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An Overview of Bacterial Microencapsulation and its Impact on Probiotics

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Abstract: *Probiotic-containing products are associated with certain health benefits. The main problem, however, is how little these bacteria can survive in food and the digestive tract. Probiotics may be safely protected and guaranteed to reach the intestines by providing a physical barrier. We believe that one of the best strategies is microencapsulation, which has drawn a lot of interest and study. However, there are still a number of challenges in the microencapsulation process that need to be overcome. The main focus of this work is the methodological approach to probiotic encapsulation, including the resources and results obtained using encapsulated probiotic in food matrices and different illnesses in animal models.*

Keywords: probiotics, microencapsulation, food, pathologies, protection

I. INTRODUCTION

The WHO defines probiotics as "live organism, which when administered in adequate amounts confer health benefits to the host" (FAO/WHO). Some studies have demonstrated that probiotics may cure intestinal diseases and affect the immune system (Kurmann & Rasic, 1991). Since these bacteria are mostly eaten, their benefits should be most noticeable in gut disorders. The modulation of systemic immune response may benefit systemic illnesses like allergies (Majamaa & Isolauri, 1997) or inflammatory diseases (Malchow, 1997), and they have been shown to treat vaginitis (Reid, 2000).

The most common probiotics are lactobacillus and bifidobacteria (Solanki et al., 2013). In addition to Saccharomyces cerevisiae, Escherichia coli, Bacillus cereus, and other species have been employed to accomplish the same goals (Burgain, Gaiani, Linder & Scher, 2011). Some of these species are used in functional foods (Champagne, Gardner & Roy, 2005). These aliments are modified foods or ingredients that give health benefits beyond nutritional needs (Sanders, 1998).

Probiotics must live and proliferate in the host to benefit health. The product's probiotic should be metabolically stable and active, survive the stomach, and reach the intestine in substantial amounts (Sanz, 2007). Probiotic viability is affected by pH, hydrogen peroxide, oxygen, storage temperature, and others (Shah, Lankaputhra, Britz & Kyle, 1995). These sensitive microorganisms can be made more resistant by selecting acid and bile-resistant strains, using oxygen-impermeable containers, two-step fermentation, stress adaptation, incorporation of micronutrients like peptides and aminoacids, and microencapsulation (Sarkar, 2010).

Microencapsulation, the final alternative, is one of the most effective and has been extensively studied. Microencapsulation retains cells in an encapsulating membrane to prevent cell damage or loss and release suitable gut bacteria (Sultana et al., 2010). Microencapsulation protects cells from bacteriphages and other harmful factors, increases survival during freeze drying, freezing, and storage, and makes them easier to use as a powder due to its homogeneous distribution. Given the significance of microencapsulation, this article reviews probiotic microencapsulation methods, components, and benefits. The impact of encapsulated probiotics in meals and illnesses is also examined.

Techniques for microencapsulation of probiotics

Several encapsulation strategies exist. Industry should have considered the following before choosing one (Zuidam & Shimoni, 2010): In what scenarios do probiotics work? Food production and processing: how? Under what conditions?

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(iii) How will encapsulated food be kept before consumption? What particle size and density are needed for food product integration?(v) Are release mechanisms or triggers known? What financial limits exist? These are the primary probiotic cell encapsulation methods. Probiotics are impacted by high temperatures, agitation, and wetness. Thus, food matrices should be produced at low temperature, controlled agitation, low oxygen, and moderate pH. Before adding particles to food matrices, authors should consider optimal storage conditions, since most experiments occur at 4ºC room temperature. Proper probiotic particle size should not feel gritty in the mouth. Soft, spherical particles are imperceptibly grainy up to 80 µm (Lawless & Heymann, 2010). Number of particles needed depends on probiotic dosage. Materials and technology determine releasing mechanism. Quelling agents, enzymatic activity, and pH changes release particles. Finally, the cost-benefit ratio must be considered since some of the technologies below need particular equipment or materials, which may raise manufacturing costs.

Extrusion Technique

Extrusion is the most used method because of its simplicity, cost, and gentle formulation conditions that ensure cell viability (Krasaekoopt, Bhandari & Deeth, 2003). We add microorganisms to a hydrocolloid solution and extrude the cell suspension using a syringe needle. Droplets get a hardening solution (Heidebach, Först & Kulozik, 2012).

