Encapsulation of Probiotic Cultures for Dahi using Spray and Freeze Drying

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In recent years, the demand for functional probiotic foods has increased worldwide due to the rising awareness of consumers regarding their health and the beneficial effects of probiotics. As a result, food producers have begun to place a greater emphasis on creating functional and probiotic foods. Probiotics are "live microorganisms that, when administered in sufficient amounts, confer a health benefit on the host," according to FAO/WHO (2001). For a product to provide the claimed health benefits, the amount of live probiotic bacteria in it at the time of intake should be greater than 10 CFU/100 g, according to the Food Safety Standards Authority of India (FSSAI). Prebiotics, on the other hand, are food ingredients that stimulate bacterial development and favour helpful bacteria in the stomach over unfavourable ones. About 30 live microorganisms and 16 compounds have received FSSAI approval for use as probiotics and prebiotics in food. The 10-100 trillion bacteria that make up the human body are mostly found in the gut and are generally referred to as the microbiota. Due to its potential to increase the viability and stability of these advantageous microorganisms, the encapsulation of probiotic cultures has attracted substantial attention in the field of food science and technology. Live bacteria and yeasts known as probiotics have a variety of positive health effects when taken, especially in fermented dairy products like *dahi.*

Probiotics *dahi* culture

The balance of gut health is maintained in large part by probiotic culture. They enhance the host's intestinal microbial balance, which benefits the host's health. Lactobacillus, Streptococcus, Enterococcus, Bifidobacterium, Saccharomyces, and other probiotic species are examples. Probiotic strains can protect the GI tract and epithelial cells, reduce inflammation in the gut, control antibodies, reduce lactose intolerance, prevent colorectal cancer, and inhibit the growth of harmful bacteria like Helicobacter pylori, among other benefits to human digestive health. According to Roobab *et al.* (2020) and Sharif *et al.* (2020), probiotics aid in the treatment of food allergies and the prevention of acute diarrhoea. The intestinal microbial equilibrium is preserved with the aid of probiotic microorganisms. Probiotic products improve human immunity and guard against oxidative damage to proteins and lipids, and reduce pathogens in the body.

Benefits

Probiotic *dahi* culture offers numerous health benefits due to the presence of live bacteria that promote a healthy gut and overall well-being.

- Improved Digestive Health
- Enhanced Immune Function
- Alleviation of Diarrhoea and Irritable Bowel Syndrome (IBS)
- Management of Lactose Intolerance

Microencapsulation

There are several different microencapsulation procedures, including spray drying, coacervation, fluidized bed coating, and emulsion-based techniques. The preferred characteristics of the encapsulated substance and the intended application determine the technology to use. The active component or core material is initially disseminated or dissolved within a covering substance known as the shell or matrix during the microencapsulation process. Depending on the demands of the application, different core-shell combinations may be used. Lipids, proteins, natural or manufactured polymers, or a combination of these, may make up the shell material.

The heat-sensitive probiotic could, however, be vulnerable to heat inactivation while drying. To avoid cellular damage and improve the survival of probiotics, thermal and cryoprotectants can be utilised during spray and freeze drying. The most widely used protectants include skim milk, sucrose, trehalose, maltodextrin, whey protein concentrate (WPC), and whey protein isolate (WPI). By forming hydrogen bonds with biomolecules and interacting with components of the cell wall, these protectants play a crucial function in shielding probiotic cells from cold shock and thermal stress. They have control over the temperature at which the bacterial cell membrane transitions to glass.

Using a variety of characterisation approaches, the size, shape, and surface morphology of dried probiotic cultures can be determined. Techniques like differential scanning calorimetry (DSC), Fourier transform infrared spectroscopy (FTIR), scanning electron microscopy (SEM), etc. were applied. These methods of characterisation provide an insight into the nature of probiotic culture encapsulation.

Spray drying

Spray drying is a widely employed technique for the encapsulation of probiotic cultures. The process involves atomizing a liquid mixture of probiotics and carrier material into a hot drying chamber. The carrier material, typically a carbohydrate-based matrix, acts as a protective shield around the probiotics, preventing their exposure to adverse environmental conditions. The atomized droplets quickly dry, forming microspheres or powder particles containing the encapsulated probiotic cultures.

