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Nano material based encapsulation of probiotic bacteria for oral drug delivery

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Abstract:

Functional foods are now a common element of diets in industrialized nations and have been shown to provide potential health advantages beyond their well acknowledged nutritional impacts. Currently, probiotics and prebiotics also referred to as "synbiotics" are the most significant and widely utilized functional food ingredients. Dairy products seem to be a great way to create nutritious dishes since they already have a positive reputation for being healthy. Such probiotic dairy products have positive effects on the host by enhancing the implantation and survival of live microbial dietary supplements in the gastrointestinal flora, by selectively promoting the growth of one or a small number of health promoting bacteria in the intestinal tract, and by enhancing the microbial balance of the gastrointestinal tract. Through this review paper we are trying to analyse the current scenarios and trends in probiotics and their potential uses in field of modern medicine.

Keywords — **Nano material; Probiotic bacteria; Drug delivery; Foods**

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I. INTRODUCTION

The gastrointestinal microflora plays a crucial role in various biological mechanisms, making it difficult to control the microbiota's equilibrium [1]. Consuming active probiotics can help with these issues and offer other health benefits. Probiotics are living bacteria that, when given to a host in sufficient quantities, have a significant positive impact on their health. The Food and Agricultural Organization of the United Nations and the World Health Organization (FAO-WHO) define probiotics as substances released from one microbe that promote the development of the other [2].

Probiotic food microorganisms have gained popularity due to their importance to health. These beneficial bacteria are purposely consumed and added to the gut microbiome during probiotic treatment, causing large numbers of beneficial bacteria to compete for nutrition with dangerous bacteria, starving them out. Probiotics participate in various health-promoting processes in the human body.

Probiotics have been shown to improve intestinal health, enhance the immune system, lower blood cholesterol, and prevent cancer. While some health advantages have strong evidence, others need more research to be confirmed. Probiotics have been effective in treating acute diarrheal illnesses, preventing antibiotic-associated diarrhea, and improving lactose metabolism. However, there is not enough data to support their use in treating other clinical problems [3].

Yogurt is a significant dairy product for delivering probiotic bacteria to consumers, and the non-dairy market is constantly changing due to food technology and rising demand. As a result, a positive feedback loop is established as new products with enhanced sensory appeal grow, customer approval rises, and the food sector increases its investment in this expanding market [4].

Probiotic producers must create probiotic cultures that can last long and resist acidity in the upper alimentary tract to enter the colon in large enough numbers to colonize the epithelium. Probiotics, such as lactic acid bacteria, are desirable subjects for industrial food items, nutritional supplements, and medicinal formulas due to their widespread distribution in foods, crops, soils, and humans.

Nano-materials are increasingly being used in the pharmaceutical industry, particularly in drug delivery systems (DDS) [5]. These systems improve pharmacokinetics by regulating the distribution of essential components and accelerating medication release and absorption. Nano-materials have a broad spectrum of applications due to their physical, mechanical, electrical, magnetic, chemical, and biological characteristics. They are increasingly being used in drug delivery systems (DDS) to address challenges such as medicinal potency, side effects, and drug incoherence in plasma [6].

Nanoparticles are advantageous for therapeutic applications due to their large surface area to volume ratio, allowing surface modification and displaying numerous surface functional groups [7]. However, the mononuclear phagocyte system quickly opsonizes and clears surface-unmodified nanoparticles. The creation of nanoparticles using polymers from natural or synthetic sources increases the possibility of shielding medications from gastrointestinal tract degradation, causing them to deliver in various inflammatory areas.

Synthetic techniques can be used to generate or regulate nanoparticles' sizes, surfaces, and other characteristics. Hybrid organic-inorganic materials can be used to modify polymeric nanoparticles, and biopolymers derived from proteins and polysaccharides are receiving more attention due to their biodegradability, biocompatibility, low immunogenicity, and antibacterial activity.

