

Honey Bees/Honey as Probiotic and Prebiotic Products

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Honey bees come from the family of Apidae and the genus *Apis*. *A. dorsata*, *A. mellifera*, *A. cerana*, *A. laboriosa*, *A. florea*, *A. andreniformis*, *A. koschevnikovi*, and *A. nigrocincta* are eight known species that can be found around the world. Honey bees are significant pollinators for cultivating crops for food production, ensuring the continuity of almost all life in this world. The honey bee's gut contains many microorganisms as its normal microbiota. Most are probiotics, made up of lactic acid bacteria (LAB) and Bifidobacterium, which are widely distributed in their digestive tract system. Probiotics were first described in 2013 by the International Scientific Association for Probiotics and Prebiotics (ISAPP) as "live microorganisms that, when administered in adequate amounts, confer a health benefit on the host". The scientific definition has been extensively applied around the globe. Probiotics enhance intestinal health and increase immune reaction by producing biological antimicrobial substances that can inhibit pathogens which caused digestive system imbalances in humans and animals.

probiotic

prebiotic

honey bee

honey

1. Introduction

Many products produced by honey bees are useful to humans, including honey, ^{[1][2]} which is the most important and widely consumed bee product worldwide. Honey, a "natural sweet substance produced by *Apis mellifera* L. bees from the nectar of plants, secretions of living parts of plants, or excretions of plant-sucking insects on the living parts of plants, which the bees collect, transform by combining with specific substances of their own, deposit, dehydrate, store and leave in the honeycomb to ripen and mature" ^[3], comes in two varieties namely: blossom/nectar honey and honeydew honey. Blossom honey is made from flowering plant nectar, whereas honeydew honey is manufactured from honeydew collected from various parts of a plant or other sap-producing plants and insects ^[4]. Honey can be divided into two categories: unifloral (monofloral) and polyfloral (multifloral). Unifloral honey is made primarily from one type of plant nectar and is identified through pollen analysis, which reveals dominant pollen from a single plant species. Polyfloral honey does not have dominant pollen from one plant species but has a mixture of pollen from several plants ^[5]. Due to its refined, one-of-a-kind, and distinct flavor, unifloral honey typically commands a higher market price than polyfloral honey. The premium quality of unifloral honey mostly depends on the exclusive geographical area or the special plant species, for example, the Manuka honey from New Zealand ^[6]. Honey may contain probiotics that have been transmitted from the guts of honey bees during the process of making honey and may remain alive for a certain period ^[7]. Thus, both honey bees and honey may provide potential probiotics for future use. The health benefits of honey concerning its probiotic bacteria are that the probiotics will help to revitalize and strengthen the immune system of the host against harmful environmental factors and pathogens, aid in digestion, detoxify harmful substances and provide essential nutrients ^[8].

Honey is mostly made up of sugars or carbohydrates such as fructose (32–44%), glucose (23–38%), and some other complex sugars (5–15%) including sucrose, maltose, lactose, raffinose, trehalose, erlose, gentiobiose, turanose, panose, melezitose, and kojibiose amongst others ^[9]. Besides carbohydrates, the quality and health advantages of honey are also ascribed to the various components it possesses, such as protein, organic acids, amino acids, vitamins, minerals, enzymes, and polyphenols ^[10]. Different varieties of honey may vary in their content due to the different sources derived, such as geographical area,

botanical origin, and bee species [9]. Blossom or nectar honey can be distinguished from honeydew honey by analyzing its carbohydrate concentration. Blossom honey contains higher concentrations of monosaccharides but is lower in trisaccharides (mainly melezitose, erlose, raffinose, and maltotriose) and other oligosaccharides compared to honeydew honey [11]. The honey's prebiotic properties are known to come from its indestructible carbohydrates that cannot be fermented by digestive enzymes in humans and are not taken up in the upper intestinal tract system. They are capable of improving and enhancing health in general and intestinal health in particular by stimulating the development and promoting metabolic activity of the typical residents of the colon [12]. Honey's prebiotic qualities can help probiotic microorganisms to flourish by supplying adequate nutrients. An increased number of probiotics may help to alleviate the total surface area for nutrient absorption, thus improving the health of the digestive system and enhancing resistance to pathogen infections [13]. These findings have sparked some ideas for conducting studies for further research on the natural microbiota of the bees' gut with probiotic properties as a disease defense mechanism to be used as prophylaxis to treat not only bees themselves but also other animals and humans [8].