Spray drying has the benefit of rapid as well as continuous encapsulation of probiotics, even though it provides rather poor survivability due to high drying temperature. It is an economic process with high production rate. Spray drying is also used to encapsulate probiotic cultures in the dairy and pharmaceutical industry. In this process, the suspension solution of microbial cells with wall material is atomized into the drying chamber, followed by rapid evaporation of water (Corcoran *et al.*, 2004). The atomized spray droplets come in contact with hot dry air inside the drying chamber. Water is evaporated by the heat in drying air, and the probiotic cells are dried into powder. The dried solid particles are separated from the drying air and are collected at the bottom part of the drying chamber. It is a rapid and cost-efficient method that produces spherical powder particles with desired properties such as specific residual moisture content, uniform shape and size. The dried solid particles are separated from the drying air and are collected at the bottom part of the drying chamber. It is a rapid and cost-efficient method that produces spherical powder particles with desired properties such as specific residual moisture content, uniform shape and size.

Freeze drying

Freeze drying, also known as lyophilization, is another popular method for probiotic encapsulation. In this process, the probiotic cultures are first frozen and then subjected to vacuum conditions. This causes the frozen water within the culture to sublime, bypassing the liquid phase and transforming directly into vapor. The resulting product is a dry powder with the probiotics encapsulated within, offering enhanced stability and extended shelf life.

Low temperature attainment and cold harm to microorganisms are drawbacks of freeze drying, however these are overcome by the benefits of cryoprotectants utilised in the process. Therefore, probiotics are frequently encapsulated through freeze drying. Freeze drying, in contrast, is based on sublimation, in which water in the solid state instantly transforms into a vapour state. Three processes make up the process: freezing, primary drying, and secondary drying. When samples are frozen, any water present crystallises at extremely low temperatures and separates away. During primary drying, the water in the frozen form is eliminated by sublimation. Desorption-based secondary drying is used to remove any remaining non-frozen water. Low freezing temperatures have the potential to alter the physical state of membrane lipids if handled carelessly.

Electrospinning

Electrospinning is a versatile technique used for the encapsulation of probiotic cultures, offering unique advantages in terms of structure and functionality. This method involves the use of an electric field to create ultrafine fibres from a polymer solution or melt. When applied to probiotic encapsulation, electrospinning provides several important benefits like biocompatibility, enhanced protection that contribute to the viability and stability of the cultures.

Comparison between spray and freeze drying techniques

The specific characteristics and outcomes of spray drying and freeze drying can vary depending on the specific parameters and conditions used in each process. The comparison between spray and freeze drying techniques for probiotic encapsulation is given in Table 1.

Table 1. comparison between spray and freeze drying techniques

Differences	Spray Drying	Freeze Drying
Process	Atomization of liquid feed inside a hot chamber	Freezing and sublimation under vacuum
Viability and survival rate	Lower due to high temperature drying process	Potentially higher due to processing at lower temperature
Moisture sensitivity	Offers better resistance to moisture due to case hardening	More susceptible to moisture absorption during storage
Cost and scalability	More economical and scalable approach	Complex and costly equipment with limiting scalability
Particle size	Wide particle size distribution	More uniform particle size distribution
Shelf life	Shorter shelf life	Extended shelf life due to superior stability

Conclusion and future trends

Microencapsulation is used to enhance the resistance of probiotics to unfavourable conditions. In encapsulation, the microbial cells are enclosed within a membrane to reduce cell injury, protect them from external stresses and to increase their viability and shelf-life.

Owing to the increasing awareness of consumers to probiotics and their health benefits, there is increasing demand for probiotic foods in India and worldwide. Food producers have therefore focused their efforts on the development of functional and probiotic foods. The viability of probiotic microorganisms is very important to realize their intended beneficial effects on health. They must stay alive in the recommended population until they reach their site of action so that their health benefits are realized. Probiotics are often destroyed in the stomach due to the harsh digestive conditions. Salt, sugar and pH in foods and the microenvironment have been found to adversely affect the viability of probiotics in foods. Therefore, protecting the probiotics and converting them into more resistant and stable forms are very important. The prominent technique to protect the probiotics in the food matrix is encapsulation, which isolates the probiotics from external influences. Viability, controlled and targeted release, handling convenience and applications in food are enhanced by encapsulating probiotics. Common technologies for encapsulating probiotic bacteria are freeze and spray drying.

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