Nano-encapsulation of probiotic bacteria for drug delivery is a widely used technique due to their widespread appearance in daily food and ability to colonize specific areas on the host body like the gut. This review paper aims to provide a comprehensive overview of different nano encapsulation techniques used for probiotic bacteria, highlighting advancements in the field and identifying various probiotics used for their nutritional benefits and overall well-being..

II. Literature Review

Probiotics are live bacteria that are commonly used in baby meals and can be found in fermented foods and cultured milk. They are considered health-beneficial microorganisms and have been shown to have various health benefits, including avoiding bowel ailments, improving the body's defenses, improving lactose intolerance and gastrointestinal microbial balance, alleviating postmenopausal disorders, and reducing traveler's diarrhea. Probiotics have also been used in the treatment of cutaneous and oral illnesses.

When choosing a probiotic bacterial type, safety concerns must be considered. Some strains of the Lactobacillus and Bifidobacterium genera are considered harmless, while others, such as Bacillus licheniformis, have been studied [8]. Safety evaluation is essential when probiotics are not from the Lactobacillus or Bifidobacterium families.

The health of the gastro intestinal tract (GIT) and probiotics is crucial, as they must remain active and viable while being stored and moving through the gut-intestinal tract (GIT). In vitro assays that mimic the GIt are used as a screening tool to determine the viability of probiotics. The adhesion of probiotic bacteria to host tissues depends on various factors, including microbial cell density, buffer components, fermentation time, and growing medium [9].

Probiotics have a positive effect on both acute and persistent infectious illnesses, not just those related to the gut. They can alter the microbial ecosystem in the intestines, improve the function of the gut barrier, promote competitive adhesion to the mucosa and epithelium, produce antimicrobial substances, and modulate immune activity. However, there is still a dearth of research on the connections between probiotics and diseases like cancer, elevated blood cholesterol, and allergic and HIV-related illnesses.

Probiotics have been shown to have some fresh advantages for the health of the epidermis, such as skin rejuvenation, improvement of atopic dermatitis, and mending of wounds and scars [10]. Probiotics have been extensively researched for their potential to treat skin disorders and improve oral health due to the rise of antibiotic-resistant bacteria. Bacteriocins, bioactive peptides produced by lactic acid bacteria, have antibacterial action against pathogenic bacteria and may reduce the expression of opportunistic bacterial virulence factors. Probiotics have been used to prevent oral illnesses like tooth caries, periodontal infection, and halitosis [11]. Recent research has shown that lactobacilli bacteria can slow the development of periodontopathogens like P. gingivalis, Prevotella intermedia, and Aggregatibacter actinomycetemcomitans.

Probiotics have been linked to human consumption of fermented foods since the dawn of time, with the first probiotic foods being lactic acid bacteria (LAB) and fungi-fermented cheeses and milks. Fermented milk has been recognized for its ability to heal digestive ailments and treat gastroenteritis [12]. However, probiotics must go through the same regulatory procedures as any new medicinal substance before being used as a medicine.

For thousands of years, both fermented and unfermented dairy products have been essential components of people's diets. Milk is a great vehicle for delivering or producing living, active cultured dairy products, which enhance the probiotic flora's ability to survive in the GI tract. However, the survival of most probiotic strains is impacted due to antagonistic interactions between starter cultures and probiotic strains in probiotic fermented dairy products [13].

Different food items have been suggested as probiotic bacteria carriers to provide consumers with significant quantities of viable probiotic cells while maintaining the highest probiotic bacteria viability and therapeutic benefits [14]. Yogurt, a fermented milk product, is a popular dietary vehicle for probiotic distribution. Yogurt has been recognized as a product with many desirable effects for consumers, and recent advances in bioscience have led to the creation of new yogurt products called "Bio-Yogurt" that contain live probiotic strains in addition to the standard cultures of S. thermophilus and L. bulgaricus [15]. Bio-Yogurt is yogurt with living probiotic cultures, which may contribute to health benefits. There are various types of Bio-Yogurts, including plain, stirred, flavored, and with additional fruits. Frozen dairy products, such as ice cream, have gained value and become a functional food due to their high protein content, thick structure, and high fat content. Ice cream's low acidity and low acidity attract people of all ages and socioeconomic strata [16].

