The Vital Role of Probiotic and Prebiotic in Enhancing Immunity and Metabolism

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Abstract

Probiotic are the beneficial bacteria, naturally present in gut and improve health. Which can be broadly classified as Lactobacillus, Bifdobacterium and Other bacteria species. Prebiotic are indigestible body component mostly oligosaccharide carbohydrates used by probiotics as feed. Probiotics and prebiotics collectively called as Synbiotics. Probiotic use prebiotics as a specific growth substrate in the synbiotic food products. In this chapter, we focus specifically on probiotic of human and insects. In human, gut microbiota play an important role in digestion, immunity and the overall health, where probiotics contribute in treatment of various health related issues like gastrointestinal disorders, Respiratory Tract Infection, Obesity and cardiometabolic parameters, Mental health, Infectious Burn Wounds, Viral Infections, anemia , COVID-19 and improved the immune response to a vaccine. On the other hand, in insects, probiotic help to regulate their microbiome, improve metabolism, immune regulatory and antibacterial activity effects, it also provides defense against toxins, increase resistance to pathogens, improve the Performance and Yield of mass-reared for feed and food, to control of the parasite-infected vectors.

Keywords: Probiotics, Prebiotics, Synbiotics, Microbiota, Immunity, Metabolism

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Introduction

Probiotics and prebiotics are the key component in retaining a healthy gut and overall health. Probiotic are the live microorganism, referred as "good bacteria" that can provide health benefit when consume in suitable quantity, mainly by improving the balance of intestinal microbiota. Instead, the Prebiotics, are non-digestible fiber that help as food for probiotics or beneficial bacteria, encouraging their growth and activity in the digestive tract. They work synergistically to support digestion, immune system and various other health benefit. Understanding the role of probiotics and prebiotics is important for improving dietary strategies to improve health (Martin & Langella, 2019).

1. Probiotics

Elie Metchnikoff's observed that older Bulgarians' regularly consume fermented dairy products which is high in Lactobacillus, such yogurt, was associated with their health improvement and longer lifespans served as an original idea of traditional probiotics. Metchnikoff noted that the natural gut microbiome might benefit from bacteria. Since then, probiotic have been represented as beneficial bacteria for the host's health. Probiotic definitions have changed significantly over time (Martin & Langella, 2019). According to definition of probiotic by the World Health Organization and Food and Agriculture Organization of the United Nations, probiotics are live, well tested strain of microbes that, when taken as directed, can improve a person's health. (Markowiak & Slizewska, 2018). In addition to help in better digestion and absorption of food residue, probiotics can also improve blood sugar and lipid metabolism, maintain balance of microflora, regulate intestinal health and treat and alleviate lactose intolerance, all of which have a positive effect on health (Oak & Jha, 2019).The four primary ways that probiotics benefit the body are by preventing and inhibiting the growth of potential infections, enhancing the gut's barrier function, immunomodulating the body, and regulating the host's neurotransmitter production. Additionally, total composition, such as the peptidoglycan, and DNA play very significant role in probiotics efficacy (Sanchez et al., 2017).

A. Types of Probiotics

Probiotics have an extensive range of distribution and variety of the species, which can be further classified into three major group shown in Fig. 1.

I. Lactobacillus

Since the Lactobacillus group is the most representative group of probiotics, the majority of research on probiotic species is currently focused on this group. Study of human gut microorganism, which is linked to the human health, Lactobacillus is a crucial probiotic. It can not only produces vital vitamins and amino acid, facilitates the mineral absorption, but it can also improve intestinal micro ecology by preventing growth of the pathogenic microorganisms (Milani et al., 2017).