Instead of spraying, prilling generates droplets under regulated circumstances. This is done via nozzle vibration or jet pulses. Another typical approach for producing small droplets is coaxial flow or an electric field. Microdroplets form at the needle tip when an electric field disrupts the liquid surface owing to electrostatic forces (Figure 1). Bead size may be changed without chemical solvents by altering voltage. A rotating disk or multi-nozzle device can mass-produce beads (figure 1). Coextrusion is also used in centrifugal extrusion. It uses a nozzle with concentric orifices around a rotating cylinder. Shell and core materials are pumped via the outer aperture and inner orifice, respectively. As it rotates, the rod fractures into capsule-forming droplets (Kailasapathy, 2002).

Alginate supports.

Alginate, a linear heteropolysaccharide comprised of D-mannuronic (M) and L-guluronic acids, is extracted from various algae. The sequence and amount of D-mannuronic and L-guluronic acids vary substantially by source. There is also a strong link between M- and G-unit sequencing and composition and alginate support function. G-units buckle, whereas M-units tend to be extended bands. Two G-units aligned side by side provide a hole large enough to bind divalent cations alone.

Combining a cell culture with sodium alginate and putting it into a multivalent cation solution (typically Ca+2 in CaCl2) creates beads. Droplets rapidly condense into gel spheres, which enclose cells in three dimensions. The exchange of guluronic acids' sodium ions for divalent cations (Ca2+, Sr2+, or Ba2+) causes polymer cross-linking. This causes a chain-chain coupling, or "egg box model."

This approach succeeds because to its benign environment and biocompatibility for the contained material. The size and spherical shape of the bead depend on the sodium alginate solution's viscosity and the syringe-calcium bath separation. Thus, high concentration increases gel viscosity and lowers bead size. Another important factor affecting droplet size is extruder orifice diameter. Alginate composition affects bead size; low guluronic alginates generate small beads (Krasaekoopt, Bhandari & Deeth, 2003).

Whey Protein

Since they are nutritious and useful, dietary proteins may replace polymeric hydrogles (Gunasekaran, Ko, & Xiao, 2007). Globular protein from cheese-making whey is called whey proteins. These proteins may interact with many active compounds, providing several possibilities for protection and reverse binding before targeted release in the host. Protein encapsulation matrices may help digestive enzymes hydrolyze dietary proteins. It may produce bioactive peptides with physiological effects in vivo. Thus, Doherty et al. (2011) encapsulated whey protein. Particles protected probiotic throughout 3 hours in vitro stomach incubation.

Pectin

Pectin is a fruit-derived heteroploysaccharide. It gels meals, stabilizes medications, and provides fiber. It survives in the stomach and small intestine. Gebara et al. (2013) made whey-protein-coated pectin microparticles. This

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microencapsulation technique protected L. acidophilus better than free cells. When subjected to simulated gastrointestinal conditions, pectin microparticles coated with whey protein did not preserve microorganisms. In contrast, Gerez, Font De Valdez, Gigante, and Grosso (2012) discovered that microencapsulating probiotics in pectin particles coated with whey protein after stomach exposure improved their lifespan.

Milk

Pure milk has been researched for encapsulation. Shi et al. (2013) created locust bean-carrageenan milk microparticles. Milk microspheres protected Lactobacillus bulgaricus well. Milk microspheres were irregular and mechanically poor. The authors added milk and alginate to enhance it (Shi et al., 2013). The experiments showed that L. bulgaricus encapsulated in these novel microspheres protects probiotics against harsh simulated gastrointestinal environments.

Human like collagen

Recombinant Escherichia coli BL21 with HLC cDNA produces HLC. An haemostatic substance, scaffolding biomaterial for organ or tissue regeneration, and functional food, this collagen is employed. Electrostatic droplet production produced alginate and HCL microspheres by Su et al. (2011). Human collagen added to alginate solution forms intermolecular hydrogen bonding or other interactions that stabilize beads. These authors found better probiotic tolerance in simulated gastric juice.

Emulsion technique

The discontinuous phase (cell polymer suspension) is introduced to a huge amount of oil. The mixture is homogenized into a water-oil emulsion. The water-soluble polymer is insolubilized (cross-linked) to create oil phase particles after the water-in-oil emulsion forms (Heidebach et al., 2012).Later filtering harvests beads (Figure 1). Bead size ranges from 25µm to 2 mm, depending on agitation speed.