Probiotic ice cream has shown promise as carriers of probiotic microorganisms due to its composition, production processes, and storage conditions. Process optimization aims to increase and maintain probiotic survival, while preserving the product's sensory characteristics and physico-chemical properties. However, some probiotic species may be less viable during the production and freezing of probiotic ice cream, affecting the functional efficacy of probiotic bacteria in frozen products.

Cheese probiotic products, such as soft, semi-soft, hard, and extremely hard cheeses, have been developed to introduce Enterococcus faecium into human gastrointestinal tracts [17]. The high protein content of cheese provides probiotic bacteria with an excellent buffering defense against the acidic environment in the gastrointestinal system, increasing their survival throughout gastric transit. The thick structure and high fat content of cheese provide probiotic microorganisms with extra protection.

Probiotic bacteria must be technologically acceptable for integration into dairy products and be capable of withstanding processing conditions and large-scale commercial cheese manufacturing [18]. They should have the same sensory and nutritional attributes as regular cheese and not degrade the cheese's quality. Processing of cheeses with high salt content should be adjusted to reduce salt's inhibitory impact.

The probiotics market is growing globally, with a market growth of 8% globally between 2020 and 2021 [1]. The COVID-19 pandemic has prompted consumers to prioritize disease prevention, health, and general well-being. Online searches have shown a growing interest in probiotics for various health goals, such as immunity, digestive health, allergies, and weight control. In a post-pandemic world, customers' interest in probiotics for prevention has outpaced that for sickness treatment.

Probiotic cheeses include feta, Swiss cheese, gouda cheese, edam cheese, caciocavallo cheese, emmental cheese, Gruyere cheese, cottage cheese, Parmesan cheese, provolone cheese, raw cheddar cheese, and kefir [19]. Feta is a low-calorie cheese made from sheep and goat milks, offering excellent calcium, phosphorus, and vitamin B content. Swiss cheese is known for its distinctive appearance and mild flavor, while gouda is a high-end semi-hard cheese with a robust taste [20].

Edam cheese matures like great wine, with a mild flavor and creamy texture. Caciocavallo cheese is a food staple from Southern Italy, with a salty and peppery taste. Emmental cheese is a light yellow color and similar holes to Swiss cheese, with a light and sweet flavor. Gruyere cheese is a delicious addition to a charcuterie board, with a nutty and creamy texture as it matures. Cottage cheese is a necessary component of many diets due to its numerous health advantages, with a small amount of fat and a lot of calcium, protein, selenium, and vitamin B [21].

Parmesan cheese is a crisp, flavorful cheese from Lombardy, Italy, popular as grated spaghetti or pizza topping. Provolone cheese is another delectable cheese from the Southern Italian region, with a peppery, nutty flavor. Raw, unpasteurized cheddar cheese offers probiotics, protein, calcium, and good fats, making it a popular choice for barbecues.

Kefir, a traditional beverage from Central Asia and the Middle East, is a naturally probiotic fermented milk product with a creamy consistency and a sour flavor. It is made from cow, goat, or sheep milk and contains lactic acid, acetic acid, CO_2 alcohol (ethanol), and aromatic compounds. Kefir's distinct sensory qualities, including a fizzy, acidic taste, sour, and rejuvenating flavors, are derived from these substrates [22]. Kefir grains are a type of fermented food that has been used for various health benefits, including nutritional, preventative, and therapeutic qualities. The microbial content of kefir grains is primarily composed of Lactobacillus and Lactococcus, with yeasts making up the rest. Kefir grains have a wide range of microorganisms, including Lactobacillus acidophilus, Lactobacillus acidoparacasei, Lactobacillus delbrueckii subsp. bulgaricus, Lactobacillus plantarum, and Lactobacillus kefiranofaciens [23].

