

## **HONEY AS A PREBIOTIC, PROBIOTIC, AND SYNPBiotic FOOD: A NATURAL ALLIANCE FOR HUMAN HEALTH**

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**Abstract:** From ancient times, honey has been used for treating gastrointestinal disorders. Several varieties of honey have been shown to have antibacterial and anti-inflammatory properties. Moreover, honey contains carbohydrates as non-digestible oligosaccharides, which suggests that some types of honey exhibit prebiotic potential. Therefore, there is growing awareness in modulating the gut microbiota to achieve a more beneficial balance, thereby promoting health through diet. Recent studies show that specific types of honey can reduce the presence of the most frequent enteropathogens in the gut, such as *Salmonella* spp., *Escherichia coli*, *Campylobacter* spp., *Shigella* spp., and *Clostridium difficile*, while promoting the growth of beneficial species (*Lactobacillus* spp. and *Bifidobacteria* spp.). This review provides a brief overview of recent studies on the synergistic benefits of probiotics and honey, with a focus on enhancing the immune system, improving gut microbiome health, and promoting overall well-being.

**Keywords:** honey, prebiotic effect, probiotics, gut microbiota, synergism

### **1. Introduction**

The gut microbiota is essential for human health and well-being because it improves digestion, synthesises vitamins, enhances the immune system, and protects against enteropathogens (*Campylobacter* spp., *Clostridium difficile*, *Escherichia coli*, *Salmonella* spp., *Shigella* spp.) (Schell *et al.*, 2022; Svenungsson *et al.*, 2000). Dysbiosis, or a dysregulated interaction between the microbiome and the host (Hrncir, 2022), can lead to the development and progression of various disorders, including inflammatory bowel disease (IBD) and colorectal cancer, as well as allergies, obesity, anxiety, and depression (DeGruttola *et al.*, 2016). Diet has a substantial impact on the composition and function of the gut microbiome; thus, there is a significant interest in modulating it through dietary approaches to achieve a more favourable balance (Schell *et al.*, 2022).

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Prebiotics, earliest defined in 1995, which are primarily non-digested carbohydrates (Ali *et al.*, 2025), have been used to produce beneficial changes in gastrointestinal tract (GIT) (Bhatia *et al.*, 2025), such as increased numbers of beneficial microorganisms, mostly bifidobacteria and lactobacilli, and increased production of metabolites such as short-chain fatty acids (SCFA) by gut microorganisms (Schell *et al.*, 2022). Since 2004, prebiotics have been classified as non-viable dietary compounds that enhance the host's health by modulating the microbiota (Bhatia *et al.*, 2025). Prebiotics such as glucans and fructans have been thoroughly studied, and evidence for the prebiotic effects of other compounds is growing, such as oligomers of mannose, glucose, xylose, pectin, starches, human milk and polyphenols (Sanders *et al.*, 2019).

The definition established in 2002 by experts from the FAO (Food and Agriculture Organisation of the United Nations) and WHO (World Health Organisation) suggests that probiotics are living strains of highly selected microorganisms that, when administered in appropriate amounts, offer a health benefit to the host (Markowiak & Śliżewska, 2017). They mainly promote intestinal barrier integrity, immune function, and gut microbiota modulation (Hemarajata & Versalovic, 2013). Species of *Lactobacillus* spp., *Bifidobacterium* spp. and *Saccharomyces* spp. have a long tradition of safe and efficient probiotic use, but *Roseburia* spp., *Akkermansia* spp., *Propionibacterium* spp., and *Faecalibacterium* spp. offer promise for the future (Sanders *et al.*, 2019).

Honey bees (*Apis mellifera*) produce honey, which is a natural product from flower or plant nectar (Schell *et al.*, 2022). It is widely used as a natural sweetener and as a functional food that is high in bioactive compounds, including enzymes, polyphenols (Bogdanov *et al.*, 2008), vitamins, amino acids, and minerals (Ahmed *et al.*, 2018). As a result of its biological properties, including antibacterial, antimutagenic, anti-inflammatory, antitumoral (Ahmed *et al.*, 2018), wound-healing, and antioxidant effects (Anwar *et al.*, 2025), it is a highly valuable natural product that promotes health.

Despite extensive studies on probiotics and honey separately as functional foods, there is growing interest in combining both of them. Furthermore, honey might act as a natural prebiotic substrate, stimulating the development and activity of beneficial microorganisms, improving probiotic stability and viability in food matrices and the gastrointestinal tract (Fratianni *et al.*, 2023). It is crucial to explore the potential synergy between probiotics and honey to develop new

functional foods with enhanced bioactive features. The goal of this review is to summarise the most recent studies on the synergistic advantages of probiotics and honey, with a focus on strengthening immunity, improving gut health, and increasing overall well-being.