Continuous phase vegetable oils are utilized in food. Mineral and white light paraffin oil were employed in several trials. Emulsifiers reduce surface tension and make particles smaller, making emulsions better (Krasaekoopt et al., 2003).

Supporting material and technological conditions

There are many supporting materials used with the emulsion technique. We described below the most used ones.

Carrageenan and its mixtures

Food additives often include marine macroalgae-derived neutral polysaccharide K-carrageenan. Carrageenan dissolves well between 60–90° C, particularly at 2-5% concentrations. Temperature fluctuations cause gelation. Probiotics are introduced to the polymer solution at 40-45º C, and gelation occurs upon cooling to room temperature. K+ ions (KCl) stabilize the gel and prevent swelling or stimulate gelation once the beads are produced. Some lactic acid bacteria are inhibited by KCl. Rb+, Cs+, and NH4+ are suggested KCl alternatives. These ions fix the issue and make stronger gel beads than potassium ions (Krasaekoopt et al., 2003).

A 1:2 carrageenan-locust gum ratio produces a robust microencapsulation gel (Miles, Morris & Carroll, 1984). Due to its lesser sensitivity to organic acids, this blend works well in lactic fermented goods like yogurt. Thus, it is commonly employed to microencapsulate probiotics in fermented goods (Audet, Paquin & Lacroix, 1988; Arnauld, Laroix & Choplin, 1992). However, k-carrageenan and locust bean gel production need calcium ions, which affect the electrolyte balance of liquids in the body and Bifidobacterium spp. survival (Sun & Griffiths, 2000).

Sodium carboxymethyl cellulose

NaCMC is a water-soluble cellulose ether derivative. It has connected glucopyranose residues with variable carboxymethyl substitution. NaCMC is used to deliver medications and probiotics because to its stomach acid resistance and intestinal solubility (Kamel, Ali, Jahangir, Shah & El-Gendy, 2008). With sodium carboxymetilceulosa and rice bran (RB) as filler, Chitprasert, Sudsai, and Rodklongtan (2012) created microcapsules. Rice milling produces bran. It fills well. Furthermore, its cheap cost may lower microcapsule manufacturing costs. A cell culture in NaCMC with and without RB was emulsified with palm oil and crosslinked with aluminum ions to make microcapsules. After

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heat exposure, NaCMC and RB microencapsulation increased Lactobacillus reuteri viability. Probiotic products as functional feeds that need heat treatment might be developed using these particles.

Cellulose acetate phtalate (CAP)

Due to its safety, this polymer controls intestinal medication release (Mortazavian et al., 2008). Advantages of CAP include being insoluble in acid conditions (pH ≤5) but soluble at pH ≥6 due to phthalate groups. Thus, microencapsulating bacteria with CAP may convey many viable bacterial cells to the colon (Burgain et al., 2011). Rao, Shiwnavain, and Maharaj (1989) discovered that a starch-oil emulsion containing CAP increased probiotic viability in simulated gastrointestinal environments. Others obtained comparable results using spray drying (Fávaro-Trindale & Grosso, 2002).

Alginate and its combinations

Probiotic bacteria are encapsulated in calcium alginate at 0.5–5% concentrations (Sheu & Marshall, 1991; Sheu, Marshall & Heymann, 1993; Truelstrup-Hansen, Allan-wojtas, Jin & Paulson, 2002; Kim, Baek & Yoon, 1996; Jankowski, Zielinska & Wysakowska, 1997; Kebary, Hussein & Badawi, 1998; Lee e Sultana et al., 2000; Krasaekoopt, Bhandari, & Deeth, 2004; Martin et al., 2013).

Internal or external gelation yields alginate microparticles (Figure 1). Water-in-oil emulsion stabilized by surfactants like Tween® 80 generates microparticles in the first scenario. Calcium chloride gels alginate in the emulsion (2.2). Microcapsules may form when alginate gels with calcium carbonate, albeit this is unusual. Water-in-oil emulsion is made, then acetic acid is added. Together with calcium carbonate, it releases calcium ions and carbonic acid in water. Alginate and calcium ions form the egg-box (Cook et al., 2012).