Kefir has been used to manage various ailments, including obesity, gastrointestinal and metabolic problems, hypertension, IHD, weight management issues, and allergies. It is produced in various countries, including Germany, Austria, France, Luxembourg, Norway, Switzerland, the Czech Republic, Slovakia, Poland, and Israel [24].

Kefir contains a wide range of health advantages, including physiological, preventative, and therapeutic qualities. The diversified microbiota and bioactive chemicals created during the fermentation process contribute to these health benefits. Studies have shown that kefir can decrease fasting blood glucose and HbA1C levels in patients with type 2 diabetes melitus, as well as in overweight or obese premenopausal women. Kefir also has positive effects on constipation symptoms in patients with functional constipation [25].

The anti-hypertensive effect of kefir has been observed in experimental and clinical investigations. The casein produced from the fermentation of milk in kefir acts as a bioactive peptide that inhibits the functioning of the angiotensin-converting enzyme (ACE). However, rare investigations in the literature have yet to examine the antihypertensive effects of milk kefir, particularly experimental and clinical trials.

Lactose intolerance is another significant health benefit of kefir grains. Lactose is present in large amounts in milk and dairy products, and it is necessary for this disaccharide to be hydrolyzed before being absorbed in the small intestine by the mucosa. Kefir grains can lower the lactose concentration of the kefir during fermentation, enabling lactose-intolerant individuals to consume it.

Probiotics are live bacteria that are commonly used in baby meals and can be found in fermented foods and cultured milk. They are considered health-beneficial microorganisms and have been shown to have various health benefits, including avoiding bowel ailments, improving the body's defenses, improving lactose intolerance and gastrointestinal microbial balance, alleviating postmenopausal disorders, and reducing traveler's diarrhea. Probiotics are also used in the treatment of cutaneous and oral illnesses.

Safety concerns are crucial when choosing a probiotic bacterial type. Some strains of the Lactobacillus and Bifidobacterium genera are considered harmless, while others, such as Bacillus licheniformis, have been studied. Safety evaluation is essential when probiotics are not from the Lactobacillus or Bifidobacterium families.

The health of the gastro-intestinal tract (GIT) and probiotics is crucial. In vitro assays that mimic the GIt are used as a screening tool to determine the viability of probiotics. The adhesion of probiotic bacteria to host tissues depends on various factors, including microbial cell density, buffer components, fermentation time, and growing medium.

Probiotics have a positive effect on both acute and persistent infectious illnesses, not just those related to the gut. They can alter the microbial ecosystem in the intestines, improve the function of the gut barrier, promote competitive adhesion to the mucosa and epithelium, produce antimicrobial substances, and modulate immune activity. However, there is still a dearth of research on the connections between probiotics and diseases like cancer, elevated blood cholesterol, and allergic and HIV-related illnesses.

Probiotics have been shown to have some fresh advantages for the health of the epidermis, such as skin rejuvenation, improvement of atopic dermatitis, and mending of wounds and scars. Probiotics have been extensively researched for their potential to treat skin disorders and improve oral health. However, the evidence supporting their potential remains inconsistent due to variations in dose, probiotic strain, application time, follow-up time, and delivery time. Bacteriocins, bioactive peptides produced by lactic acid bacteria, have antibacterial action against pathogenic bacteria, potentially leading to novel alternative therapies for bacterial infections.

Probiotics have also been linked to oral health improvement, as they may help prevent oral illnesses like tooth caries, periodontal infection, and halitosis. Recent research has shown that lactobacilli bacteria can slow the development of periodontopathogens like P. gingivalis, Prevotella intermedia, and Aggregatibacter actinomycetemcomitans. L. fermentum and L. salivarius have antagonistic impacts on the development of periodontal pathogens like S. mutans, S. sanguis, and P. gingivalis. In vitro suppression of Prevotella nigrescens, Prevotella intermedia, and P. gingivalis has also been documented.

