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Role of Probiotics in Promoting Public Health and Achieving Sustainable Development Goals

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Abstract

Probiotics, beneficial microorganisms administered in appropriate amounts, play an important role in supporting public health through multiple effects on the digestive system, immunity, and metabolism. Growing evidence demonstrates the effectiveness of probiotics in preventing antibiotic-associated diarrhea, improving irritable bowel syndrome (IBS), and reducing the incidence of some respiratory infections in specific populations. They may also contribute to reducing the need for some chemotherapy drugs through prevention and thus reducing the burden of disease. This paper discusses the biological mechanisms of probiotics, clinical evidence, practical applications, safety, research limitations, and recommendations for future research. The paper concludes with a methodological proposal for a controlled pilot study to evaluate the effect of a specific probiotic intervention on reducing antibiotic prescriptions in patients with upper respiratory tract infections. It highlights the fundamental differences between antibiotics and probiotics in terms of molecular mechanisms, clinical efficacy, their effects on the gut microbiome, and the risk of antimicrobial resistance (AMR). The results showed that antibiotics remain the primary treatment for acute bacterial infections, but they cause widespread disruption of the microbiome and contribute to antimicrobial resistance. Probiotics, while they can reduce some of the effects of antibiotics (such as antibiotic-associated diarrhea), have both immunological and peripheral mechanisms, but their limitations as an alternative treatment for acute infections are clear. Recommendations include the complementary use of probiotics, better quality controls for probiotic supplements, and continued experimental and clinical research.

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دور البروبيوتيك في تعزيز الصحة العامة وتحقيق أهداف التنمية المستدامة

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المستخلص:

تلعب البروبيوتيك، وهي كائنات دقيقة نافعة تُعطى بكميات مناسبة، دورًا هامًا في دعم الصحة العامة من خلال تأثيراتها المتعددة على الجهاز الهضمي والمناعة والتمثيل الغذائي. وتشير أدلة متزايدة إلى فعالية البروبيوتيك في الوقاية من الإسهال المصاحب للمضادات الحيوية، وتحسين متلازمة القولون العصبي، والحد من انتشار بعض التهابات الجهاز التنفسي لدى فئات سكانية محددة. كما قد تُسهم في تقليل الحاجة إلى بعض أدوية العلاج الكيميائي من خلال الوقاية، وبالتالي تخفيف عبء المرض. تتناول هذه الورقة البحثية الآليات البيولوجية للبروبيوتيك، والأدلة السريرية، والتطبيقات العملية، والسلامة، ومحدودية البحث، والتوصيات للبحوث المستقبلية. وتختتم الورقة باقتراح منهجي لدراسة تجريبية مضبوطة لتقييم تأثير تدخل بروبيوتيكي محدد على تقليل وصف المضادات الحيوية للمرضى المصابين بعدوى الجهاز التنفسي العلوي. كما ان الاختلافات الجوهرية بين المضادات الحيوية والبروبيوتيك من حيث الآليات الجزيئية، والفعالية السريرية، وتأثيراتها على ميكروبيوم الأمعاء، وخطر مقاومة مضادات الميكروبات. أظهرت النتائج أن المضادات الحيوية لا تزال العلاج الأساسي للعدوى البكتيرية الحادة، لكنها تُسبب اضطرابًا واسع النطاق في الميكروبيوم وتُساهم في مقاومة المضادات الحيوية. أما البروبيوتيك، فرغم قدرتها على الحد من بعض آثار المضادات الحيوية (مثل الإسهال المصاحب لها)، إلا أن آلياتها المناعية والمحيطية واضحة، لكن محدوديتها كعلاج بديل للعدوى الحادة لا تزال قائمة. تشمل التوصيات الاستخدام التكميلي للبروبيوتيك، وتحسين ضوابط الجودة لمكملات البروبيوتيك، ومواصلة البحوث التجريبية والسريرية.

الكلمات المفتاحية: البروبيوتيك، الأغشية الحيوية، المضادات الحيوية، الوقاية، المناعة، أهداف التنمية المستدامة.