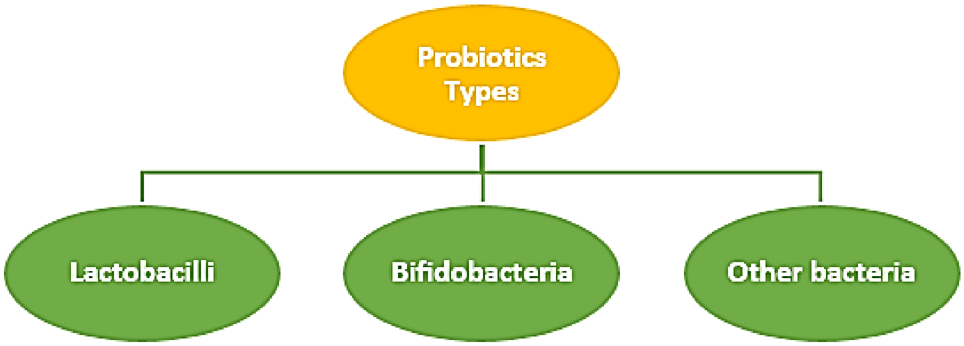

Fig. 1: Classification of Probiotics.

II. Bifdobacterium

Bifidobacterium belong to genus of Gram-positive anaerobic bacteria, bifurcated end, which is also the foundation of its name (Henrick et al., 2018). It is an important class of probiotics and a physiological bacterium found in the human body. The following are the major physiological roles of Bifdobacterium. Similar to other LAB, Bifdobacterium can suppress pro-inflammatory cytokines and limit the pathogenic bacteria growth to preserve balance of normal gut bacterial flora. Bifdobacterium has also been shown in related research to provide both in vivo and in vitro protection against intestinal barrier failure. This protecting effect is linked to the improved intestinal tight junction integrity, inhibition of pro-inflammatory cytokine secretion and vimentin release (Krumbeck et al., 2018). *Bifidobacterium bifurcum* is believed to improve bone health by increasing calcium bioavailability and synthesizing vitamin and amino acid in intestine. *Bifdobacterium bifidum* has antitumor effect (Sadiq et al., 2021).

III. Other Bacterial Species

In addition, the Lactobacillus, Bifidobacterium and Gram positive parthenococci are also commonly used in the food industry. One important characteristic of an Enterococcus strain as a probiotic its capacity to live, adhere and compete to host cell in intestine. Furthermore, Enterococcus accounts for its high resistance to broad range of temperature, pH with remarkable capacity to produce bacteriocin, a natural antibacterial agent that utilized in food industry. Today, probiotic food is produced commercially using *Saccharomyces cerevisiae*, a well-known as selective probiotic and non-pathogenic (Hanchi et al., 2018).

For instance, the probiotic effect of *Saccharomyces boulardii* has been thoroughly investigated. It is frequently used to treat digestive diseases, including the symptoms of diarrhea, particularly when used in combination with antibiotic therapy. Additionally, *Saccharomyces boulardii* has a greater ability to survive in the digestive tract than other probiotics, which helps in preserving balance of the intestinal tract microbiota. Additionally, during pathogenic infection or chronic disorder, it exert immunomodulatory effect that help to fine-tune immune pathway (Szajewska et al., 2020). In addition to yeast and enterococci mentioned above, probiotic category that are more commonly occur is Bacillus specie, Streptococcus species and *E. coli* (Yin et al., 2022). On the basis of recently published work, application and the role of some common probiotic were summarized in the Table 1.

Table 1: Probiotics Functions and Applications.

Strain	Application	Function
Lactobacillus casei	Dairy fermentation	Treatment or prevention of disease that disturb gut microbiota
Lactobacillus acidophilus	Medicine and clinic	Relieve in inflammatory bowel disease by reduce cytokines, modulate immunity, alleviate cancer, relieve diarrhea and lower cholesterol
Lactobacillus rhamnosus	Fermentation of the milk, millet, Medicine and fruit juice	Fight against pathogenic fungi and bacteria in genitourinary tract, in postmenopausal women inhibiting recurrence of urinary tract infection
Lactococcus lactis	Fermentation of cheese	Helps improve fermented product flavor and texture profile, and amino acid metabolic break down to produce volatile flavor substance
Bifidobacteria	Used as starter culture for the fermented food	The exopolysaccharide produced have anticancer, antioxidant, immunological and antibacterial activity
Bacillus coagulans	Medicine and animal husbandry	Regulate intestinal microbiota balance, improve utilization of nutrient, metabolism and improve immunity, and has characteristic of acid resistance, bile resistance and high temperature resistance
Bifidobacterium adolescentis	Medicine and clinic	Reduce inflammation of brain and spleen, and change cecum and colon microbiota
Bacillus subtilis	Aquaculture	Improved immunity, growth, nutrition and disease resistance of aquatic specie