Critical fatigue syndrome (CFS) is a complex and crippling condition characterized by extreme fatigue that can be worsened by physical or mental activity and is not alleviated by bed rest. A pilot study found that L. casei strain Shirota significantly reduced anxiety symptoms in CFS patients.

The idea of probiotic bacteria is ancient and has been linked to human consumption of fermented foods since the dawn of time. The first probiotic foods were lactic acid bacteria (LAB), fungi-fermented cheeses and milks, and yeast-fermented leavened bread. Fermented milk can heal various digestive ailments and treat gastroenteritis. However, probiotics must go through the same regulatory procedures as any new medicinal substance before being used as a medicine. To ensure the safety and effectiveness of probiotic products for their effective use in many nations worldwide, there is an urgent need for worldwide harmonization of regulatory requirements on probiotic microorganisms.

For thousands of years, both fermented and unfermented dairy products have been essential components of people's diets. Milk is a fantastic vehicle for delivering or producing living, active cultured dairy products, which enhances the probiotic flora's ability to survive in the GI tract. For several reasons, fermented dairy products are excellent for fostering the probiotic bacteria's favorable health reputation. Additionally, probiotic bacteria used as starter organisms combine the favorable perceptions of fermentation and probiotic cultures.

Fermented dairy products are excellent for fostering the probiotic bacteria's favorable health reputation. They include live microorganisms (starter cultures), consumers already have a favorable perception of them as being healthy. However, due to antagonistic interactions between starter cultures and probiotic strains in probiotic fermented dairy products and acid generation in these cultured goods, the survival of most probiotic strains is impacted. This has led to the emergence of a new tendency in the production of probiotic non-fermented dairy products, including cheese, ice cream, and fresh milk.

Different food items have been suggested as probiotic bacteria carriers so that consumers can ingest significant quantities of viable probiotic cells while maintaining the highest probiotic bacteria viability and best therapeutic benefits. Yogurt, a fermented milk product, is one of the most common dietary vehicles for probiotic distribution. Yogurt has long been acknowledged as a product with many desirable effects for consumers. Modern yogurt manufacturing uses components such as milk, milk powder, sugar, fruit, flavors, colorings, emulsifiers, stabilizers, and standard pure cultures of LAB (Streptococcus thermophilus and L. bulgaricus).

Recent advances in bioscience have supported the idea that diet may modulate various bodily functions, leading to the creation of new yogurt products called "Bio-Yogurt" that contain live probiotic strains in addition to the standard cultures of S. thermophilus and L. bulgaricus. Bio-Yogurt products include Lactobacillus and Bifidobacteria species, including L. acidophilus, L. casei, L. gasseri, L. rhamnosus, L. reuteri, B. bifidum, B. animalis, B. infantis, and B. longum. Frozen dairy products, such as ice cream, are made from various ingredients, including milk, flavors, sweeteners, stabilizers, and emulsifiers. These products contribute to the positive effects on health and can be used in various ways, including treating skin disorders, improving oral health, and promoting overall well-being.

III. NANO MATERIALS IN MEDICINES

Nano-materials are a versatile and versatile material that have been widely used in pharmaceutical and medical applications due to their unique mechanical, optical, and electrical properties. These materials enable innovative therapies, imaging of sick tissues, and the detection of biological molecules. The use of nano-based particles (1-100 nm) allows for downsizing biosensors, allowing for smaller samples for various biochemical analyses and point-of-care diagnostics. Drug delivery systems using nano-pharmaceutics are tailored for enhanced bioavailability of the medication at the target location.

Nanotechnology is an interdisciplinary field that connects fields such as physics and chemistry with biology, engineering, and medicine to create a new technological age. The term "nanotechnology" refers to the study of particles at the 1 nm (one millionth of a meter) nanoscale level. The large surface area to volume ratio of nanoparticles aids in high drug loading, and the interaction between individual molecules and groups of molecules with respect to their bulk macroscopic properties is considered. The most important use of nanotechnology is "Nano medicine," which uses molecular knowledge to diagnose, prevent, and treat illnesses at the molecular level.