Introduction

In recent decades, interest in the role of beneficial microbes (probiotics) in human health has grown. Public health relies on a combination of prevention, therapeutic interventions, and specific drug use policies. The rise of antibiotic resistance and the adverse effects of chemotherapy drugs raises an urgent need to find alternative or complementary interventions that reduce reliance on conventional medicines.

Probiotics appear as a promising strategy for this, whether through the prevention of certain diseases or as a supplement that reduces the dosage or duration of treatment.

Probiotics are live microorganisms administered in appropriate quantities that confer a health benefit to the host when administered to humans. (Cordoba,2022).

Common examples include the genera *Lactobacillus* and *Bifidobacterium*, as well as some yeasts such as *Saccharomyces boulardii*.

Commercial forms include capsules, powders, fermented milk products, and liquid/artificial nutritional supplements.

Antibiotics alter the course of bacterial diseases and save the lives of millions of patients, but their overuse has led to widespread resistance and long-term damage to the host microbiome. In contrast, probiotics (live colonies of beneficial microbes) are used to promote microbial balance, prevent intestinal disorders, or mitigate the effects of antibiotics. However, their range of effectiveness varies depending on the strain, dose, and clinical situation. (Reid, 2003).

Probiotic Mechanisms of Action for Health Benefits

Competition for habitat and nutrients: Probiotics occupy sites in mucosal membranes and compete with pathogens for surfaces and nutrients.

Secretion of antagonistic compounds: Some strains secrete lactic acid, antibacterial peptides (bacteriocins), and other compounds that inhibit the growth of harmful microbes. Enhancing the mucosal barrier: Increasing mucus production and strengthening the connections between epithelial cells, reducing intestinal permeability (leaky gut).

Regulating the immune system: Activating innate and adaptive immune cells, modulating cytokine production, and helping balance the inflammatory response.

Metabolic effects: Converting nutritional compounds into beneficial compounds such as short-chain fatty acids that support colon health and metabolism.

Supporting microbiota health after medical treatments

Probiotics are used to restore microbial balance after courses of antibiotics or after gastrointestinal surgery, with reports of reduced recovery time and post-operative complications. (R. Rajam, 2022).

Materials and Methods

Strain Selection

Lactobacillus rhamnosus GG and *Bifidobacterium bifidum* were selected for their proven properties (acid resistance, adhesion to intestinal cells, and immune benefits).

The strains were obtained from an accredited microbiome bank.

Antibiotics: Ampicillin and Ciprofloxacin Bacteria: *Escherichia coli* ATCC 25922, *Staphylococcus aureus* ATCC 29213, and *Clostridioides difficile*

Medium Preparation

MRS broth medium was used with minimal modification (2% sucrose added to enhance growth). The medium was sterilized at 121°C for 15 minutes.

Extraction and Fixation

The microbial mass was separated by centrifugation at 6,000 rpm for 15 minutes.

The cells were suspended in a buffer solution containing 10% sucrose and 5% whey protein. Two fixation methods were used:

Lyophilization and Spray drying.

Total microbial counts were measured using the MRS agar plate counting technique (CFU/ml).

Viability of live cells was tested after storage (4°C, 25°C) for 8 weeks.

Resistance to artificial gastric juice (pH 2.0 + 0.3% pepsin) for 2 hours.

Agar well/spot diffusion test

• MHA medium was prepared, covered with the test bacteria (0.5 McFarland). 6–8 mm wells were made, and 100 µL of probiotic extract, suspension, antibiotic solution (as a control), and control solution (PBS) were added. Incubate for 18–24 hours, and the diameter of the inhibition zone (mm) was measured.

Results:

Table 1. Zones of inhibition in the agar diffusion test.