2. Prebiotics

In 1995, term "prebiotic" was firstly used to define an indigestible body components. It is substance that is resistant to the gastric acid, cannot be digested by mammalian enzyme and cannot be absorbed by gastrointestinal system. Prebiotic are fermented by intestinal flora and selectively activate specific bacteria in colon, thus modifying their activity and growth to positively influence the host. Prebiotic are substances that can be fermented selectively and precisely modify the activity and composition of beneficial intestinal microbiota, referred to as "bifidogenic factor". In 2016, under the assumption that they are helpful to health of host, the International Scientific Association for the Probiotics and Prebiotics defined prebiotic as chemicals that host intestinal flora can selectively transform and use. Non-carbohydrate included in new definition of prebiotic and their mode of action is not limited to the food or gastrointestinal system (Gibson et al., 2017).

Types of Prebiotics

According to previous studies, prebiotics are oligosaccharide carbohydrate, mainly galacto-oligosaccharides (GOS), inulin, lactulose, xylooligosaccharides (XOS) and its derived fructose-oligosaccharides (FOS) (Yin et al., 2022). But according to the new research, prebiotic also contain non-carbohydrate that meet prebiotic requirement, like polyphenol extracted from fruit like black raspberries and blueberries. New prebiotic specie, primarily, polyphenols, polysaccharide and polypeptide polymers are continuously being generated as result of continuous refining of manufacturing process for prebiotic. This specie offers a wide range of study opportunities Jiao et al., 2019).

3. Synbiotics

Synbiotics are combination of probiotics and prebiotics shown in Figure 2, used to enhance the health of human or animal (Markowiak & Slizewska, 2017). Probiotic use the prebiotics as a specific growth substrate in synbiotics food products (Sharma & Shukla, 2016). A group of specialist recently updated the concept of synbiotics by International Scientific Association for Probiotic and Prebiotic. According to them, synbiotics are of two types: synergistic and complimentary. A complementary synbiotics consists probiotic and prebiotic that work collectively to provide health advantages without requiring co-dependent functions. A synergistic synbiotics contains Co-administered microorganisms that use the substrate selectively. Future research on the interaction between pre- and probiotics and the development of synbiotics products for health and therapeutic uses will benefit from the suggestions above (Swanson et al., 2020).

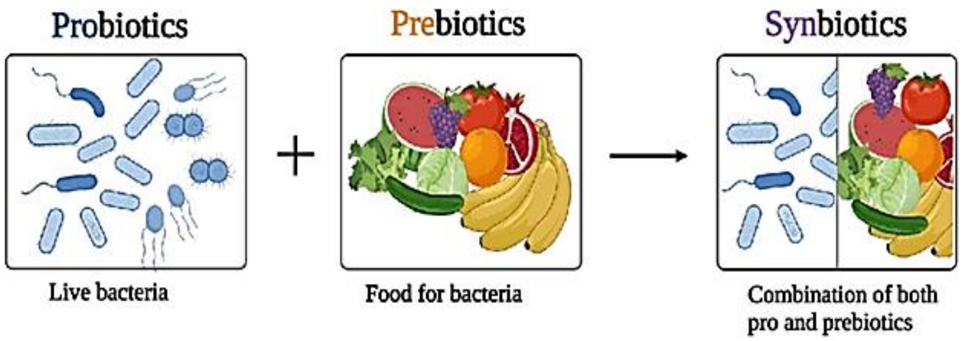

Fig. 2: Combination of Probiotics and Prebiotics Forms Synbiotics.

Role of Probiotics

Probiotics are beneficial microorganism crucial to the health of different organism, play a vital role in sustaining the balance of microbiome and supporting key physiological functions shown in Figure 3. In this chapter, we focus specifically on humans and insects, as insects and humans are two independent but equal areas in the field of analysis of probiotic. In human gut microbiota play a role in health, where probiotics contribute in digestion, immunity and even mental health. On the other hand, in insects, probiotic help to regulate their microbiome, improve nutrient absorption and increase resistance to pathogens. The discovery of probiotics in these two groups elucidates the generality of their health management implications across a variety of species (Swanson et al., 2020).

