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Mini Review

Metabiotics as Potential Therapeutic Agent in Mucosal Immunity

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Abstract

Synbiotics area mixture of pre and probiotics and considered an economical and safe substitute for treating infectious and non-infectious diseases and improving human health. Synbiotics stimulate native gut microbiota to promote health. Prebiotics and undigested dietary polysaccharides support the progression of probiotics and concurrently destroy the actions of opportunistic germs in the colon. Synbiotics maintain gastrocolic microbial equilibrium and avoid dysbiosis. Metabiotics are the cellular or assistant substance of probiotics and have advantageous importance in tackling many disorder rsrelated to the enteric and systemic milieu. One of the essential metabiotics is short-chain fatty acids, which is considered its epigenetic medicine for cancer therapy. Synbiotics optimize the attentiveness of gut-associated metabiotics to modulate enteric physiopathology. Synbiotic therapy might be the future therapeutic modality for managing and curing various ailments..

Keywords: Epigenetics; Gut; Pathogenesis; Probiotics; Prebiotics

Introduction

The human microbiome evolved progressively in various anatomical milieus conferring health benefits, including shaping immunity against infection and pathogenesis. The co-existence of symbionts congregation regulates the contagious homeostasis of the human body.Pathobionts, antibiotics, and other eco-friendly pollutants disrupt microbial equilibrium to challenge immunity, leading to the deterioration of mucosal obstruction function and causing adverse physiological conditions. Bacterium gets the opportunity to disrupt the mucosal barrier prominent to the declining population of probiotics.The increase of proinflammatory cytokines like IL-1β, IL-6, and TNF-α are key regulators of disease manifestation; these cytokines might be related to the pathogen's growth regulators. In connection with these pathophysiological conditions, the administration of synbiotics plays a crucial partin conserving the gut's bacterial homeostasis. Therapeutic intervention of synbiotics restores and conserves the disrupted ecological niche of the human microbiome [1]. Metabiotics act as anti-pathogenic and epigenetic modulators against infection and pathogenesis. Therefore, synbiotics and their metabolites are beneficial in health and diseases. The link between prebiotic, probiotic, and symbiotic has been depicted in (Figure 1).

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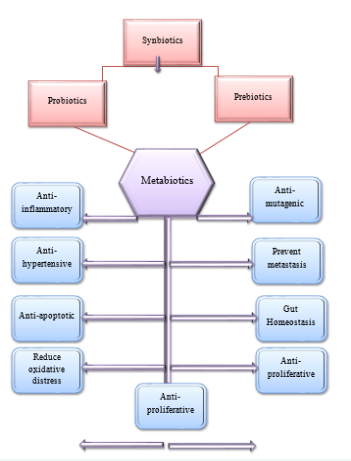

Figure 1 Prebiotic and probiotic and symbiotic link with metabiotics potential health-promoting properties.

Probiotics

Considering the UN Food and Farming Society, probiotics are living microbes once directed in sufficient quantities, and it convenes health-related advantage on the congregation." About forty-seven probiotics are used to manipulate gut flora; they are supposed to utilize both anti-cancerous and anti-mutagenic activities [2].

Microbicidal Effect of Probiotics

Probiotics dwellers in the gut have a genetic perspective to encode anti-pathogenic constituents and it releases in their vicinity to kill/antagonize the progression of enteric pathovirulents. Lactic acid bacteria, such as *Lactobacillus*, *Lactococcus*, etc., secrete acids (probiotic), which is responsible for reducing enteric lumen pH to a certain level, below which pathogens can compete effectively. Numerous classes of *Lactobacilli* and *Bifidobacterium* have been designated to occupy receptor sites that competitively exclude microbial pathogens [3,4].

Transgenic probiotics equipped with anti-virulent genetic components for efficient synthesis and release of therapeutic molecules against microbial pathogens have been proven to be a potential therapeutic strategy to prevent and cure infectious diseases. However, virulent bacteria get attached to the gut epithelial surface and deliver their toxins in its vicinity, thereby triggering the pathogenesis process through various mechanisms, Lievin-Moal and Servin (2014) [5] reviewed the elimination or killing of intracellular pathobiont by probiotic-secreted factors. Recombinant *Lactobacillus casei* equipped with the human lactoferrin gene has recently been investigated for its microbicidal efficacies in *in-vitro* and *in vivo,* which was found to be effective against pathovirulent bacteria [6]. Furthermore, a recombinant probiotic with antivirulence efficacies against *Listeria monocitogenes* has been designed which inhibit *L. monocytogenes* infection and its translocation to systemic organs from the gastrointestinal barrier by blocking the adhesion sites at the Gastrointestinal (GI) mucosal surface [7]. Therefore, genetically modified probiotics are receiving more consideration in the healthcare system due to their novel therapeutic strategy with extreme urgency.