Bad things about alginate microparticles. For instance, acidic environments harm them. These circumstances produce mechanical instability and cracking. Monovalent ions or chelating compounds (phosphates, lactates, and citrates) breakdown alginate gel, which is made of calcium ions. Industrial applications might be difficult. These pores let moisture and other substances swiftly diffuse through the beads. Environmental barrier properties decline (Gouin, 2004). To address flaws, alginate may be mixed, coated, or structurally changed (Krasaekoopt et al., 2003).

Alginate and maize starch encapsulate microorganisms (Martin et al., 2013; Zou, 2011). All green plants produce starch, a polysaccharide composed of α-D-glucose units linked by glycosidic bonds. Pancreatic amylases cannot break down resistant starch in the small intestine. This facilitates colon fermentation. This selectivity boosts intestinal delivery. Resistant starch helps probiotic cells adhere to starch granules (Anal & Singh, 2007), which may increase colon probiotic delivery in a viable and metabolically active state (Vivek, 2013). Alginate with a resistant starch was bled to generate cell-viable particles by Sultana et al., 2000; Sun, 2000; Truelstrup-Hansen, 2002; Krasaekoopt, 2003.

Adding alginate to glycerol improves cell viability at -20ºC owing to its cryogenic properties (Sultana et al., 2000).

Alginate particle physical and chemical stability is improved by semipermeable chitosan films surrounding capsules. Calcium-chelating and antigelling do not destroy its structure. Stronger beads prevent fracturing and cell release (Krasaekoopt et al., 2003). Low-molecular-weight chitosan diffuses faster into alginate and produces denser, stronger spheres (Krasaekoopt, Bhandari, & Deeth, 2006).

Also, calcium chloride coating (Chandramouli, Kailasapathy, Peiris & Jones, 2004). This coating stabilises beads and boosts probiotic cell health.

Polyamines coat. Thus, poly-L-lysine (PLL) strongly complexes with alginate matrix, providing it chitosan advantages. Multilayer PLL shells on alginate capsules have been explored. First PLL coating provides particle surface positive charge, second alginate layer gives beads negative charge. This technique repeats. Alternative polycationic polymers include polyetylenamine and glutaraldehide (Mortazavian et al., 2007).

Encapsulating alginate with fatty acids is conceivable. Amine et al. (2014) generated palmitolated alginate microparticles from emulsion. Le-Tien, Millette, Mateescu, and Lacroix (2004) extruded microparticles. Both particle types stabilized probiotics.

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Chitosan

Chitosan is a positive-charged linear polymer made by deacetylation of crustacean shell chitin. Like alginate, it forms a gel by ionotropic gelation and is water-soluble at pH < 6. As said, chitosan inhibits lactic acid bacteria, making it a popular coating material (Groboillot, Champagne, Darling & Poncelet, 1993).

Gelatin

Collagen is partially hydrolyzed to make gelatin. It creates a high-viscosity solution in water that gels on cooling due to its unique structure and diverse functional capabilities. It synergizes with anionic polysaccharides like gellan gum due to its amphoteric character. Both polymers have net negative charges and resist each other, making them miscible at pH above 6. Adjusting pH below gelatin's isoelectric point results in a positive net charge on gelatin, triggering interaction with negatively charged gellan gum. Gelain-toluene diisocyanate mixture provides robust, crackle-resistant capsules, particularly at higher doses. This is because these polymers cross-link. Lactobacillus lactis ssp. Cremoris was encapsulated in the combination (Hyndman, Groboillot, Poncelet, Champagne & Neufeld, 1993). Genopin and alginate have been crosslinked to gelatin to prevent pepsin from degrading gelatin microspheres in simulated gastric juice (Annan, Borza & Truelstrup Hansen, 2008).

Chickpea protein

Chickpea protein worked well as an encapsulant due to its nutritional value and functional properties. Chickpea's lower allergens make it appealing. Salt-soluble globulin-type storage proteins legumin and vicilinttributes dominate this protein. Wang et al. (2014) created chickpea protein–alginate microcapsules utilizing emulsion technique. In synthetic gastric juice, the particles protected B. adolescentis. The beads produced with this design were <100 µm in size. Consumers did not notice any negative sensory impacts from this component in dishes. The research implies chickpea protein-alginate capsules might be food-grade probiotic carriers. Klemmer, Korber, Low, and Nickerson (2011) extruded pea protein-alginate microcapsules. Particles protected B. adolescentis in simulated gastric juice and intestinal secretions. However, capsules were too big for meals.