4. Probiotics in Human Health Management

a. Gastrointestinal Disorders

Probiotic supplements have been shown to have significant positive benefits in diarrhea, especially in treating children's acute diarrhea and preventing traveler's diarrhea. A Cochrane review of 82 research involving both adults and children, however, concluded that it is uncertain if probiotics may reduce the duration of severe diarrhea. The most widely utilized probiotics linked to positive results in diarrheal disorders are *Lactobacillus rhamnosus* and *Saccharomyces boulardii* (Jenkins & Mason, 2022).

b. Respiratory Tract Infection

According to a study of systematic review and Meta-analyses published in the last five years. Probiotic have been shown to significantly reduce duration and incidence of upper respiratory tract infection, including the common cold, in healthy individuals. Two of these analyses showed improvements in the influenza vaccine's effect, while one showed beneficial effects on immunological markers. *Lactobacillus rhamnosus* GG and *Streptococcus thermophilus* have been utilized with good results in the trials included in these analyses (Jenkins & Mason, 2022).

c. Obesity and Cardiometabolic Parameters

Recent studies show that probiotics enhance cardiometabolic parameters and aid in weight loss. Based on four recent systematic evaluations, consuming probiotics and synbiotics leads to weight loss in overweight and obese subject, but the reduction in visceral fat and waist circumference is small. Lactobacillus strains have been utilized extensively in studies with positive results in obesity. In individuals with metabolic syndrome/type 2 diabetes, including pregnant women with gestational diabetes, probiotics can enhance insulin metabolism, glycemic control and inflammatory indicators such C-reactive protein. Additionally, probiotics have been demonstrated to improve cardiovascular disease indicators such as dyslipidemia and hypertension. It is currently challenging to determine the advantages of probiotics in relation to obesity and cardiometabolic parameters because study in these systematic review frequently lack homogeneity. The most effective strains, according to the overall findings of these meta-analyses, are *Lactobacillus acidophilus, Bifidobacterium lactis*, or *Lactobacillus plantarum* (Jenkins & Mason, 2022).

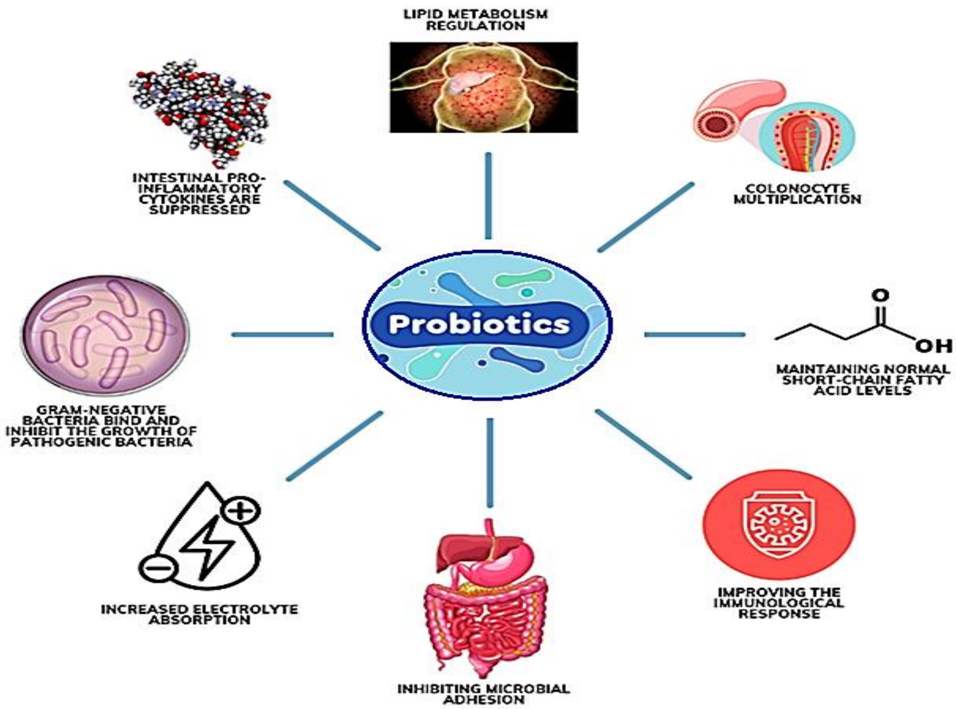

Fig. 3: Action Mechanism of Probiotic Showing the Various Pathways Through Which Probiotics Exert Their Beneficial Effect.