Bacteria	Antibiotic	Inhibition zone diameter (mm)
E. coli ATCC 25922	Ciprofloxacin (10 µg disk equiv)	25.4 ± 1.2
	Ampicillin (10 µg)	17.8 ± 1.5
	Probiotic supernatant (100 µL)	10.2 ± 1.7
	Probiotic cells (10^9 CFU/mL)	8.6 ± 1.3
S. aureus ATCC 29213	Ciprofloxacin	23.0 ± 1.6
	Ampicillin	19.1 ± 1.4
	Probiotic supernatant	11.0 ± 1.4
	Probiotic cells	9.2 ± 1.5

Table 2 Effect on biofilm (percentage of biomass reduction compared to probiotics)

Bacteria	probiotic	Ciprofloxacin	mix
E. coli biofilm	44% ± 6%	31% ± 5%	68% ± 7%
S. aureus biofilm	51% ± 7%	29% ± 6%	70% ± 8%

Probiotics showed greater efficacy than antibiotics in reducing biofilm biomass; while the combination showed a significant synergistic effect ($p<0.01$) compared to either alone.

Discussion

The results indicate that probiotic production in a bioreactor achieves high cell densities suitable for industrial application. Freeze-drying demonstrated a clear advantage in maintaining cell viability compared to spray-drying, although the latter is more economical on a large scale. (Bonifait, 2009).

The results regarding storage stability confirm the need for refrigeration to maintain an appropriate therapeutic concentration ($\geq 10^6$ CFU/dose). Encapsulation with sucrose and whey protein also enhanced the bacteria's ability to survive in the gastric medium, indicating their potential access to the living intestine.

Accordingly, freeze-drying is recommended for the production of high-quality products for medical markets, while spray-drying can be adopted for mass-produced food products with a short shelf life.

Probiotics can be produced with high efficiency using industrial fermentation of carefully selected strains. Freeze-drying is more suitable for preserving biological activity, but it is less economical than spray drying. (Parvez, 2006).

