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Postbiotics: Revolutionizing the Future of Food

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Postbiotic is a term derived from the Greek word in which '**post**' is referred to as after and '**bios**' as life. Therefore, according to the definition given by the International Scientific Association for Probiotics and Prebiotics (ISAPP) in mid-2021, postbiotics are defined as products that are derived from inanimate microorganisms or their components which are either no longer alive or are inactivated and aim at conferring health benefits to the host (Salminen et al 2021). Probiotics are defined as the live microorganisms that are found in the gut of an organism to contribute towards the health-promoting benefits in an adequate amount whereas postbiotics can be defined as the probiotic metabolites or the byproducts of probiotic action such as fermentation found in the microbiota of the gut. Post-biotics are preferred over probiotics as the postbiotics provide the same health benefits as the host cells which are provided by the probiotics without allowing the consumption of microbial cells to be regarded as unsafe for use. For other reasons postbiotics are preferred over probiotics, such as probiotics being living microorganisms are known for having issues in standardization of dose whereas postbiotics don't have such issues but on the other hand are simple to maintain as their maintenance demands low temperature, easier to store and transport and has a longer shelf life (upto 5 years) which is not quite easily found in probiotics. The administration of live probiotic bacterial cells is associated with various risk factors such as flatulence, bloating, transfer of antibiotic resistance genes, and bacteremia (Doron and Snydman 2015). As a result of such risk factors, the use of postbiotics is considered a safer alternative to avoid these risks which in turn provide the potential for the postbiotics to act as saviors in the treatment of a variety of diseases and disorders (Haileselassie et al 2016). The end products produced by different signaling molecules of postbiotics serve various purposes which can be categorized as anti-inflammatory, antioxidant, anti-proliferative, hypocholesterolemic, anti-hypertensive, anti-obesogenic, and immunomodulatory activities (Nakamura et al 2016).

Postbiotics act as anti-obesogenic agents as they aim at improving insulin functioning in obese people by reducing the blood sugar levels in their bodies (Rad et al 2022). The primary strains used for the extraction of postbiotics are those of *Lactobacillus* and *Bifidobacterium* strains which are also termed producer strains. Along with these primary strains, various other strains of species such as *Streptococcus*, *Faecalibacterium,* and *Saccharomyces boulardii* are also been used for the production method of postbiotics (Gezginç et al 2022).

Postbiotics are differentiated into various important different groups such as organic acids, proteins, lipids, carbohydrates, vitamins, co-factors, teichoic acids, plasmalogens, and short-chain fatty acids. The actions of postbiotics are affected both by internal as well as external factors present in the food. The internal factors such as pH, moisture level, and food components, and external factors such as light exposure, temperature, and oxygen levels are the factors that play a major role in influencing the working efficiency of postbiotics and their bioactive compounds (Patil et al 2019). The ideal pH range suitable for postbiotics is between 4 and 9 (Prabhurajeshwar & Chandrakanth 2017). The fermentation process is the usual and natural method for the production of postbiotics but on the other hand, many other laboratory practices such as ultraviolet light, light pressure, thermal treatment, use of formalin, ohmic heating, pH changes, and drying are regarded as more efficient ways to inactivate and create postbiotics (Almada et al 2016).

Classification of Postbiotics

The postbiotics are divided into various classes based on their chemical properties and bioactivities. These classes are discussed as follows:

Organic Acids

One of the important classes of postbiotics is categorized as organic acids. Organic acids such as tartaric acid, citric acid, lactic acid, and acetic acid act as antibacterial agents by bringing down the pH of harmful pathogens present in a substance and in turn generating the acidic environment by dissolving their cell membranes which contributes to the prevention of infections.

Peptides

Peptides are another class categorized under the types of postbiotics which are produced by microorganisms. Antimicrobial peptides (AMPs) are a class of peptides that are antimicrobial as these

peptides play a key role in hindering the formation of bacterial cell walls or producing pores in bacterial cell membranes. The overall charge and tendency of AMPs to act as amphipathic help in the interference of AMPs with the components of the bacterial cell membrane. The mechanism of action of AMPs is the interaction of positively charged AMP amino acids with the negatively charged bacterial cell membrane components through the means of electrostatic interactions.