d. Mental Health

There is growing evidence that probiotics can help with mental health issues like anxiety and depression but also some null finding. Parkinson's disease is another exciting study topic related to probiotic supplement and nervous system disorder and multiple sclerosis (Jiang et al., 2021).

5. Probiotic and Treatment of Infectious Burn Wound

Since the skin serves as the body's first defense against microbes, its removal exposes the lesions to pathogen and Gram-positive bacteria (*Staphylococcus aureus*) of normal skin flora, which are primary cause of the infection (Sekhar et al., 2014). Additionally, one of the most common causes of wound infections in recent years has been recognized as the Gram-negative bacterium *Pseudomonas aeruginosa*. Probiotics, a revolutionary treatment that encouraged the growth of helpful microorganisms, were found when doctors and pharmacists explored for alternate remedies to control wounds. Clinical studies have shown the advantages of probiotic in both preventing and treating skin infection. They are known as topical probiotics because they effectively cure wounds by secreting antimicrobial compounds like bacteriocin and hydrogen peroxide, which prevent wound infections and growth of pathogenic microorganism (Barzegari et al., 2020).

6. Probiotics in Viral Infections

The evidence supporting probiotic in relation to the number of important viral illnesses, such as SARS-CoV-2 infection, influenza, human immunodeficiency virus (HIV), viral hepatitis, human papilloma virus (HPV) and immunization, will be examined in this section. Since lactic bacteria, such as Lactobacillus and Bifidobacterium strains, have been marketed as potential immunomodulatory, the majority of clinical trial examining potential therapeutic role of the probiotics related to SARS-CoV-2 have been published to date. A study by Rathi et al. (2021) reported improvement in patients who took probiotic and enzyme supplement. On day 14 of the treatment, 91 out of 100 SARS-CoV-2 patients who took probiotic (*Bacillus clausii, Bacillus coagulans*, and *Bacillus subtilis*) indicated less mental and physical fatigue than 15 out of 100 patients who took a placebo.

Hepatitis B (HBV) and C (HCV) infection are worldwide health issues, especially in the developing nation. Between hosts and virus immune system the pathogenic interaction can result in liver damage, including hepatocellular cancer and cirrhosis. Lee et al. (2013) revealed that cell extract of *B. adolescentis* SPM0212 suppressed HBV in in vitro cell model Hep G2.2.15, which contained integrated HBV DNA and secreted hepatitis B virus surface antigen-AgHBs. Its antiviral mechanism was linked to the Mx GTPase pathway. In IFN-mediated antiviral response one of the four primary effector pathway is Mx GTPase pathway. Remarkably, Inoue et al. (2018) found a significant correlation between the advancement of chronic hepatitis C (CHC) and a particular species, *S. salivarius*.

7. Vaccine and Probiotics

The adaptive immune system is activated by vaccination to identify pathogens prior to infection. This enables quick reaction in the case of additional exposure (Harper et al., 2021). According to published reports, in an animal trial, specific probiotic strains improved immune response to a vaccine and reduced the risk of following infection. In terms of human research, an increasing amount of monitored trials have shown that certain probiotics enhanced the response to vaccinations against cholera, influenza and other children illnesses (Sen, 2019).