Prebiotics

Prebiotics are selectively fermentable, non-digestible oligosaccharides; these oligosaccharides are made up of more than or equal to 3-10 monosaccharides responsible for alterations in the alignment and movement, which leads to the gut flora for conversing to wellbeingvalues. As proposed by Gibson et al. (2004) [8] that three food components are classified as prebiotics, which involve in:

i. To maintain Gastroesophageal Reflux (GER) and hydrolysis by enzymes secreted from mammals like amylase, pepsin trypsin, etc., as well as GI engagement.

ii. It is responsible for fermentation by bacteria and other microorganisms in the bowel.

iii. It encourages the formal growth and activity of microflora, which is related to health and comfort based on the conditions mentioned above; there is about three prebiotics like lactulose and inulin-type fructans, Trans-galacto-oligosaccharides utilized in the industries [9]. Prebiotics have been supposed to be good, helpful energy sources for gut flora to maintain and restore the balance of gut microflora by increasing probiotics such as *Bifidobacterium* and *Lactobacilli*, inhibiting the growth of pathogens. Prebiotics also significantly modify the gut environment by decreasing pH in the fermentation process [10]. It has been reported that the structure and inhabitants of the gut microbiota improved the pH decrease from 6.5 to 5.5 [11]. Subsequently, cardiovascular disease is one of the significant reasons which causes people's death in recent days; in this connection, there are many studies favoring the role of dietaryfibers and prebiotics consumption on cardiovascular disease [9]. Many reports show that prebiotics positively affects Cardiovascular Disease (CVD) by reducing inflammatory compounds.

Prebiotics such as oligofructose-enriched inulin reduces severe diarrhea; conversely, they increase β-glucuronidase activity in fecal contents, a key bacterial enzyme mediating CPT-11-related intestinal toxicity [12]. Fructans (prebiotics) protect colon cancer [13]. Gut-associated biofilm of probiotic microbial groups modulates enteric barrier occupations. Biofilms of *Lactobacilli* have remained to produce anti-pathogenic and anti-inflammatory issues that convene accurate health welfare [14]. Biofilms of unlike species of probiotic microbesfashioned on the gut membrane need to be protected and maintained. The dietary intervention of prebiotics can achieve this. Prebiotics-stimulated symbionts and biofilm of mucus-alliedprobioticsact synergistically as an anti-pathogenic shield in conjunction with the epithelial tight junction proteins leading to the prevention and blockage of microbial/antigenic translocation to the gut-associated organs like the liver and spleen there by protecting these vital organs against infection and inflammation.

Consequently, a healthy enteric nervous system that controls and quantifies water and minerals present in the body between the intestinal lumen and extracellular fluid partitionscan be maintained through collaborating action of prebiotics and probiotics. Likewise, *in vivo* studies presented that the management of probiotics effectively improves lipid panel, which is a significant cause of coronary infarction. Pre, as well as probiotics, reduce the lipid panel tests that include cholesterol (Total), HDL-Cholesterol, LDL Cholesterol, and triglycerides, including the reduction of adipose tissue, thus reducing the risk of myocardial infarction [15,16]. Clinical trials of a diabetic patient verify probiotics possess a positive impact on reducing blood sugar as well as insulin extent that play jobs to improve HbA1c as well as insulin refusal. So many factors present in pre, as well as probiotics, play important roles, including regulation of immune differentiation factor and insulin extent, inhibition of pathogenic bacteria adhesion to the bowel and translocation to fatty cells, and improvement of intestinal barrier function [17].

Antioxidant Properties of Probiotics

An imbalance between free radicals and an antioxidant contributes to microbial infection of Irritable Bowel Syndrome (IBS) and colorectal cancer. Investigations over probiotics for their antioxidant properties in rats in *in-vitro* experiments proved that certain probiotic strains are proficient inhuntingfree radical species from the host [18]. Antioxidants inhibit oxidation, mainly ones used to counteract the deterioration of stored food products almonds are enriched with antioxidants as they contain α-tocopherol and polyphenolics. Almond drink contains 6.33 mg 100 g-1 vitamin E in the form of α-tocopherol, equivalent to 42% of the 15 mg recommended daily amount [19].