Short Chain Fatty Acids (SCFA'S)

SCFAs are produced as a result of end products produced by microbiota present in the postbiotics act as signaling molecules for improving the regulation of glucose homeostasis, lipid metabolism, and insulin sensitivity by activating receptors such as G protein-coupled receptors (GPRs) which contributes to the regulation of energy balance along with the maintenance of metabolic homeostasis. Specific SCFAs such as butyrate, acetate, and propionate are also proven for their contribution towards plasma cholesterol homeostasis in rodents as well as in humans.

Exopolysaccharides

Microorganisms during their growth period produce biopolymers which are released outside the bacterial cell wall exhibiting chemical properties. These bio-polymers form a heterogeneous group of substances which are termed exopolysaccharides (EPSs). EPSs are utilized in the food industry as stabilizing, emulsifying as well as water-binding agents. EPSs change in immune response by interacting with dendritic cells (DCs) and macrophages which results in enhancing the proliferation of T and Natural Killer (NK) lymphocytes.

Mechanism of Action

Immunomodulatory Mechanism

One example of short-chain fatty acid (SCFA) is propionate which helps in enhancing the formation of T-cells whereas on the other hand butyrate is another example categorized under SCFA playing a key role in the differentiation of T-cells.

Antitumor Mechanism

Inflammation is directly related to the carcinogenesis process therefore any substance that helps in inhibiting the inflammation is termed as an anti-cancer agent having anti-cancerous properties. SCFAs play an important role in controlling the regulation of oncogenes along with the suppressor genes. One of the examples of SCFA is propionate produced by *Propionibacterium freudenreichii* which is known for selectively inducing the mechanism of cellular suicide i.e. apoptosis in gastric cancerous cells.

Antiatherosclerotic Mechanism

Postbiotics act as antiatherosclerotic agents by playing a major role in the metabolism of lipids which further results in reducing the risks related to the rate of cardiovascular diseases. One example is that of the SCFA class of propionate which causes the inhibition of the condensation process of cholesterol precursors causing statin-like effects. Another example of such a mechanism can be accounted for the Kefiran exopolysaccharide molecule which has antiatherogenic properties as it helps in preventing the accumulation of cholesterol and its precursors in macrophage cells along with the reduction of levels of lipid concentration and inflammation. *Lactobacillus* bacteriocin-like substances (BLs) are also found to reduce the levels of triglycerides together with the low-density lipoprotein (LDL) which is bad cholesterol by further increasing the level of good beneficial high-density lipoprotein (HDL) cholesterol.

Autophagy

Autophagy is defined as the mechanism of the body via which it cleans out damaged organelles and other molecules. This process occurs in response to various stress stimuli such as nutrient stress. Post biotically derived *Lactobacillus fermentum* initiates the process of autophagy in hepatic cells HepG2 which results in providing protective effects against liver toxicity.

Applications

Considering their benefits, postbiotics have a variety of promising applications in different fields:

Human Health and Nutrition

Postbiotics can help improve gut health by enhancing the gut microbiota, promoting the growth of beneficial bacteria, and inhibiting harmful pathogens. They have immunomodulatory properties, helping to boost the immune system and potentially reducing the risk of infections. Certain postbiotics possess anti-inflammatory properties, which can help manage inflammatory conditions and improve overall health. Postbiotics can aid in regulating metabolic processes, potentially helping in the management of diabetes, obesity, and metabolic syndrome.

Food Industry

Postbiotics can act as natural preservatives, extending the shelf life of food products by inhibiting spoilage microorganisms. They can be used to fortify foods with beneficial bioactive compounds, enhancing

the nutritional value of various products. Postbiotics can contribute to the flavor, texture, and overall sensory properties of fermented foods, making them more appealing to consumers.