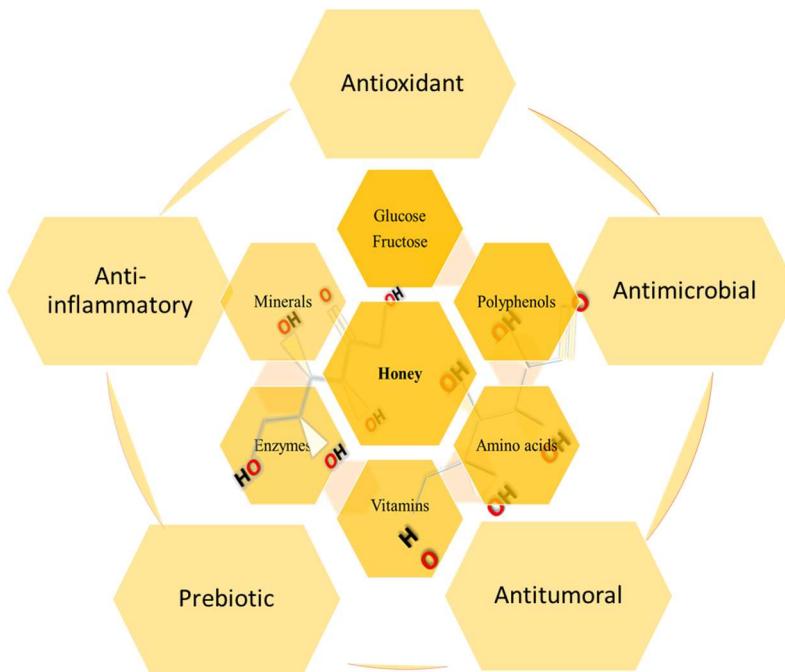
## **2. Composition and bioactivity of honey**

Honey is primarily composed of carbohydrates, mainly fructose (38%), glucose (31%) (Ahmed *et al.*, 2018) (up to 70% from total carbohydrates) (Schell *et al.*, 2022), and 22 complex sugars (5-15%) such as sucrose, maltose, lactose, raffinose, trehalose, erlose, gentiobiose, turanose, panose, melezitose, and kojibiose (Mustar & Ibrahim, 2022). Other disaccharides found in honey include maltose, sucrose, maltulose, turanose, isomaltose, laminaribiose, nigerose, kojibiose, gentiobiose, and  $\beta$ -trehalose (Siddiqui *et al.*, 2017). The trisaccharides such as maltotriose, erlose, melezitose, centose 3-a5, isomaltosylglucose, 1-kestose, isomaltotriose, panose, isopanose, and theanderose were also found in honey (Ahmed *et al.*, 2018). It also contains a wide range of bioactive compounds, including organic acids, amino acids, vitamins, minerals, enzymes (glucose oxidase, invertase, diastase, catalase, and acid phosphatase), flavonoids, phenolic acids, and proteins (Ahmed *et al.*, 2018) (Figure 1). Honey contains 26 amino acids, with proline comprising 50-85% of the total. Vitamins in small amounts include riboflavin, niacin, folic acid, pantothenic acid, vitamin B6, and ascorbic acid. Different trace elements include calcium, iron, zinc, potassium, phosphorus, magnesium, selenium, chromium, and manganese. Another important group of compounds in honey is organic acids, which include lactic, acetic, butyric, citric, succinic, malic, and gluconic acids, as well as a variety of other aromatic acids (Ahmed *et al.*, 2018; Siddiqui *et al.*, 2017).

Globally, there are over 300 different types of honey, with unique phytochemical patterns and sensory attributes (Bogdanov *et al.*, 2008). Monofloral honeys, such as those from manuka, acacia, clover, sage, and buckwheat, are primarily made from a single floral source, whereas multifloral honeys are made from a variety of nectars. The honey content in phytochemicals is modulated by diverse factors, as floral source, origin, and processing techniques (Ahmed *et al.*, 2018). Honey has strong antibacterial properties due to its high osmotic pressure, low pH, hydrogen peroxide levels, and bioactive compounds such as phenolic acids and flavonoids (kaempferol, quercetin, chrysin, pinobanksin, luteolin, apigenin, pinocembrin, genistein,

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hesperetin, *p*-coumaric acid, naringenin, gallic acid, ferulic acid, ellagic acid, syringic acid, vanillic acid, and caffeic acid). Honey also comprises antioxidant compounds that enhance the immune system and reduce oxidative stress. The presence of non-digestible oligosaccharides in certain types of honey suggests its potential prebiotic effect (Fratianni *et al.*, 2023).



