Schotten Baumann response between a corrosive chloride and a compound containing a functioning hydrogen molecule, for example, an amine or liquor, polyesters, polyurea, polyurethane. Under the correct conditions, thin adaptable dividers shape quickly at the interface (Ribonson *et al*., 1987) [21]. An answer of the pesticide and a di-acid chloride are emulsified in water and a watery arrangement containing an amine and a polyfunctional isocyanate is included. Base is available to kill the corrosive framed amid the response. Dense polymer dividers frame immediately at the interface of the emulsion beads.

2. In-situ polymerization

In a couple of microencapsulation forms, the immediate polymerization of a solitary monomer is done on the molecule surface. In one process, for example Cellulose filaments are typified in polyethylene while drenched in dry toluene. Regular testimony rates are about 0.5µm/min. Covering thickness ranges 0.2-75µm. The covering is uniform, even over sharp projections.

3. Matrix polymer

In various procedures, a center material is imbedded in a polymeric grid amid development of the particles. A basic strategy for this sort is shower drying, in which the molecule is framed by vanishing of the dissolvable from the network material. In any case, the cementing of the network likewise can be caused by a substance change. (Bansode *et al*., 2010) [2].

Release Mechanisms

Mechanisms of drug release from microspheres are

1. Degradation controlled monolithic system

The drug is broken up in network and is circulated consistently all through. The drug is firmly connected to the network and is discharged on debasement of the framework. The dispersion of the drug is moderate as contrasted and debasement of the framework.

2. Diffusion

It's the most ordinarily included component wherein the disintegration liquid infiltrates the shell, breaks up the center and hole out through the interstitial channels or pores.(Gunder *et al*., 1995) Thus, the general discharge relies upon, (a) the rate at which dissolution fluid penetrates the wall of microcapsules, (b) the rate at which drug dissolves in the dissolution fluid, and (c) the rate at which the dissolved drug leak out and disperse from the surface. (Higuchi, 1963) [14]

3. Osmosis

The polymer layer of microcapsule goes about as semi porous film and permits the production of an osmotic weight contrast between within and the outside of the microcapsule and drives tranquilize arrangement out of the microcapsule through little pores in the coat.

Application Fields of Microencapsulation

Microencapsulation innovation is broadly utilized in a few ventures, particularly food and pharmaceutical businesses, since it can expand dissolvability, upgrade soundness, and enhance the controlled discharge properties of mixes, for example, basic oils, cancer prevention agents, catalysts, drugs, and so on. In this way, this segment centers around the uses of microencapsulation in these ventures.

Applications in the food industry

The food industry uses practical fixings to enhance flavor, shading, and surface properties and to broaden the timeframe of realistic usability of items. Additionally, fixings that have practical medical advantages, for example, cancer prevention agents and probiotics, are of incredible intrigue (Borgogna *et al*., 2010) [3]. Be that as it may, the vast majority of these fixings have low-security and are effectively decayed by ecological elements. In this way, the arrangement of highstability bioactive mixes is critical. Microencapsulation is one approach to address these issues. As of late, there has been a lot of research on the creation of high productivity microcapsules and their applications in the sustenance business.

Beverages

(Burin *et al*., 2011) [4] assessed the steadiness of anthocyanin, which was embodied inside various bearer operators in an isotonic soft drink system. Anthocyanins are water-solvent shades got from plants. These shades are commonly utilized as colorants in nourishments and beverages, since they have high colorant control, low poisonous quality, and high water solvency. Besides, numerous examinations have demonstrated that anthocyanins have critical cancer prevention agent and anticarcinogenic properties (Wang and Xu, 2007) [29]. All things considered, anthocyanins are flimsy shades and can be disintegrated to dry mixes by numerous components including pH, temperature, light, oxygen, and the nourishment lattice (Wang and Xu, 2007) [29]. In this manner, microencapsulation

has been utilized to build the dependability of these mixes. In their investigation, the splash drying system was utilized to typify anthocyanins started from Cabernet Sauvignon grapes. They found that the got microcapsules introduced uniform molecule sizes and a circular surface. Additionally, a blend of maltodextrin (MD) and gum Arabic (GA) brought about expanded security of the anthocyanin shades.

Baked Goods

(Obrien *et al*., 2003) [19] embodied vegetable shortening to increment oxidative strength and convert fat into a steady powder for use in short batter bread creation. At present, most fixings utilized in business bread generation are in dry frame. Be that as it may, the fat fixing must be included the type of fluid (oil) or block (fat), which requires an extra manual advance. The goal of this exploration was to create microcapsules of high-fat powders and assess their impact on bread quality contrasted with the nature of a control roll delivered with hydrogenated vegetable fat. It was discovered that microencapsulated vegetable fat delivered at a low homogenization weight, with whey protein focus (WPC) containing 5% protein as the epitomizing specialist, could be utilized for creating bread rolls with worthy qualities. Subsequently, microencapsulated high-fat powders could be utilized as a substitution for fat/oil in business scone generation.

Meat and Poultry

(Jiménez-Martín *et al*., 2016) [15] utilized microcapsules of omega-3 unsaturated fats from fish oil for enhancing solidified chicken tenders and examined the impact of time of solidified stockpiling on the oxidative solidness and tangible properties of this item in contrast with that with mass fish oil expansion. It was discovered that season of solidified stockpiling had no impact on the tangible nature of chicken strips enhanced with omega-3 unsaturated fats. Microencapsulation of omega-3 unsaturated fats from fish oil could be utilized for the improvement of pre-singed solidified meat items with fish oil, enhancing the oxidative time span of usability and saving the tangible quality attributes of the advanced items.

(Comunian *et al*., 2014) [5] assessed the impact of encapsulated ascorbic acid on physicochemical and sensory security of chicken sausages. Ascorbic corrosive is a characteristic cell reinforcement gotten from products of the soil. Be that as it may, it is truly precarious. It is effectively decayed by different variables including, warm, light, high oxygen focus, and high water movement. Ascorbic acid is usually utilized in hotdogs to supplant sodium erythorbate. Thus, this investigation meant to embody ascorbic acid in wieners, since this procedure takes into account the consolidation of a compelling cell reinforcement with nutrient usefulness and enhances steadiness of the item. The outcomes demonstrated that it was conceivable to create sausages with worthy tactile attributes, when utilizing ascorbic acid as a cell reinforcement or antioxidant.

Future Trends in Food industries

The extension in useful foods is by all accounts a long haul incline with essential market potential. In this manner, new developments have been presented in the food industry (Santiago and Castro, 2016) [24]. Microencapsulation is one of the advancements that are right now of intrigue. Also, numerous analysts keep on creating novel parts for use as useful fixings, additives, colorants, and seasons in sustenance items utilizing microencapsulation systems.

Conclusion

Microencapsulation has been connected in a wide assortment of items from various zones, and studies have appeared gigantic potential to furnish the center with beneficial highlights, bringing about unrivaled quality items, incorporating into the food industry. In any case, much exertion through innovative work is as yet expected to distinguish and grow new wall materials and to enhance and advance the current strategies for the better utilization of microencapsulation and its potential applications.

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