Modification of nanoparticles to have a variety of sizes, shapes, and surface properties results in amazing optical, electrical, magnetic, and biological applications. Nano-machinery is the long-term objective of nanomedicine research, seeking to characterize the quantitative components at the molecular scale. Early diagnosis and therapy, as well as a thorough understanding of biological mechanisms, are crucial components of nanotechnology. The creation of nanomachines and nanorobots is one of the most exciting areas of advanced nanotechnology.

Nano-imaging is a prominent example of semiconducting nanocrystals, with quantum dots (Q-dots) being a prominent example. The sensitivity of quantum dots detectors is at least five times greater than that of organic fluorescence molecules. However, they are currently only utilized for in vitro research diagnosis due to concerns about their toxicity.

Tissue engineering aims to supply cells with high control and efficiency, increasing tissue engineering's competitiveness. Biomaterials are employed in regulated organizations at the nanoscale scale to improve and enrich the biological activities of cells and pharmaceuticals encapsulated. Nanofiber-based scaffolds, due to their characteristics, are favorable for growth, proliferation, and cell adhesion. This offers a solid foundation for enhancing an electrospun nanofibrous scaffold in the field of tissue engineering in the future.

Drug delivery is another area where nano-materials can be used. Polymer or solid fat nanoparticles can transport a large variety of chemicals without the need for inorganic materials. However, there is limited room for using additional particles, particularly inorganic ones. Polymer nanoparticles were widely employed in the 1970s as a delivery system for proteins, peptides, and anti-tumor medicines. Later, fat, dendrimers, fellurenes, and nanocrystal nanoparticles were developed in the mid-1990s. The development of appropriate techniques to improve the specificity of delivery systems for target cells and more effectively transport active substances to the destination within the cell poses challenges despite the promising future for drug delivery systems. Carbon nanotubes have effectively been used in medicine, providing a good means of delivering medications into cells without first passing through the body's metabolism. Gene therapy is a novel method used to treat various illnesses, such as cancer, AIDS, and cardiovascular disease. It involves providing the patient's cells with the necessary gene materials to replace damaged genes. To prevent the breakdown of the gene by serum and macromolecules, genes must be encapsulated. A new substance, nitric oxide (NO), has been discovered, which has antibacterial and wound-healing properties. Researchers are interested in designing and producing NO-donating medications and materials. Nanoparticles with the capacity to store and transport NO scaffolds efficiently make them promising for applications in patches, wound dressings, and medical instruments that touch blood.

Antibiotic-resistant bacteria, such as Entercoccus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, and Enterobacter species, have developed resistance to antibiotics. Gold nanoparticles, due to their unique qualities, are used as an antibacterial agent due to their unique qualities. Scientists are interested in creating gold nanoparticles for medicine delivery and cancer therapy.

IV. CONCLUSIONS

Probiotics are living microorganisms that offer various health benefits to the host when given in sufficient doses at the intended target region in the digestive system. They can provide protection against enteric infectious diseases, improve metabolism, calcium absorption, vitamin synthesis, and pre-digestion of proteins, and have anti-mutagenic and anti-carcinogenic properties. Probiotics have the potential to be used in the treatment of conditions like cancer and inflammatory bowel disease due to their immunomodulatory properties.

Probiotic microencapsulation has several benefits, including increasing probiotic bacteria's survival by shielding them from the harsh gastrointestinal environment, facilitating efficient attachment to intestinal mucosal tissues, and ensuring controlled and targeted release of encapsulated materials with desirable effects. Traditional encapsulating materials have been made from various synthetic and natural materials, but there is always opportunity for development. One strategy that enhances the delivery of active probiotics to the site of action is the use of nanomaterials in microencapsulation. This method allows for customization of the physical and chemical characteristics of microcapsules, addressing the challenges of survival, long-term storage, and passage through the gastrointestinal tract.