**Fig. 1.** Bioactivity properties of honey

Honey exhibits a wide antimicrobial activity influenced by both phytochemical and physicochemical factors (Rakabizadeh & Tadayoni, 2022). Its low pH (typically between 3.2 and 4.5) inhibits pathogens' growth (*Streptococcus pyogenes*, *Streptococcus typhi*, *Staphylococcus aureus*, coagulase-negative *Streptococcus* and *Escherichia coli*), whereas the high sugar content and low water activity induce osmotic stress for pathogens (Mandal & Mandal, 2011). Additionally, the enzymatic production of hydrogen peroxide by glucose oxidase considerably influences its antibacterial activity, whereas compounds such as methylglyoxal (MGO) contribute to non-peroxide activity, especially in manuka honey (Kwakman & Zaai, 2012). The total polyphenolic content of honey, especially flavonoids (such as quercetin, kaempferol, and chrysin) and phenolic acids (including caffeic acid and gallic acid), demonstrates its antioxidant capacity (Cianciosi *et al.*, 2018). By scavenging free radicals, chelating transition metals, and modulating

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cellular redox signalling pathways, these compounds prevent oxidative stress and inflammation, according to [Ahmed et al. \(2018\)](#).

Honey has antifungal properties. *Microsporum gypseum*, *Aspergillus niger*, *Aspergillus flavus*, *Penicillium chrysogenum*, *Candida albicans*, *Saccharomyces* spp., and *Malassezia* spp. have all been found to be susceptible to its antifungal properties ([Dahiya et al., 2024](#)). Methylglyoxal, glucose oxidase, and honey's high sugar content are thought to be responsible for its antifungal properties.

Several elements of honey are thought to have antiviral properties against the rubella, herpes simplex, and varicella-zoster viruses. For instance, copper inactivates the virus, while ascorbic acid, flavonoids, and honey's production of H<sub>2</sub>O<sub>2</sub> all contribute to the inhibition of viral multiplication by interfering with viral transcription and translation ([Ahmed et al., 2018](#)).

Honey's oligosaccharides and other non-digestible carbohydrates confer prebiotic activity, in addition to the antibacterial and antioxidant activity of honey. These compounds particularly enhance the colonisation and activity of beneficial bacteria such as *Lactobacillus* spp. and *Bifidobacterium* spp. ([Sanz et al., 2005](#); [Schell et al., 2022](#)), as being resilient to digestion in the upper part of the gastrointestinal tract. Honey's oligosaccharides have been reported to support gut microbial balance, inhibit pathogens, and increase the production of short-chain fatty acids (SCFAs) ([Asghar et al., 2024](#); [Fratianni et al., 2023](#)). Honey is a unique functional food that offers significant benefits in symbiotic formulations with probiotics due to its dual behaviour as a prebiotic substrate and an antibacterial compound.

### **3. Probiotics: mechanisms and health benefits**

Probiotics are well-defined as “live microorganisms that, when administered in adequate amounts, confer health benefits on the host” (FAO/WHO, 2002; [Hill et al., 2014](#)). The genera *Lactobacillus* and *Bifidobacterium* comprise the most widely utilised probiotic strains, while other microorganisms, consisting of *Saccharomyces boulardii*, *Streptococcus thermophilus*, and several *Bacillus* species, have also shown valuable properties ([Gibson et al., 2017](#); [Markowiak & Śliżewska, 2017](#)). These strains are generally recognised as safe (GRAS), having a long tradition in fermented foods and dietary supplements production.

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According to [Rodríguez \*et al.\* \(2023\)](#), probiotics primarily influence the gut microbiota and host immune system responses. They produce antimicrobial compounds such as bacteriocins and organic acids, struggle with harmful bacteria for adhesion sites and nutrients, and enhance the integrity of the intestinal barrier ([Hemarajata & Versalovic, 2013](#)). Consuming probiotics has been linked to better gut microbial balance, increased mucosal immunity, and a lower risk of gastrointestinal infections and diarrhea associated with antibiotics ([Plaza-Diaz \*et al.\*, 2019](#); [Sanders \*et al.\*, 2019](#)). Additionally, some probiotic strains have been demonstrated to alleviate the symptoms of lactose intolerance, inflammatory bowel disease (IBD), and irritable bowel syndrome (IBS). They also contribute to systemic effects, including improved metabolic health, less severe allergies, and modulation of the gut-brain axis.