2. Probiotic Properties of Honey Bees and Honey

Table 1 highlights the studies that have been performed in several countries on honey bees' guts and honey as the origin of potential probiotics. The majority of honey bee probiotics have been identified from *A. mellifera* spp., with a few from the *A. cerana* spp., and *A. dorsata* spp. Probiotics isolated from the honey bee gut were composed of diverse microorganisms including Bifidobacterium and lactic acid bacteria (LAB), as well as Fructophilic lactic acid bacteria (FLAB) which is a subgroup of LAB, yeasts, and other types of bacteria such as the *Bacillus* spp.

Table 1. Potential probiotics in the bees' gut and honey.

Probiotic	Source	Origin/Country	Reference
<i>Bifidobacterium</i> spp.	<i>Apis cerana japonica</i> gut	Tsukuba, Japan	[14]
<i>Bifidobacterium</i> spp., <i>Lactobacillus</i> spp., <i>Bacillus</i> spp.	<i>Apis cerana indica</i> gut	Samut-Songkhram, and Chumphon, Thailand	[15]
<i>Lactobacillus</i> spp.	<i>Apis cerana indica</i> gut	Karnataka, India	[16]
<i>Lactobacillus plantarum</i> , <i>Lactobacillus pentosus</i> , <i>Lactobacillus fermentum</i>	<i>Apis dorsata</i> gut	Terengganu, Malaysia	[17]
<i>Lactobacillus kunkeei</i> strains	Yigilca honey bee gut	Duzce, Turkey	[18]
<i>Lactobacillus plantarum</i> , <i>Lactobacillus paraplantarum</i> , <i>Lactobacillus plantarum</i> strains	<i>Apis mellifera</i> gut	Menoua, Cameroon	[19] [20]
<i>Lactobacillus plantarum</i> strains	<i>Apis cerana indica</i> gut	Kerala, India	[21]
Lactic Acid Bacteria (LAB) genera: <i>Enterococcus</i> , <i>Lactobacillus</i> , <i>Micrococcus</i> , <i>Lactococcus</i> , <i>Streptococcus</i> ,	<i>Apis cerana indica</i> Fabricius, <i>Apis mellifera</i> Linnaeus, <i>Apis florea</i> Fabricius, & <i>Apis dorsata</i> Fabricius guts and honey	Tamil Nadu, India	[22]