Fluid bed

Cell suspension is sprayed and dried on inert carriers using a Wurster fluidized bed technique. Complete temperature control and cheaper cost are benefits of this technology. This technology is hard to learn and takes a long time. Encapsulating probiotic culture in skimmed milk calcium alginate or lipids before drying is necessary. Also utilized is shellac, a refined resin from the insect Kerria lacca (Coccoidea). Shellac's physicochemical qualities vary by insect strain, host tree, and refining procedure (Buch, Penning, Wächtersbach, Maskos & Langguth, 2009). Shellac is suitable for food supplement coatings due to its natural nature. Shellac is stomach fluid-resistant, making it suitable for enteric coating. Using shellac as an enteric coating polymer is limited by its poor digestive fluid solubility, particularly for hydrophobic compounds. Stummer et al. (2010) added sodium alginate, hydroxypropyl methylcellulose, polyvinylpyrrolidone, glycerol, and glyceryl triacetate to shellac to increase its enteric coating qualities. Scaling fluid beads is simple. Therefore is one of the most used commercial probiotic encapsulation methods. Company products including Probiocap® and Duaolac® use it (Burgain et al., 2011). It can create layered coatings. Champagne, Raymond, and Tompkins (2010) coated with two fats using this approach.

Rennet-gelled protein encapsulation

Food-grade rennet with aqueous milk protein solution may make microcapsules. Rennet, a proteolytic enzyme complex, cleaves k-casein, aggregating casein micelles (Heidebach, Först & Kulozik, 2009). The formation of non-covalent cross-links between micelle chains leads to a gel above 18º C (Bansal, Fox & McSweeney, 2007). Probiotics may be encapsulated without cell loss in these microcapsules. Due to protein buffering ability, the protein matrix of capsules has a greater local pH value, which may explain cell survival. In simulated stomach circumstances at low pH, it protects cells. These proteins also make microcapsule size management easier, which is important for final product sensory effect. This method looks ideal for better probiotic food application for those reasons.

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Freeze Drying

Encapsulating probiotic powders is new, while freeze-drying has been used for decades. Sublimation involves freezing, primary, and secondary drying. Cells are dried by sublimation under high pressure after freezing. Freeze drying offers higher probiotic survival rates than spray drying due to gentler processing. This approach freezes and sublimates solvent. Freezing damages cell membranes by crystal formation and excessive osmolarity stress. To retain probiotic viability, skim milk powder, whey protein, glucose, maltodextrine, and trehalose are added to the drying medium before freeze drying. Pre-fermented media may include cryoprotectants to assist bacteria adapt. The internal and external osmotic difference is reduced by cryoprotectants accumulating within cells.

Spray Freeze drying

Spray freeze drying uses freeze and spray drying techniques. A cryogenic liquid like liquid nitrogen atomizes probiotic organisms in a solution. This procedure disperses frozen droplets. Freeze dryers dry frozen droplets (Amin, Thakur, Jain, 2013). This method allows for regulated capsule size and a bigger surface area than spray-dried capsules. In addition, fluid beads may coat capsules to protect them from external conditions (Semyonov et al., 2010). However, this procedure uses a lot of energy, takes a long time, and costs 30–50 times more than spray-drying (Zuidam & Shimoni, 2010).

Semyonov et al. (2010) used maltodextrin as a wall matrix to reduce cell mobility in the glassy state. Trehalose, a disaccharide in the matrix, acts as a cryoprotectant, improving cell viability during freezing, freeze drying, and storage of dried bacteria. Trehalose forms hydrogen bonds with proteins and lipid membrane polar head groups, limiting structural damage during dehydration. The authors showed that spray freeze drying can dry L. paracasei microcapsules. These particles remain viable throughout spraying, freezing, and drying.

Spray chilling

Spray-cooling and spray congealing are synonyms. This method produces little droplets like spray drying. Spray-chilling solidifies particles by injecting cold air. Atomising a molten matrix containing the bioactive ingredient creates droplets that solidify swiftly in cold air (Champagne & Fustier, 2007).