Although probiotics exhibit well-documented health benefits, their application is limited by challenges related to viability and stability throughout processing, storage, and passage through the gastrointestinal tract. Oxygen exposure, temperature, moisture, pH sensitivity, and interactions with other food ingredients (synthetic flavouring and colouring agents) all affect probiotic survival ([Terpou \*et al.\*, 2019](#)). Following ingestion, probiotics must be resilient to gastric acid, to resist the harmful effects of bile salts in the small intestine, and to reach the colon in higher concentration ([Abdelsamad \*et al.\*, 2022](#)). It was recognised that the minimum level of viable probiotics is at least 106 CFU/g of viable cells throughout the product shelf-life ([Terpou \*et al.\*, 2019](#)). Strategies such as microencapsulation, such as spray-drying and freeze-drying, protective carrier matrices ([Jan \*et al.\*, 2025](#)) (e.g., dairy, honey, prebiotics), and novel delivery matrices are being developed to increase probiotic stability and efficacy ([Ali \*et al.\*, 2025](#); [Jan \*et al.\*, 2025](#)).

The gut microbiota of honeybees is the main source of probiotic bacteria found in honey. However, environmental sources can also contribute, according to recent research ([Baltić \*et al.\*, 2025](#)). Strains of the probiotics *Lactobacillus* spp., *Bifidobacterium* spp., *Saccharomyces* spp., *Streptococcus* spp., *Bacillus* spp., ([Maftei \*et al.\*, 2024](#)), *Pediococcus* spp., and *Enterococcus* spp. ([Tajabadi \*et al.\*, 2013](#)), and *Apilactobacillus* spp. ([Ferdouse \*et al.\*, 2023](#)) are several bacteria isolated from honey (Table 1). These beneficial microbes provide several health advantages, including enhancing the function of the intestinal barrier and the balance of the gut microbiota, inhibiting pathogenic bacteria ([Coppola \*et al.\*, 2025](#)), and modulating the mucosal and systemic immunity ([Ranneh \*et al.\*, 2021](#)). Probiotics are also associated with a reduced severity of irritable

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bowel syndrome (IBS) symptoms as well as a decrease in the frequency and severity of gastrointestinal infections (Sanders *et al.*, 2019), and a gut-brain axis support system for mental health (Mohan *et al.*, 2017). However, a significant formulation challenge remains the viability of probiotics throughout storage and transit through the gastrointestinal tract.

**Table 1.** Probiotics in honey

<b>Honey type</b>	<b>Origin</b>	<b>Probiotic strain</b>	<b>Reference</b>
Polyfloral honey	Romania	<i>Bacillus mycoides</i> , <i>Bacillus thuringiensis</i> , <i>Bacillus amyloliquefaciens</i> , <i>Bacillus subtilis</i> , <i>Bacillus velezensis</i>	Pașca <i>et al.</i> , 2021
Honey	Iran	<i>Bacillus subtilis</i> , <i>Brevibacillus brevis</i> , <i>Bacillus megaterium</i> strains, <i>Lactobacillus acidophilus</i>	Mustar & Ibrahim, 2022
Mustard and multifloral honey	India	<i>Lactiplantibacillus plantarum</i>	Roy & Mandal, 2024
Honey	Iran	<i>Lactobacillus plantarum</i> , <i>Lactobacillus rhamnosus</i> , <i>Lactobacillus acidophilus</i>	Goli Mehdi Abadi <i>et al.</i> , 2023
Honey	Algeria	<i>Leuconostoc mesenteroides</i>	Mustar & Ibrahim, 2022
Honey	Malaysia	<i>Lactobacillus plantarum</i> , <i>Lactobacillus pentosus</i> and <i>Lactobacillus fermentum</i>	Tajabadi <i>et al.</i> , 2013
Honey	Algeria	<i>Fructobacillus fructosus</i> , <i>Apilactobacillus kunkeei</i> , <i>Lactobacillus kimbladii</i> , <i>Lactobacillus kullabergensis</i>	Meradj <i>et al.</i> , 2023
Honey	Bangladeshi	<i>Pediococcus pentosaceus</i> , <i>Apilactobacillus Kunkeei</i>	Ferdouse <i>et al.</i> , 2023
Stingless bee honey	Thailand	<i>Heyndrickxia coagulans</i>	Prakit <i>et al.</i> , 2025

Recently, the capacity of honeybees' stomach strains to adhere to intestinal cells was demonstrated by survival at pH 2.0, as well as their good autoaggregation and hydrophobicity. Ehb3, Ehb5, and Ehb8 were the isolates with the best adhesion-related properties, while Ehb3 and Ehb5 had the highest antioxidant activity (both ABTS and DPPH) (Shehata *et al.*, 2024).