Substances like Eudragit S100 and MgO nanoparticles have been shown to fill gaps in the hydrogel structure of microcapsules, increasing the probiotic bacteria's resistance to severe conditions. Nanocellulose can be adsorbed on the surface of microorganisms to prevent ice crystals from forming close to the cells during the freeze-drying process. Nanofiber and nanocoating types, such as alginate electrospun nanofibers, have been employed to increase the survival of probiotic microorganisms throughout storage and the digestive process.

Probiotic cells can be released into the gut while being shielded from the stomach's acidic pH by EMs. The rapid transit of probiotic bacteria from the intestine in feces is a significant obstacle that must be overcome. Nanomaterials like chitosan nanoparticles or nanocoatings can improve mucoadhesion to the gut wall. Future developments in nanotechnology and nanostructured microencapsulation methods may further improve probiotic products and further our understanding of their health advantages.

REFERENCES

[1] Giordano-Kelhoffer, Barbara, Cristina Lorca, Jaume March Llanes, Alberto Rábano, Teodoro Del Ser, Aida Serra, and Xavier Gallart-Palau. "Oral microbiota, its equilibrium and implications in the pathophysiology of human diseases: a systematic review." *Biomedicines* 10, no. 8 (2022): 1803.

[2] Savelli, Carmen Joseph, Adam Bradshaw, Peter Ben Embarek, and Céu Mateus. "The FAO/WHO international food safety authorities network in review, 2004–2018: learning from the past and looking to the future." *Foodborne pathogens and disease* 16, no. 7 (2019): 480-488

[3] Motamedi, Hamid, Matin Fathollahi, Ramin Abiri, Sepide Kadivarian, Mosayeb Rostamian, and Amirhooshang Alvandi. "A worldwide systematic review and meta-analysis of bacteria related to antibiotic-associated diarrhea in hospitalized patients." *PLoS One* 16, no. 12 (2021): e0260667.

[4] Mahmoodi Pour, Hamed, Mohammad Hossein Marhamatizadeh, and Hossein Fattahi. "Encapsulation of different types of probiotic bacteria within conventional/multilayer emulsion and its effect on the properties of probiotic yogurt." *Journal of Food Quality* 2022 (2022): 1-12.

[5] Aziz, Tariq, Asmat Ullah, Amjad Ali, Muhammad Shabeer, Muhammad Naeem Shah, Fazal Haq, Mudassir Iqbal, Roh Ullah, and Farman Ullah Khan. "Manufactures of bio-degradable and bio-based polymers for bio-materials in the pharmaceutical field." *Journal of Applied Polymer Science* 139, no. 29 (2022): e52624.

[6] Ariga, Katsuhiko, Hiroshi Ito, Jonathan P. Hill, and Hiroshi Tsukube. "Molecular recognition: from solution science to nano/materials technology." *Chemical Society Reviews* 41, no. 17 (2012): 5800-5835

[7] Anselmo, Aaron C., and Samir Mitragotri. "Nanoparticles in the clinic." *Bioengineering & translational medicine* 1, no. 1 (2016): 10-29.

[8] Zúñiga, Manuel, Vicente Monedero, and María J. Yebra. "Utilization of host-derived glycans by intestinal Lactobacillus and Bifidobacterium species." *Frontiers in microbiology* 9 (2018): 1917.

[9] La Fata, Giorgio, Peter Weber, and M. Hasan Mohajeri. "Probiotics and the gut immune system: indirect regulation." *Probiotics and antimicrobial proteins* 10 (2018): 11-21.

[10] Majeed, Muhammed, Shaheen Majeed, Kalyanam Nagabhushanam, Lincy Lawrence, Sivakumar Arumugam, and Lakshmi Mundkur. "Skin protective activity of LactoSporin-the extracellular metabolite from Bacillus coagulans MTCC 5856." *Cosmetics* 7, no. 4 (2020): 76.