In light of the study carried out by Amaretti, et al. (2013) [20] and several published research articles, it has been proven that probiotics increase the substratum of the cellular antioxidant defense mechanism of the host. Probiotics induce the transcription of genetic components for synthesizing a complex molecule like glutathione in GI mucosa [20,21]. Peran, et al. (2007) [22] also stated that probiotic *Lactobacilli,* as well as *Bifidobacteria*, restore the concentration of Glutathione (GSH) in imbalance among free radicals as well as an antioxidant-induced rat. Enteric microbes broaden the bioavailability of antioxidant compounds present in the diet [23]. Sun, et al, in 2013 [24], reported that iron (Fe) can encourage hydrogen peroxide and hydroxyl radical generation in the colonic mucosa, promoting the growth of Fe-dependent bacteria. *Lactobacilli* can survive in a Fe-containing environment and have been found to inhibit ROS-producing bacterial species in mice [24]. Hence,

prebiotics and probiotics modulate the antioxidant defense machinery of the gut, thereby inhibiting ROS-mediated pathogenesis. The therapeutic intervention can strategically cure imbalance among free radicals and antioxidant-induced progression and genesis of gut diseases of genetically modified probiotics which efficiently yield certain antioxidant enzymes. LeBlanc, et al. 2015 [25] have recently reviewed several transgenic probiotics with antioxidant properties. The dietary prebiotic compound might be responsible for producing antioxidant enzymes by modulating the associated genetic components of probiotics. Therefore, the characterization of antioxidant modulators of prebiotic nature may be a potential therapeutic agent against diseases where oxidative stress is implicated [26-38].

Metabiotics

Synbiotics-derived effectors having satisfying importance are described as metabiotics. The effectors' components of synbiotics have a local function to attenuate or kill pathogenic microorganismsin the gut, like *Clostridium*, *Bacillus cereus*, etc. In contrast, theefflux of metabiotics in enteric and systemic circulation has a broad spectrum of therapeutic actions in almost all cells/tissues and organs of the body.

Probiotic microbes are the source of significant metabiotics like bacteriocins, Short-Chain Fatty Acids (SCFA), peptidoglycans, polysaccharides, and vitamins. Different metabiotics and linked probiotic strains make diverse sets of Low Molecular Weight (LMW) bioactive molecules that could be attractive aspirants for metabiotic. Some of them can be seen in (Table1).

Table1: Various biological active compounds and their suggested health benefits as metabiotics.

Biological active compounds	Proposed health benefits	References
Acetate	• Suppresses obesity • Recovers glucose tolerance • Decreases the appetite	[26]
Short-chain fatty acids	• Effective in ulcerative colitis and Crohn's disease • Reduces the cholesterollevels	[27-29]
Lactate	• Regulates the immune function • Energy source • Regulates signaling molecules	
Butyrate	• Anti-inflammatory • Anticancer • Reduces intestinal epithelial permeability	[30-33]
Propionate	• Deters the use of acetate for lipid and cholesterol synthesis • Anti-inflammatory • Act as gluconeogenic substrate	[34,35]
Mutacin	• Exhibits potential effects in dental carries	[36-38]
Nisin	• Effective in peptic ulcer	
Epidermin	• Effective in skin infections	

Metabiotics Mechanism

Studies assumed that the metabiotics differentiated biological function may be a consequence of epigenetic modifications that subsequently tend to different biochemical and signaling pathways and lead to positive modulation in host physiological processes. The numerous epigenetic processes, including phosphorylation, histone acetylation, biotinylation, and DNA methylation, involve the host cell epigenetic control [39,40]. These modifications substantially influence numerous biochemical processes, such as immunomodulation, regulating epithelial cell barrier function, and quorum sensing interference. Moreover, these biochemical alterations can move to exert their valuable role in the inhibition of numerous fatal diseases, for instance, cancers, autoimmune disorders, etc. [41]. The possible therapeutic role deliberated by metabolites leads to establishing a model in the emerging health-promoting agents. However, further studies are required to know the exact mechanisms to reveal the potential mode of action [42].