Most spray-chilling employs fat matrices. Due to the crystalline structure and polymorphic arrangement of many lipid materials during solidification and crystallisation, microparticles can have low encapsulation capacity and expel core material during storage (Sato & Ueno, 2005). Spray chilling is the cheapest industrial-scale encapsulating method (Gouin, 2004). The tiny beads produced by this method may be useful in food preparation. Pedroso, Thomazini, Barrozo Heinemann, and Favaro-Trindade (2012) microencapsulated Bifidobacterium lactis and Lactobacillus acidophilus in interesterified fat with palm and palm kernel by spray chilling. The solid lipid microparticles protected probiotics from stomach and intestinal fluids and could be kept at low temperatures. Microparticle shapes and sizes may promote material flow without affecting food texture.

Ultrasonic vacuum spray dryer

Using spray drying, thermal and oxidative stressors may be reduced. In the drier chamber, an ultrasonic nozzle, low temperatures, and vacuum are used. Semyonov, Ramon, and Shimoni (2011) chose a wall material of maltodextrin and trehalose because these components can increase probiotic cell survival by maintaining membrane integrity during drying and storage and stabilizing bacteria proteins. Protein and carbohydrate mixture maintained good viability following spray drying and extended survival rates throughout storage.

Hybridisation system

Dry encapsulation is used for hybridisation. It has a stator, powder recirculation circuit, and six-bladed high-speed rotor. The blade's high-speed air stream impactions the powder mixture (host and guest particles) in the jar. Guest particles are embedded or filmed onto host particles to generate an ordered combination. Takafumi, Honda & Koishi (1993) found that the hybridization method maximizes microcapsule yields and reduces heat-induced bacterial damage by maintaining temperatures below 30 ªC. This method has evaluated sorbitol, mannitol, lactulose, xylitol, inulin,

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fructooligosaccharide, and raffinose. Results show that double microencapsulation by hybridisation efficiently provides probiotic benefits to the host (Ann et al., 2007).

Impinging aerosol technology

Impinging aerosol system employs two aerosols. One with calcium chloride and one with microbial suspension in alginate solution. Calcium chloride is injected from the base of a cylinder while alginate is pumped from the top. Alginate microbeads with an average diameter of less than 40 μm are produced using this approach (Sohail et al., 2011). Impinging aerosol technique encapsulates heat-labile and solvent-sensitive compounds without heat or solvent. It may spray or freeze dry microbeads and produce enormous volumes. Sohail et al. (2011) found that impiming aerosol microbeads and extruded macrobeads (2 mm diameter) protected L. rhamnosus GG in acid and bile tolerance studies. Sohail et al. (2012) examined how microencapsulation affected Lactobacillus rhamnosus GG and L. acidophilus NCFM survival and acidity in orange juice at 25 °C for nine days and 4 °C for 35 days. The unencapsulated L. rhamnosus GG survived well in orange juice at both temperatures. However, unencapsulated L. acidophilus NCFM was much less viable. Encapsulating these two bacteria reduced acidification at 25° C and 4° C but did not improve survival. In conclusion, L. rhamnosus GG survived well in orange juice and microencapsulation may reduce acidification and poor sensory effects of probiotics in fruit-based products.

Electrospinning

Electrospinning is a flexible technology that combines electrospray with spinning. A melt or solution pouring out of a die, which functions as an electrode, is subjected to a strong electric field. This deforms the droplet and ejects a charged jet from the tip to the counter electrode, forming continuous fibers (Figure 3).

Electrospinning produces a few nanometer fibers or capsules with high surface areas. This technology is appealing for various applications due to its simplicity and ability to produce huge quantities (Agarwal, Wendorff & Greiner, 2008). Electrospinning using whey protein concentrate and pullulan has encapsulated probiotics. Whey protein concentrate microcapsules outperform pullulan structures in cell survival (López-Rubio, Sanchez, Wilkanowicz, Sanz & Lagaron, 2012).