[11] Krakowski, Andrew C., Lawrence F. Eichenfield, and Magdalene A. Dohil. "Management of atopic dermatitis in the pediatric population." *Pediatrics* 122, no. 4 (2008): 812-824.

[12] Mokoena, Mduduzi Paul, Taurai Mutanda, and Ademola O. Olaniran. "Perspectives on the probiotic potential of lactic acid bacteria from African traditional fermented foods and beverages." *Food & Nutrition Research* 60, no. 1 (2016): 29630.

[13] Giraffa, Giorgio. "Selection and design of lactic acid bacteria probiotic cultures." *Engineering in Life Sciences* 12, no. 4 (2012): 391-398.

[14] Routray, Winny, and Hari N. Mishra. "Scientific and technical aspects of yogurt aroma and taste: a review." *Comprehensive Reviews in Food Science and Food Safety* 10, no. 4 (2011): 208-220.

[15] Yangilar, Filiz, and Pinar Oguzhan Yildiz. "Effects of using combined essential oils on quality parameters of bio-yogurt." *Journal of Food Processing and Preservation* 42, no. 1 (2018): e13332.

[16] Lourens-Hattingh, Analie, and Bennie C. Viljoen. "Yogurt as probiotic carrier food." *International dairy journal* 11, no. 1-2 (2001): 1-17.

[17] Klare, Ingo, Carola Konstabel, Dietlinde Badstübner, Guido Werner, and Wolfgang Witte. "Occurrence and spread of antibiotic resistances in Enterococcus faecium." *International journal of food microbiology* 88, no. 2-3 (2003): 269-290.

[18] Noskin, Gary A., Lance R. Peterson, and John R. Warren. "Enterococcus faecium and Enterococcus faecalis bacteremia: acquisition and outcome." *Clinical infectious diseases* 20, no. 2 (1995): 296-301.

[19] Top, Janetta, Rob Willems, and Marc Bonten. "Emergence of CC17 Enterococcus faecium: from commensal to hospital-adapted pathogen." *FEMS Immunology & Medical Microbiology* 52, no. 3 (2008): 297-308.

[20] Lee, Terence, Stanley Pang, Sam Abraham, and Geoffrey W. Coombs. "Antimicrobial-resistant CC17 Enterococcus faecium: The past, the present and the future." *Journal of global antimicrobial resistance* 16 (2019): 36-47.

[21] Blanchette, L., D. Roy, G. Belanger, and Sylvie F. Gauthier. "Production of cottage cheese using dressing fermented by bifidobaceria." *Journal of dairy science* 79, no. 1 (1996): 8-15.

[22] Saleena, Lejaniya Abdul Kalam, Pui Liew Phing, Ren-You Gan, Anas Al-Nabulsi, Tareq Osaili, Afaf Kamal-Eldin, and Mutamed Ayyash. "Fermented dairy products from Middle Eastern and Northern African (MENA) countries: Insight on production and physiochemical characteristics." *International Dairy Journal* 141 (2023): 105614.

[23] Tamang, Jyoti Prakash, Paul D. Cotter, Akihito Endo, Nam Soo Han, Remco Kort, Shao Quan Liu, Baltasar Mayo, Nieke Westerik, and Robert Hutkins. "Fermented foods in a global age: East meets West." *Comprehensive Reviews in Food Science and Food Safety* 19, no. 1 (2020): 184-217.

[24] Sani, Ali Mohamadi, Mohammad Rahbar, and Mahya Sheikhzadeh. "Traditional beverages in different countries: Milk-based beverages." In *Milk-Based Beverages*, pp. 239-272. Woodhead Publishing, 2019.

[25] Singh, Pranav K., and Nagendra P. Shah. "Other fermented dairy products: Kefir and koumiss." In *Yogurt in health and disease prevention*, pp. 87-106. Academic Press, 2017.