Modulation of Mucosal Barrier Function

Protecting the Gut by Anti-Inflammatory Action through Pre and Probiotics

Gut-associated mucus acts as a physiological barrier that protects the epithelial surface from being colonized by pathobionts. Mucin induces instruction of microbial cell wall proteins crucial for linkage to the gut epithelium [43,44]. Probiotics have adapted to defend mucus and related epithelial layer contrary to various stressors generated on the exterior of the gut. Probiotics compete to link and adhere to probiontsto restrain epithelial constricted junction proteins. Several species of *Lactobacilli* and *Bifidobacterium* came to be reported to restrain epithelial constricted junction proteins and enhance epithelial blockade functions. Endogenous and exogenous oxidative stress andantigenic pressure on the gut wall trigger development of a disease (pathogenesis). Pathogenesis of IBD involves the accumulation of ROS, microbial antigens, and environmental elements, resulting in the induction of inflammation, subsequently developing mucosal lesions and repair. This implicates the loss of local physiological regulatory mechanisms and perhaps a breakdown of oral tolerance toluminal antigens in these diseases [45-48]. Altered GI epithelial absorbency is allied with the pathogenesis of various diseases [49-52]. Entero-pathogenic bacteria and their secreted yields can elicit a cascade of signals and molecular events resulting in inflammation/malignant growth [53]. The consequences are inflammatory comebacks, which involve the recruitment afro-inflammatory cytokines and chemokines, attracting phagocytes and other immune cells toward the site of infection.

The interactive action of prebiotics and probiotics has been implicated in protectingthehuman gut against deleterious effects. Angiogenesis exhibits wound healing and repair. Deregulated angiogenesis is involved in gastrointestinal inflammation. Probiotic *Bacillus polyfermenticus*is clinically used for intestinal wound healing [54]. Secreted protein p40 of *Lactobacillus rhamnosus* GG activates the Epidermal Growth Factor Receptor (EGFR) pathway, thereby suppressing the cytokine-induced epithelial cell apoptosis and protection against experimental colitis [55]. *Lactocepin* (protease), a secreted product of *Lactobacillus paracaseiis* capable of degrading some proinflammatory chemokines, including CXC-chemokine ligand 10 (CXCL10), which inhibits the recruitment of inflammatory cells to the mucosal tissue, and protects against colitis in mice [56]. *Lactobacillus brevis*-secreted polyphosphate has been reported to have protective effects on epithelial cells via the activation of the mitogen-activated protein kinase p38 [57]. Other unknown compounds secreted by *Faecali bacteriumprausnitzii* and *L. paracasei*can inhibit nuclear factor-κB (NF-κB) activation and protects against experimental colitis or ongoing inflammation in tissues in patients with Inflammatory

Bowel Disease (IBD) [58]. Therefore, prebiotics and probiotics have the potential to modulate gut-associated functions by strengthening the mucosal barrier via immune and non-immune-mediated effects. Genomics and proteomics of probiotics must be investigated to characterize the secreted molecules of therapeutic importance. Probiotic-based new metabolomic agents will undoubtedly emerge as effective therapeutic modalities to cure chronic diseases.

Mucosal Immunity

Prebiotics Modulate Mucosal Immunity

A large body of evidence supports the variation in enteric microbial alignment, and untimely mucosal immune function initiates its pathogenesis process. Disruption and inappropriate function of gut-associated immuno-active components such as Mucosa-Associated Lymphoid Tissues (MALT) and injury of mucosal immune response to normal bacterium play a decisive role in the pathological process of chronic intestinal inflammation. Activation of immune cells of the MALT can be mediated through activation of the G-protein coupled SCFAs receptors. Possibly another interface point is between prebiotics and carbohydrate receptors on immune cells. The soluble β-glucans from yeast cell walls can interact with receptors on natural killer cells, and specific receptors on heterophils and monocytes recognize a variety of β-glucans from fungi and plants. Macrophage activity and proliferation may be induced as a direct effect of immune modulation due to prebiotic stimulus. Prebiotics (mannan-oligosaccharide-MOS and Fructo-Oligosaccharide-FOS) modulates immune responses in gut-associated lymphoid tissue of chickens [59]. Thus; both arms of the immune system (humoral and cell-mediated) can be activated by supplementing the diet with prebiotic compounds.

In recent years, many studies have shown that polysaccharides, either in the form of homopolysaccharides or heteropolysaccharides, had proficiency in regulating intestinal mucosal immunity [60]. Many kinds of research revealed dietary fibers such as cellulose, a type of non-digestible polysaccharide, could be acknowledged as prebiotics have the potential for the usage of gut microbiota; these gut microbiotas are playing the leading role in the modification of microbial variety and arrangement [61]. There are some examples of polysaccharides from Dendrobium Olhanense has been utilized as a folk medicine in China and could encourage cytokines building and encourages the immune cells propagation and variation in the intestine, which are leading cause to improvement and increases the number of useful bacteria like *Lactobacillus*, *Parabacteroides*, *Prevotella*, *Porphyromonas* and reduces the harmful bacteria like *Helicobacter*, *Clostridium* in mice colon [62].