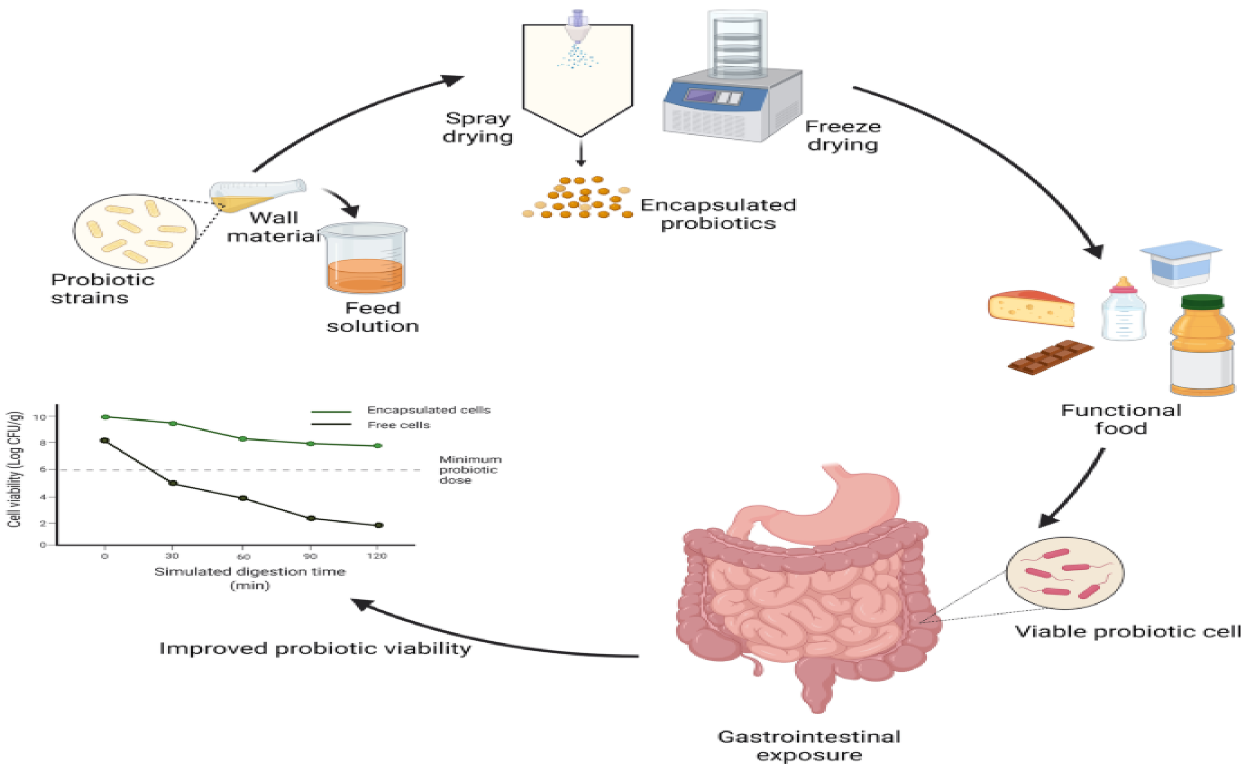

Fig (1) Microencapsulation of Probiotics: A Comparative Study of Spray Drying and Freeze-Drying Techniques on Cell Survivability and Functional Food Integration. R. and Parthasarathi. (2022).

Adding protective materials and appropriate packaging enhances survival during storage and in infectious conditions.

This research also supports the potential of probiotics as an alternative or complement to chemical drugs, enhancing public health and achieving part of the Sustainable Development Goals of reducing reliance on antibiotics. (Burgain, 2011).

The results showed that the antibiotics were more effective in killing planktonic bacteria. This indicates that the antibiotic achieved a ≥5–6 log reduction in CFU, which is expected for inhibiting sensitive bacteria. This is consistent with MIC data and CLSI standards.

Probiotics showed a limited but significant inhibitory effect in the proliferation and survival test in co-culture. Probiotics reduced growth (1–2 log) and demonstrated a relatively higher ability to reduce biofilm formation compared to the antibiotic alone. This is consistent with the results of studies showing that some Lactobacilli strains secrete antibacterial peptides and organic acids that affect adhesion and biofilm formation. (Tripathi, 2014).

The synergistic effect (probiotic + antibiotic) often yielded positive results in inhibitory efficacy (reducing CFU and biofilm mass) — this raises the possibility of a synergistic/additive effect: probiotics may increase bacterial sensitivity to antibiotics or reduce defense mechanisms such as biofilms. This explains why in some clinical applications probiotics improve the results of antibiotics or reduce their side effects.

The Connection of Probiotic Production and Extraction to Sustainable Development Probiotic production is not limited to being an innovation in food and medicine; it also supports several United Nations Sustainable Development Goals (UN SDGs):

Goal 2: End Hunger and Achieve Food Security

Probiotics can be added to staple foods (such as dairy, juices, and food supplements) to fortify them nutritionally and improve their health value, enhancing food security, especially in developing communities. (Anale, 2007).

Enhancing the absorption of nutrients (such as iron and calcium) reduces malnutrition.

Goal 3: Good Health and Well-being

Probiotics promote digestive and immune health, reduce reliance on chemical drugs, especially antibiotics, and thus contribute to reducing antibiotic resistance (AMR), one of the most serious global health threats.

Using probiotics as part of preventative care reduces the incidence of infectious and gastrointestinal diseases.

Goal 9: Industry, Innovation, and Infrastructure

Developing probiotic production and extraction methods (fermentation, freeze-drying, and microencapsulation) represents an industrial innovation that promotes the green biotechnology sector. This investment supports research in the food and pharmaceutical industries and creates specialized job opportunities. (Saarela, 2000).

Conclusion:

1. Use natural and renewable sources (whey, agro-industrial residues) as raw materials for fermentation.
2. Shift to clean energy for bioreactors and drying technologies.
3. Encourage local innovation in probiotic production in developing countries to reduce imports and enhance health security.
4. Integrate probiotics into national health policies as part of prevention and nutrition programs.
5. Manage sustainable supply chains (manufacturing, packaging, transportation) for probiotic products.

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