Probiotic	Source	Origin/Country	Reference
<i>Pediococcus</i> , <i>Leconostoc</i>			
<i>Enterococcus faecalis</i> strains, <i>Lactobacillus brevis</i> , <i>Lactobacillus casei</i>	<i>Apis mellifera</i> gut	Cairo, Egypt	[23]
<i>Fructobacillus fructosus</i> strains, <i>Lactobacillus kunkeei</i> strains	<i>Apis mellifera mellifera</i> , <i>Apis mellifera ligustica</i> and hybridized bee guts, larvae and honey	Aland Island, Finland	[24]
<i>Lactobacillus kunkeei</i> strains (sixty- six strains), <i>Lactobacillus casei</i> (one strain), <i>Lactobacillus</i> spp. (five unidentified strains), <i>Fructobacillus fructosus</i> strains (eight strains), <i>Enterococcus</i> (five strains), <i>Bifidobacterium asteroides</i>	<i>Apis mellifera</i> gut	The Caucasus Mountains, and Kolkheti Valley, Georgia	[25]
<i>Lactobacillus kunkeei</i> strains, <i>Lactobacillus fructosus</i> strains	<i>Apis mellifera</i> gut	Lublin, Poland	[26]
<i>Lactobacillus kunkeei</i> strains, <i>Fructobacillus fructosus</i> strains	<i>Apis mellifera</i> Linnaeus gut	Pulawy, Poland	[27]
<i>Fructobacillus fructosus</i> , <i>Proteus mirabilis</i> , <i>Bacillus subtilis</i> , <i>Bacillus licheniformis</i> , <i>Lactobacillus kunkeei</i> , <i>Enterobacter kobei</i> , <i>Morganella morganii</i>	<i>Apis mellifera jemenitica</i> gut	Riyadh, Saudi Arabia	[28]
<i>Apilactobacillus kunkeei</i> strains	<i>Apis mellifera</i> Linnaeus gut	N/A	[29]
<i>Bacillus</i> spp.	<i>Apis cerana japonica</i> gut	Tsukuba, Japan	[30]
<i>Bacillus subtilis</i> strains	Honey bee gut and honey	N/A	[31]
<i>Bacillus licheniformis</i> , <i>Paenibacillus polymyxa</i> (<i>Bacillus polymyxa</i>), <i>Wickerhamomyces anomalus</i> , <i>Lachancea thermotolerans</i> , <i>Zygosaccharomyces mellis</i> ,	<i>Apis mellifera carnica</i> gut <i>Apis mellifera ligustica</i> gut	Giza, Egypt	[32]
<i>Lactobacillus kunkeei</i> strains, <i>Lactobacillus</i> spp.	Honey (<i>Apis dorsata</i>)	Kedah, Malaysia	[33]
<i>Leuconostoc mesenteroides</i> strains	Honey (<i>Apis mellifera</i>)	Algeria	[34]
Lactic Acid Bacteria (Species and subspecies not mentioned)	Honey (<i>Apis mellifera</i>)	Indonesia	[35]

Probiotic	Source	Origin/Country	Reference
<i>Bacillus</i> spp.	Commercial honey (Libya, Saudi Arabia and Egypt)	N/A	[36]
<i>Bacillus subtilis</i> , <i>Brevibacillus brevis</i> , <i>Bacillus megaterium</i> strains, <i>Lactobacillus acidophilus</i>	Local honey	Iran	[37]
<i>Bacillus subtilis</i> strains <i>Bacillus endophyticus</i>	Mountain honey Persimmon honey (commercial)	Nigeria Egypt	[38]
<i>Bacillus</i> spp.	Honey	China	[39]
<i>Bacillus subtilis</i> , <i>Bacillus mycoides</i> , <i>Bacillus thuringiensis</i> , <i>Bacillus amyloliquefaciens</i> , <i>Bacillus velezensis</i>	Raw honey (Polyfloral)	Romania	[40]
<i>Gluconobacter oxydans</i>	Honey (<i>Apis cerana indica</i>)	Tamil Nadu, India	[41]
<i>Saccharomyces cerevisiae</i> strains, <i>Meyerozyma guilliermondii</i>	Raw honey (<i>Apis dorsata fabricius</i>)	Ratchaburi, Thailand	[42]

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Table 2. Probiotic potential of honey.

Probiotic	Sources of Prebiotic	Country	Key Findings	Reference
<i>Lactobacillus acidophilus</i> strains	Honey	India	<ul style="list-style-type: none">- Honey enhanced the coaggregation of <i>E. coli</i> with <i>L. acidophilus</i> NCDC 291 more than with <i>L. acidophilus</i> NCDC 13.- Both strains showed a higher capability of autoaggregation and hydrophobicity, and reduced autolytic activity with inulin compared to honey.	[44]
<i>Lactobacillus acidophilus</i> , <i>Bifidobacterium bifidum</i>	Sesame honey (<i>Sesamum indicum</i>)	India	<ul style="list-style-type: none">- Sesame honey (5%) exhibited selective and significant growth-supporting properties of the probiotics.	[45]
<i>Lactobacillus acidophilus</i> , <i>Lactobacillus rhamnosus</i>	Chestnut honey	Turkey	<ul style="list-style-type: none">- Chestnut honey has positively impacted probiotic bacteria by increasing growth and modulating probiotic properties such as auto-aggregation and surface hydrophobia.	[46]
<i>Lactobacillus plantarum</i> strain	Wild honey (Polyfloral)	Cameroon	<ul style="list-style-type: none">- <i>L. plantarum</i> 29 V can survive for 28 days at 4 °C and 25 °C due to their	[47]