Strong antibacterial activity was shown by *Pediococcus pentosaceus* and *Apilactobacillus kunkeei* strains that were isolated from Bangladeshi honey. These strains inhibited the growth of

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pathogens such *Bacillus cereus*, *Staphylococcus aureus*, *Vibrio cholerae*, *Salmonella typhi*, and *Candida albicans*. Additionally, tests showed that they have a high tolerance to phenol, bile salts, and low pH, suggesting that they could thrive in the human gastrointestinal tract. In addition, these bacteria showed high adherence to hydrophobic surfaces, autoaggregation, and coaggregation, indicating their capacity to colonize the intestinal tract. Their potential to promote health is further highlighted by their high antioxidant activity, which is determined by their capacity to scavenge DPPH free radicals. Importantly, safety studies verified that there was no hemolytic activity and resistance to several classes of antibiotics ([Plăder et al., 2025](#)).

Currently, from mustard honey and multifloral honey in India, two strains of *Lactiplantibacillus plantarum* (strains LMEMh and LMEMh1) were reported as probiotics. The strains inhibit the growth of Gram-positive (*Staphylococcus aureus*, *Bacillus cereus*, *Enterococcus faecalis*, *Streptococcus pneumoniae*) and Gram-negative (*Pseudomonas aeruginosa*, *Escherichia coli*, *Klebsiella pneumoniae*, *Acinetobacter baumannii*) bacterial pathogens. Also, the isolates demonstrated resistance to high concentrations of bile salt, sodium chloride, and low pH. Finally, naturally occurring honey can be a valuable source of probiotics. The probiotic strains that are obtained can be used as natural antibacterial agents, as an alternative to antibiotics.

#### **4. Honey as a natural prebiotic**

Recent studies show that honey contains non-digestible carbohydrates, including oligosaccharides, which have prebiotic effects by promoting the growth of beneficial gut microorganisms. *In vitro* studies have revealed that honey oligosaccharides support the growth of probiotic *Bifidobacterium* and *Lactobacillus* species, such as *B. longum*, *B. adolescentis*, *B. breve*, *B. bifidum*, and *B. infantis*, as well as *L. acidophilus*, *L. plantarum*, *L. reuteri*, and *L. rhamnosus* ([Fratianni et al., 2023](#); [Sanz et al., 2005](#)). When oligosaccharide prebiotics, such as fructooligosaccharide (FOS), galactooligosaccharide (GOS), or inulin, are used as controls, the growth-promoting impact of honey on bifidobacteria and lactobacilli is often similar ([Schell et al., 2022](#)). These results are further confirmed by animal studies, which show that adding honey to the diet enhances *Lactobacillus* and *Bifidobacterium* colonisation in the gut microbiota while decreasing potentially harmful bacteria ([Schell et al., 2022](#)) and reducing constipation and ulcerative colitis symptoms. Additionally, human trials suggest that honey intake may improve the

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gut microbiome composition, although further clinical data is needed ([Plaza-Diaz \*et al.\*, 2019](#)) (Table 2).

Previous studies have shown that oligosaccharides, short-chain carbohydrates that are not fully digested in the upper gastrointestinal tract, are responsible for honey's prebiotic properties. In fact, they reach the colon, which may provide prebiotic benefits. Although honey mainly consists of simple sugars that are rapidly absorbed in the small intestine, small amounts of di-, tri-, and oligosaccharides are also present. Due to these low-molecular-weight polysaccharides being resistant to human enzymes, they can enter the lower gut and support the honey's prebiotic effect ([Dimitriu \*et al.\*, 2023](#)). Well-known prebiotics include xylooligosaccharides, lactulose, pyrodextrins, fructose-oligosaccharides (FOS), and inulin ([Mustar & Ibrahim, 2022](#)). The most common oligosaccharide types found in honey are panose, kestose, maltotriose, raffinose, and isomaltose ([Thakur & Rana, 2024](#)).