Animal Health

Postbiotics can be incorporated into animal feed to promote gut health, improve nutrient absorption, and enhance growth performance in livestock. They can be added to pet foods to support the health and well-being of pets by improving digestion and boosting the immune system.

Cosmetics and Personal Care

Postbiotics can be included in skincare formulations for their anti-inflammatory, antioxidant, and moisturizing properties, promoting healthy skin. They can be used in hair care products to improve scalp health and enhance hair quality.

Pharmaceuticals and Supplements

Postbiotics can be marketed as dietary supplements for their health benefits, such as improving gut health, boosting immunity, and reducing inflammation. They have potential applications in the development of new therapeutic agents for treating various diseases, including gastrointestinal disorders and inflammatory conditions.

Environmental Applications

Certain postbiotics can be used in environmental cleanup processes to degrade pollutants and contaminants, contributing to environmental sustainability.

Postbiotics represent a versatile and innovative approach to enhancing health, food quality, and environmental sustainability, making them a significant focus of research and development in various industries.

Status of Postbiotics in India

The postbiotic market in India is experiencing significant growth, driven by increasing awareness of gut health, the rising popularity of functional foods as well as beverages, and a growing interest in natural and sustainable health solutions. Moreover, the Indian government is promoting health and wellness through various initiatives, encouraging the development and consumption of nutraceuticals, including postbiotics.

In the market segment, the Postbiotics are being formulated into dietary supplements aimed at improving gut health, boosting immunity, and offering other health benefits. Companies are incorporating postbiotics into functional foods and beverages such as yogurts, fermented drinks, and health bars and there is potential for the use of postbiotics in pharmaceuticals for the prevention and treatment of various health conditions, including gastrointestinal disorders.

Global companies with established probiotic and postbiotic products are entering the Indian market, leveraging their research and development capabilities and the Indian companies are also investing in the development of postbiotic products, focusing on catering to local tastes and preferences.

In the Indian market, several notable postbiotic products are available. Yakult offers Yakult Light, a probiotic fermented milk drink containing *Lactobacillus casei strain Shirota*, which produces postbiotic compounds beneficial for gut health. Dr. Reddy's Laboratories provides Nutracitics Probiotic & Prebiotic Capsules, blending probiotics and prebiotics to generate postbiotic metabolites that support digestive health. Himalaya Wellness has developed Quista Pro Advanced, a protein supplement enriched with probiotics and postbiotic metabolites to enhance digestion and nutrient absorption. Amul's Probiotic Lassi is a traditional yogurt-based drink fortified with probiotics that produce postbiotic compounds for improved gut health.

Internationally, several companies offer prominent postbiotic products. Seed Health's Daily Synbiotic combines probiotics and postbiotics to support gut health, immune function, and overall wellness. Glanbia Nutritionals provides Bioferrin, a lactoferrin-based postbiotic used in dietary supplements and functional foods for its immune-boosting properties. ADM (Archer Daniels Midland Company) offers Biopolis Microbiome Solutions, a range of postbiotic ingredients for dietary supplements, functional foods, and beverages to enhance gut health and overall well-being. Kerry Group's Wellmune is a postbiotic beta-glucan derived from yeast, used in various food and beverage products to support immune health.

Limitations

Navigating the regulatory landscape for functional foods and dietary supplements can be challenging. Clear guidelines and regulations are essential for market growth. Educating consumers about the benefits of postbiotics is crucial for market acceptance. Awareness campaigns and informational initiatives can help in this regard.

Future Prospects

Continued research into the health benefits and applications of postbiotics will drive innovation and expand the market. As consumer awareness grows, the market for postbiotics is expected to expand beyond major urban centers to smaller towns and rural areas. Collaborations between research institutions, government bodies, and private companies can foster the development and commercialization of new postbiotic products. The postbiotic market in India is poised for growth, with opportunities for innovation and expansion in various sectors. As consumer awareness and demand for health-focused products continue to rise, the market is expected to see substantial development in the coming years.

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