8. Probiotics in the Treatment of Anemia

Numerous investigations have demonstrated a strong link between iron deficiency and gut flora. Additionally, studies have demonstrated therapeutic effect of probiotic bacteria on improving iron absorption and the reciprocal association between deficiency of iron and gut microbiota composition (Hadadi et al., 2021). Probiotic bacteria such as *Lactobacillus cremoris, Lactobacillus lactis*, *Candida famata, Bacillus pseudocatenulatum*, *Bacillus adolescentis*, *Candida guilliermondii, Candida glabrata*, *Yarrowia lipolytica*, *S. cerevisiae* and *Pichia glucozyma* are the source of a water-soluble B vitamin (folic acid), that is essential for treating and managing anemia. These microorganisms are used to improve folic acid absorption in the gut. Foods that have been fermented with lactic acid help improve iron absorption and are used to treat anemia. They help in the digestive tracts, pH optimization and activate the phytase enzyme, assisting in the absorption of nutrients. Additionally, to treat megaloblastic anemia, a mixture of probiotic bacteria has been added to diet. These probiotics mitigate the negative effects of antibiotics and encourage intestinal fermentation (Ohtani et al., 2014).

9. Probiotics in COVID-19

The coronavirus disease 2019 (COVID-19) pandemic has sadly affected a great number of people's lives. Even after strict public health precautions like mask requirements, personal hygiene, social distancing and lockdowns were widely implemented, the virus to propagate and increasing infections and deaths globally. Severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) is major cause of this illness, distinguishing it different from other coronaviruses that have been found. As a result, current antiviral therapies have shown only modest efficacy (Singh & Rao, 2021). In this perspective, natural product like probiotics and their derivative are being explored for their potential benefit to pandemic general management, treatment and prevention, extending to post-pandemic period and other infections (Brahma et al., 2022; Banerjee et al., 2023).

10. Exploring The Role of Probiotics in Insect Health

i. Introducing Probiotic in Insect

Studies investigating spectrum of symbiotic interactions, numerous bacteria and yeast species have been shown to have positive effects on certain insects, leading to their use as probiotics. For instance, *Ceratitis capitata* (Wiedemann) (Diptera: Tephrtidae) larval growth was enhanced by probiotic application like an Enterobacter strain and *Klebsiella oxytoca*. This was primarily because the bacteria produced nutrients and provided protection against pathogens by releasing certain antimicrobial compounds. When transgenic *Plutella xylostella* (L.) (Lepidoptera: Plutellidae) was inoculated by *Enterobacter cloacae* (Jordan), the larvae aseptically reared that then had poor survival and low pupal weight showed major increase in the male fitness and pupal weight (Somerville et al., 2019).

Additionally, microbiota are acquired through vertical transmission, coprophagy transplantation and trophallaxis e.g. in bees and termite (Weiss et al., 2019). Different bacterial communities in insects evolve defense mechanisms that enable them to endure in adverse host conditions, such as highly alkaline gut of the lepidopteran specie. This was demonstrated by RNA-sequencing, which revealed that *E. mundtii* has upregulated pathway in gut of *Spodoptera littoralis* (Boisduval) (Lepidoptera: Noctuidae) for surviving with high alkaline stress. (Mazumdar et al., 2020).

ii. Role in Metabolism

Microbes with a primary focus on mutualistic or symbiotic by the breaking down indigestible plant-derived carbohydrate, play crucial role in the metabolism, through microbiota-encoded carbohydrate-degrading enzyme in hindgut and midgut of caterpillar, honey bees, termites, crickets, beetles and other herbivorous insect. These enzymes, are typically absent in insects, include cellulases, hemicellulases and pectinases. The gene encode these enzyme in gut bacteria also be encoded in the genomes of some hosts, including mustard leaf beetle *Phaedon cochleariae*. This indicates horizontal gene transfer. As a result of breakdown of plant cell wall component, short-chain fatty acid are produced, which affect the nutrition of the microbe and the host and support integrity of intestinal barrier. In pea aphid that provide essential amino acid, absent in insect diet (Gandotra et al., 2018).