Encapsulated probiotic in food matrices

Although probiotics are drugs, health food is becoming popular, supporting Hippocrates' "let food be your medicine" adage. Refrigerated dairy accounts for most probiotics. International studies show probiotic microorganisms survive poorly in fermented dairy products. Although strain-specific, food probiotic bacteria should survive at 106-108 CFU/g. These bacteria grow, survive, and die depending on food characteristics and storage conditions. Food matrices should help probiotics populate the gut. Thus, selecting the correct food systems to deliver probiotics is essential for successful probiotic meals. In certain food matrices, microencapsulation boosts probiotic viability. Recently, probiotic-encapsulated foods have been introduced (Burgain et al., 2011).

Studies of the effects of microencapsulated bacteria on some pathologies

As noted in section 1, probiotics may help numerous ailments. They must reach the stomach in sufficient amounts to benefit. The rough gastrointestinal route may allow encapsulated probiotics. Few in vivo studies have examined the benefits of encapsulated probiotics in diverse illnesses.

Probiotics impact glucose. Bacteria reduce cholesterol and immunity (Bhatia et al., 2012). Related: immunomodulation, diabetes. Bhatia, Sharma, Sood, and Singla (2013) found that encapsulated Lactobacillus (LB10) from healthy buffalo milk and LeeBiotic Capsule (LCap) commercial probiotics are more effective antidiabetic agents. Extrusion created tiny particles. Without encapsulation, LB10 and LCap cut glucose levels by 37.85% and 36.50%, respectively, whereas LB10 with the commercial probiotic dropped them by 41.84% and 40.97%. The bacteria normalized glucose in 14 days. Glibenclamide lowered glucose 7 days. The medication caused hypoglycemia. Encapsulation may boost gut bacterial survival and lower blood glucose. Instead of lowering blood glucose, encapsulating bacteria may prolong probiotic health benefits.

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CLA conversion from LA may help probiotics. These fats lower cholesterol (Schlegel, Ringseis, Windisch, Schwarz & Eder, 2012). According to Bhatia et al. (2012), encapsulated and unencapsulated Lactobacillus from healthy buffalo milk plus Atorvastatin reduced cholesterol. Extrusion created tiny particles. Unencapsulated and encapsulated microorganisms lower cholesterol like drug-treated rats. Probiotics work independent of encapsulation, the research showed. Encapsulated microorganisms release slowly but maintain, so they may take longer to operate, say researchers.
According to Cheng et al. (2008), solid tumor micromilieu promotes facultative and strictly anaerobic bacteria growth. In certain settings, Lactobacillus and Clostridium inhibit tumor development. Bacteriolytic treatment, where living bacteria attack tumors, was inspired by similar outcomes. Bacteria's lysis may harm non-tumor cells. Site-specific injection and reduced microbe dispersion are possible with a non-pathogenic strain and confinement. Dwivedi, Nomikou, Nigam, and McHale (2012) externally gelated Lactobacillus casei NCDO 161 microencapsulated formulations to evaluate the method. These compounds destroyed tumor cells in vitro. In vivo studies examined microencapsulated formulations' impact on tumor development after direct intratumoural administration. The data showed considerable cancer growth suppression and indicated this method may treat solid tumors.
Ruan et al. (2007) used B. longun, B. bifidum, and B. adolescentis to investigate gelatin microparticles in a hemorrhagic shock model Compared to phosphate buffered saline, encapsulated and unencapsulated Bifidobacteria decreased cecum aerobes, bacterial translocation, plasma endotoxin, and ileal villous damage in rats Encapsulated Bifidobacteria decreased more than undamaged ones, even after ileal villous injury. Bifidobacteria-treated hemorrhagic rats had less bacterial translocation than controls. However, hemorrhagic shocked rats receiving the supplements had comparable total anaerobes and Bifidobacteria.

II. CONCLUSION

Microencapsulation is one of the greatest methods to keep probiotics alive throughout food preparation, storage, and digestion. Electrospinning is being researched for microencapsulation matrices other than polysaccharides. Industrial homogeneous particle production requires innovative technology or equipment. Finding acceptable carrier matrices and bacterial strains need further research. Microencapsulation costs must be examined and reduced. Simpler technology, fewer bacteria, and healthier products may save money. Encapsulated probiotics in varied food matrices are the study's emphasis.
Few studies have studied encapsulated probiotics' advantages in vivo. Though hopeful, animal trials were done. Medical trials with large patient populations are required to confirm encapsulated probiotics' preventive and therapeutic benefits. Formulations must have enough bacteria, viability, and niche colonization. The administration schedule must be standardized for consistency.

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