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Probiotic	Sources of Prebiotic	Country	Key Findings	Reference
			ability to resist lower pH and the presence of oligosaccharides (fructo- and gluco-oligosaccharides) in honey recognized as prebiotics.	G.; Di aluation
			- Hypercholesterolemic rats treated with honey containing <i>L. plantarum</i> 29 V showed an increase in HDL-cholesterol level and lowers total cholesterol, LDL-cholesterol, triglycerides and atherosclerosis index in serum.	, against 129.
				ir, N.M. isolated
<i>Lactobacillus acidophilus</i> , <i>Lactobacillus gasseri</i> , <i>Lactocaseibacillus casei</i> , <i>Lactocaseibacillus rhamnosus</i> , <i>Lactiplantibacillus plantarum</i>	Fir, strawberry tree, ivy, tree of heaven, sulla, cardoon, rhododendron honey (Commercial, organic, monofloral honey)	Italy	- Fir, ivy, and sulla honey (1% and 2%) stimulate the growth of all the probiotics tested with various actions compared to more specific cardoon honey.	[48] ota of s and
<i>Bifidobacterium longum</i> strains, <i>Bifidobacterium breve</i> , <i>Bifidobacterium bifidum</i>	Agmark grade honey	India	- Honey showed a prebiotic effect on all isolates, especially on <i>B. longum</i> at 3% and 5% honey.	[49] t. Foods ois enes and
<i>Bifidobacterium bifidum</i> and Lactobacilli	Clover honey (Unprocessed and sterilised)	Egypt	- Increased <i>B. bifidum</i> colony counts were observed in all honey-supplied group (Group A-5 g, B-10 g, and C-15 g honey), with group B, showing a significant rise in comparison with the control.	[50] w bacillus
Bifidobacteria	Buckwheat honey	China	- Buckwheat honey assists in propagating native Bifidobacteria and prohibits the growth of the pathogenic bacterium in the gut system.	[51] among I. Agric. M.T.; st biota.
N/A	Manuka honey (MGO™)	Ireland	- Honey-containing oligosaccharides inhibited <i>P. aeruginosa</i> (52%), <i>E. coli</i> O157:H7 (40%) and <i>S. aureus</i> (30%) in the cancer cells.	[52] M.G.; Appl.

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Both types of honey, either monofloral or polyfloral, can serve as good prebiotic sources in foods. Honey is combined with dairy products derived from the fresh milk of cows [56][57][58][59][60] and [61][62], camels [57], and buffalo [63] to produce yogurt. Some researchers also utilized skimmed milk powder to produce yogurt [64][65][66]. As for the Food Chain products, kefir, soy milk [68][69], and hydrolyzed soybean extract [67] were chosen to replace the animal's milk. The most common starter culture probiotics used to produce yogurt are the *S. thermophilus* and *L. delbrueckii* ssp. *bulgaricus*. The findings of numerous investigations revealed that the number of probiotics in honey-containing foods is significantly enhanced. Monofloral honey (chestnut, acacia, lime honey) and polyfloral honey (eucalyptus, greenbrier) in yogurt were found to be good prebiotic sources for cultivating *Bifidobacteria* strains of diverse subspecies [64][68]. Saudi Arabian raw honey [56], black locust honey [57], Kerala natural honey [59], and a commercial prebiotic, inactivity by some probiotics to produce biofermented milk for culture [62].

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