iii. Defense Against Toxins

Insects that engage in herbivory also come into contact with a range of harmful plant defense compounds, which their gut symbionts help detoxify, allowing them to succeed as pest. This kind of detoxifying symbiosis provides resistance to both pesticides and plant allelochemicals (Xia et al., 2018). Gut symbionts play a vital role in enhancing resistance of the host to pathogens such as Yellow meal worm *T. molitor*, by enzymatically degrading toxic phytochemical compounds. They also increase host resistance to the pathogen such as inhibiting infection in Tsetse fly *Glossina morsitans* Westwood colonized with the *Kosakonia cowanii* Zambiae. Gut symbiont can protect host by space and nutrient competition with pathogen, edge them out in mammal and assumed in case insect host. The microbiota also improves function of epithelial barrier to prevent the systemic infection by pathogen, as seen in mosquitoes (Savio et al., 2022).

iv. Antibacterial Activity and Immune Regulatory Effect

The Lactobacillus genus has been found to have antibacterial and immune regulatory effects in the microbiota of honeybee *Apis mellifera* and silkworm *Bombyx mori* when infected with *Nosema spp*., and *Pseudomonas aeruginosa* respectively (Nishida et al., 2017). *Galleria mellonella* studies have demonstrated antimicrobial properties of *Lactobacillus reuteri* and *Lactobacillus rhamnosus* against *Pneumonia aeruginosa*, *Candida albicans*, *Escherichia coli* and *Staphylococcus aureus*. Probiotic strains and small-molecule RNA interference techniques have been used against *Nosema ceranae* on honey bee to reduce the bee spore capacity and viability, improving its performance and survival (Burnham, 2019). Lactobacillus and Bifidobacteria affect pathogen, but sucrose and *L. rhamnosus* in honeybees reduce *N. ceranae's* impact, resulting in reduced phenol oxidase production and higher mortality rates. (Marusc akova et al., 2020).

Studies on *Galleria mellonella* and *Drosophila melanogaster*, infected with *C. albicans* and *diaporthe FY*, have shown positive effect of *Lactobacillus spp.* on host fungal infections (Rossoni et al., 2018). Enterococcus have been studied for reducing bacterial diseases, while activation of generic or insect-specific immune responses by probiotics for viral diseases is still unclear. Wolbachia and Spiroplasma, while not considered probiotics, have shown positive results in increasing resistance to viral diseases in *G. mellonella* and *T. molitor* (Jung et al., 2014). Probiotic usage in disease control is extremely promising, but it is currently hindered by a lack of understanding regarding the dynamics between insects and pathogens, as well as how stressors affect both the susceptibility of insects to diseases and their production performance. This necessitates the overall management of mass rearing systems to remain holistic, accounting for genetic, environmental, dietary and microbial aspects (Savio et al., 2022).

11. Probiotic Applications in the Mass Production of Insects for Sustainable Food and Feed

The application of probiotics on mass-reared insect for food and feed to improve insect fitness or performance against the natural pathogen in mass rearing environment of the insect shown in Table 2 (Savio et al., 2022).

Table 2: Probiotics Tested on Insects Mass-Reared for Food and Feed.