Probiotics Modulate Mucosal Immunity

Oral delivery of probiotic microbes can modulate the immune system [1]. It has been reported that feeding *L. acidophilus* and *bifidobacteria*in a fermented milk product to human volunteers resulted in a significant increase of total IgA, specifically in the levels of IgA specific for *salmonella enterica subsp. enterica serovar typhimurium* [63]. It has also been reported that diverse strains of *Lactobacilli* exposed at lethal dosescan differentially activate mouse Dendritic Cells (DCs), notably with substantial differences between strains in the ability to induce Interleukin-12 (IL-12) and tumor necrosis factor [64]. Numerous constituents derived from probiotic bacteria have recently been used as immune agonists and vaccine adjuvants [65,66]. Probiotics induce indirect immunomodulation through action on non-immune cells, such as mucosal epithelial cells. It may also exert its effects independent of the immune system by inhibiting the establishment of the intestinal mucosa by microbial pathogens and/or by inducing the release of antimicrobial peptides. Some of these activities are mediated by postbiotic compounds [67]. The efficacies of probiotic actions on immune modulation can be broadened through the dietary supplement of prebiotics. According to Matthias Volkmar Kopp. Apparently, the interaction of enteric bacteria and the intestinal epithelial mucosal immune system plays a crucial part in the development of IBD. However, there are insufficient data to recommend the routine use of prebiotics or probiotics for either the induction or maintenance of the remission of ulcerative colitis or Crohn's disease. Several Reviews concluded about some promising results achieved but still, there is a lack of well-designed randomized controlled clinical trials in this area, and further research is needed [68,69].

Todd R. Klaenhammer (T.R.K.) reported that there are some form of inherent variability found in the healthy subjects that mayundoubtedly results in diverse immunological responses through the treatment group. There are many study based evidence in which probiotic microorganisms is responsible for nourishing to animals and humans, and immunological responses are measured. Hense among those evidence the reports based on we may consider the report which has been developed by van Baarlen, et al. [70,71]. Through which we can evaluate the *in vivo* human mucosal transcriptome responses to differentiate among the species of *Lactobacilli*, which indicates how probiotics control human cellular pathways. Transcriptomes clustered has been found most closely within each individual subject by Van Baarlen, he also found big variation in gene expression between different individuals, rather than between different probiotic strains. In most of the healthy subject the Immunological responses would be anticipated when following the consumption of probiotic, especially those probiotic microorganisms that produce pro-inflammatory or anti-inflammatory responses dominantly, if someone consumed prophylactically over extended periods of time. In most of the cases, there will be questions that must be consider about transferring an immunological state of health. Therefore, healthy individuals that consume anti-inflammatory probiotic cultures regularly, potentially become more susceptible to infectious pathogens. According to Matthias Volkmar Kopp not only the prebiotic or probiotic but it alone producing essential immunomodulatory effects. It is important that the host dependent factors even either equally or more efficiently work on such genetic background of the individual have specificcompositionofgut microbiota, their diet and potentially other lifestyle factors.

Reversal of Incipient Tumour into Normal Tissue by Prebiotic and Probiotic Action

Probiotics exert their anticancer activity mainly by modulation of gut flora, improving Physico-chemical conditions of the gut, enhancing gut barrier utility, and modulating intestinal bacterial metabolism and enzymes, thereby preventing carcinogens, secreting anticancerous metabolites, and reducing inflammation. The advantageous consequences of probiotics include maintaining colon equilibrium, which is responsible for stopping acute loose motion, irritable bowel syndrome, colitis, and constipation, among others [72]. The recent data have highlighted the significance of specific bacterial species in anastomosis leakage that has potential jobs in the comeback of cancer [73]. Several *in vitro* [74,75] animal studies [76-79], as well as clinical trials [80,81], indicated probiotics have anti-cancerous attributes specifically against CRC [82-85].