Insect Species	Probiotics	Effects on Performance and Yield
Silkworm (*Bombyx mori*)	*Bifidobacterium bifidum*	Immunomodulating agent (increase in invertase, protease and amylase activity); with fewer cocoon increased production of raw silk
	Lactobacillus acidophilus	Increase in silk yield by Stimulated growth factor
	L. casei	Improved the weight of larva, cocooning, pupation and economic character e.g. cocoon weight and size, in larvae infected by microsporidium *Nosema bombycis*
	L. plantarum	increase the body weight, cocoon and pupation
	Staphylococcus gallinarum strain *SWGB 7* & *S. arlettae* strain SWGB 16	Increased larval growth and cocoon character (filament weight and length, finer denier)
	Saccharomyces cerevisiae	Immunomodulating agent; with fewer cocoon increased raw silk production; increased the protein content
	Trichoderma harzianumas	Enhanced digestion which increase resistance and growth to mortality by *Beauveria bassiana* and *Metarhizium anisopliae*
Greater wax moth (*Galleriamellonella*)	*Clostridium butyricum Miyairi* 588	Increased survival rate and Induced immune response against enteropathogenic *Listeria monocytogenes* or *Escherichia coli, Salmonella enterica* serovar Typhimurium.
	Lactobacillus acidophilus ATCC 4356	Increased the survival from the infection of the *Candida albicans*
	L. kunkeei	Affecting their stability and through biofilm formation to reduce infection of *Pseudomonas aeruginosa*
	L. rhamnosus ATCC 7469	Encouraged protection in larvae infected with the *Escherichia coli* or *Staphylococcus aureus*.
	L. rhamnosus ATCC 9595	Affecting their stability and through biofilm formation to reduce *Pseudomonas aeruginosa* infection
	L. rhamnosus GG	Increased survival rates and induced immune response against *Salmonella enterica* serovar Typhimurium, enteropathogenic *Listeria monocytogenes* or *Escherichia coli*.
Yellow mealworm (*Tenebrio molitor*)	*Bacillus subtilis*	Improved growth and nutrition
	B. toyonensis	Improved dry matter weight and growth of produced feed
	Enterococcus faecalis	Enhanced gain in larval weight, size and shorter pupation rate, also improved crude protein
	*Pediococcus pentosaceus (*Isolated from the gut of Tenebrio larvae)	Reduces larval mortality and accelerate developmental rate. The strain has antimicrobial activity against many pathogenic bacteria including several *Bacillus thuringiensis*, Pseudomonas and Serratia spp.
Black soldier fly (*Hermetia illucens*)	*Arthrobacter AK19*	Enhanced larvae growth rate
	Bacillus subtilis S15 S16 S19; B. subtilis natto D1	Increased larval weight and development
	Bifidobacterium breve	Larvae had appeared weak/slow/discolored and lower weight
	Rhodococcusrhodochrous	Increased larva feed conversion rate, protein content, Energy production and storage.
House fly (*Musca domestica*)	*Enterobacter hormaechei*	Increased body weight and length, weight of pupa and shortened the growth cycle, which is a significant beneficial to increase production and cost saving in large-scale feeding facilities.

12. Control of the Parasite-Infected Vectors

Numerous bacterial genera that protect against Plasmodium infestation have been identified in the midget of mosquitoes (Ramirez et al., 2014) including *Serratia marcescens*, *E. coli*, *Pseudomonas stutzeri*, *Comamonas spp*., *Enterobacter spp*., *Chromobacterium, Bacillus pumilis* etc. An isolate of *Serratia marcescens* product inhibited multiple stages of parasite (Bahia et al., 2014). In another study, by strengthening the vector immune response to the parasite, in vector gut presence of *Enterobacter cloacae* led to a notable decrease in number and density of oocysts. Despite not being a naturally occurring component of the mosquito gut microbiome, Wolbachia is another symbiotic bacterium that has demonstrated great promise in controlling parasite-infected vector by lowering the sporozoite infection in vector and potentially influencing its egg-laying by producing reactive oxygen species (ROS) (Shaw et al., 2016).

Many bacteria studied, have detrimental effects on the parasite developments in vector through numerous mechanism discussed by Dennison et al. (2014b). Their low abundance in environment and the mosquito stomach is the primary barrier to using these bacteria to decrease vector populations. In their natural home, these bacteria have a fragile relationship with their host and natural mosquito strains can readily outcompete the vector that carries them. Nonetheless, some research has successfully established a maternally transmitted, stable Wolbachia-infected Anopheles insect line that exhibits no decline in fitness or reproduction. Field tests for dengue therapies using Wolbachia infestation have shown promise in the management of other mosquito-borne illnesses, such as malaria (Bian et al., 2013).

Conclusion

In conclusion, probiotics play a role in maintaining and improving health in both humans and insects. In humans, probiotics contribute to digestion, immunity, and the management of various health conditions, including gastrointestinal disorders, respiratory infections, obesity, cardiometabolic health, mental health issues, infectious wounds, viral infections, anemia, and enhancing vaccine responses. Similarly, in insects, probiotics help regulate the microbiome, improve metabolism and immunity, and provide antibacterial effects, as well as defense against toxins and pathogens. Additionally, probiotics enhance the performance and yield of mass-reared insects for feed and food and aid in controlling parasite-infected vectors. The synergistic relationship between probiotics and prebiotics as synbiotics highlights their significance in promoting health and sustainability across diverse biological systems.

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