The suppressive agents such as prebiotics, probiotics, and their metabolites, suchas postbiotics, exhibit reversal mechanisms of transition from incipient tumourtonormal cells/tissue. Accumulation of oncogenic agents at GI mucosa may have the opportunity totransform stem cells. If oncogenic particles get attached to and enter the dormant malignant stem cells and thus transform them, then neoplastic growth formsatumor. Administration of prebiotics such as oligofructose or inulin in the dietsignificantly suppressed the total number of Aberrant Crypt Foci (ACF) per colon, an early paraneoplastic marker of malignant in the process of colon carcinogenesis [86]. Therefore, protecting crypt stem

cells by inhabitantprobiotics or therapeutic intervention of probiotics and prebiotics may inhibit malignant transformation. Metabolites of prebiotics and probiotics (so-called 'post biotic'), such as butyrate, can promote epigenetic remodeling and the expression of pluripotency-associated genes of stem cells derived from human adult or fetal fibroblasts [87].

Butyrate is a cell-permeable small molecule that can provide a simple tool for further investigations of the molecular mechanisms of cellular reprogramming of various human adult somatic cells, including cells from patients that are more refractory to reprogram. Several lines of evidence suggest that cancer stem-like cells exist in various malignant tumors, such as leukemia, breast cancer, and brain tumors. These stem cells express surface markers similarto normal stem cells in each tissue [88-91]. In a recent study, Kato, et al. (2011) [92] isolated side and non-side population cells derived from a rat endometrial cell line expressing human 12Val-KRAS (RK12V) cells and determined the side-population phenotype. They studied the self-renewal capacity, the potential to develop into stromal cells, reduced expression levels of differentiation markers, long-term proliferating capacity in cultures, and enhanced tumorigenicity, indicating that RK12V-SP cells have cancer stem-like cell features. RK12V-SP cells also have capable of exhibiting higher resistance to conventional chemotherapeutic drugs.

In contrast, sodium butyrate showed the reduction of self-renewal capacity and complete suppression of colony formation of RK12V-SP cells in soft agar, demonstrating an inhibitory effect of sodium butyrate on the proliferation of endometrial cancer stem-like cells [93]. Therefore, it may be hypothesized that prebiotic and postbiotic compounds synergistically exert their effects on proliferating crypt stem cells for normal cell cycle regulation. More research is needed to exploresignal mechanisms involved in the 'transition switch' of proliferating normal crypt stem cells into incipient neoplastic cells.

Conclusion

The gut is the most important luminal and portal system to supply almost all essential nutritional requirements vital for life. Good health depends on a healthy enteric system. Prebiotics, probiotics, and their metabolites have been recognized as modulators of GI functions. Alteration in gut microbiota compositions leads to dysbiosis persistence, which is linked with pathogenesis. The transition of dysbiosis into normobiosis can be achieved through the dietary and therapeutic intervention of prebiotics and probiotics. Inappropriate dietaryhabits and chemotherapeutic intervention cause the deregulation of GI function, resulting inthedepletion of enteric barrier functions and hence, the progression of pathogenesis. Persistently colonized oncogenic bacteria elicit inflammatory pathways, which further emerge into tumorigenesis. GI stem cells are more susceptible to getting transformed by oncogenic products of bacterial pathogens.

A balanced combination of prebiotics and food-basedprobiotics might be potential biotherapeutic strategies to protect the GI stem cells. These dietary interventions may also enhance the renewal capacityofthe GI tract through a controlled and coordinated proliferation of stem cells, leading to the homeostasis of the mucosal cells.

Inflammasomes shape the enteric microbiota dysregulation of inflammasomes elicits the process of pathogenesis. Further research is urgently needed to unravel the molecular and signal mechanisms involved in complex interactions of diet-gut-microbiome and inflammasomes. Probiotic-based metabolomic compounds have recently been recognized as potent epigenetic modulators. They can program and reprogram cellular events and associated renewal mechanisms of the enteric system. Such new compounds'potencycan be effective in cell-based renewals of diseased and damaged tissues.

Developing scientific indulgent to investigate the therapeutic implications of postbiotic compounds derived from the interactive action of pre and probiotics isurgently needed to unravel the possibilities of reactivation of epigenetically silenced genes and the renewal potential of stem cells. New models to investigate and validate the interaction of the prebiotic microbiome and the gut will bring a better understanding of establishing a new therapeutic target. Therefore, it is expected that dietary prebiotics and probiotic-based therapeutic molecules will be future medicine to prevent and cure gut-associated disorders and cancer worldwide.

Future Prospect

The importance and utility of prebiotics and probiotics have rapidly been emerging into a wide range of biomedical research to identify and characterize new compounds of prophylactic and therapeutic nature. This emerging area of research will undoubtedly open new prospects for both research scientists and the pharmaceutical industry to work together to develop new biotherapeutic medicine to tackle global health-related problems.

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