Source-specific oligosaccharides can be found in honey. For instance, native New Zealand honeys exhibited high levels of isomaltose and melezitose, whereas raffinose was found in Italian honey. Additionally, the prebiotic potential of honey can be influenced by varying concentrations of common oligosaccharides ([Schell \*et al.\*, 2022](#)). FOS (390 mg/g) was the prebiotic with the highest content, followed by GOS (310 mg/g) and inulin (69 mg/g), in Indonesian honey ([Fuandila \*et al.\*, 2020](#)).

The growth of faecal bacteria was positively impacted by oligosaccharides derived from honeydew, particularly by increasing the populations of *Lactobacillus* spp. and beneficial *Bifidobacterium* spp. and decreasing the numbers of pathogenic *Bacteroides* spp. and *Clostridium* spp., with prebiotic values between 3.38 and 4.24 ([Sanz \*et al.\*, 2005](#)).

**Table 2.** Prebiotic effects of various types of honeys

<b>Honey type and source</b>	<b>Key findings</b>	<b>Reference</b>
<i>in vitro</i> studies		
Honey, Spain	increase in beneficial lactobacilli and bifidobacteria, reduction in enteric bacteria and <i>Bacteroides</i> / <i>in vitro</i> fermentation system	<a href="#">Sanz <i>et al.</i>, 2005</a>

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<b>Honey type and source</b>	<b>Key findings</b>	<b>Reference</b>
Honey, India	increase <i>Bifidobacterium</i> isolates	<a href="#">Schell et al., 2022</a>
Honey, India	maintaining <i>L. helveticus</i> , <i>Streptococcus thermophilus</i> , 3 weeks/ yogurt with 5% honey	<a href="#">Mohan et al., 2017</a>
Chestnut honey, Turkey	increasing growth and modulating the auto-aggregation and surface hydrophobia, on <i>L. acidophilus</i> , <i>L. rhamnosus</i>	<a href="#">Mustar &amp; Ibrahim, 2022</a>
Fir, ivy, and sulla honey, Italy	stimulated the growth of <i>L. acidophilus</i> , 1-2% honey	<a href="#">Fratianni et al., 2021</a>
Manuka Honey, Ireland	reduced the adhesion of <i>Escherichia coli</i> O157:H7, <i>Staphylococcus aureus</i> , and <i>Pseudomonas aeruginosa</i> to HT-29 cells	<a href="#">Lane et al., 2019</a>
Honeysuckle flowers, Romania	positive impact on the growth of <i>Limosilactobacillus reuteri</i> DSM 20016	<a href="#">Dimitriu et al., 2023</a>
Basil honey, Italia	influenced the growth and the hydrophobicity of <i>L. casei</i> Shirota and <i>L. gasseri</i>	<a href="#">Nazzaro et al., 2024</a>
<i>in vivo</i> and human studies		
Cotton, Egypt	increase in <i>Bifidobacterium</i> and <i>Lactobacillus</i> / in Swiss male albino mice	<a href="#">Schell et al., 2022</a>
Honey, Indonesia	enhance gut microbiota composition, stimulate the growth, and inhibit pathogen growth in Nile tilapia ( <i>Oreochromis niloticus</i> )/ 0.25%, 0.5% and 1% doses (g/kg diet)	<a href="#">Aryati et al., 2021</a>
Honey, Indonesia	increase of aquaculture probiotics ( <i>Microbacterium</i> spp., <i>Lactobacillus</i> spp. and <i>Neptunomonas</i> spp.)/ in Pacific white shrimp	<a href="#">Hasyimi et al., 2020</a>
Honey, Indonesia	improvement of the growth performance and immune response/ Pacific white shrimp	<a href="#">Fuandila et al., 2020</a>

<b>Honey type and source</b>	<b>Key findings</b>	<b>Reference</b>
Manuka, New Zealand	( <i>Litopenaeus vannamei</i> ) infected with <i>Vibrio parahaemolyticus</i> no alterations in the populations of gut microbiota (positive or negative), no antimicrobial effects on the gut microbiota/ pilot human trials where subjects took 20 g of honey daily	<a href="#">Schell et al., 2022</a>
Manuka honey, USA	increased abundance of <i>Akkermansia</i> and <i>Faecalibacterium/</i> in individuals with overweight and obesity, daily consumption of one tablespoon of Manuka honey, 4-week trial	<a href="#">Eaton, 2025</a>

Honey has also been shown to have a prebiotic effect on shrimp, promoting the growth of known aquaculture probiotics such as *Microbacterium* spp., *Lactobacillus* spp., and *Neptumonas* spp. ([Hasyimi et al., 2020](#)). Additionally, compared to the control group or the shrimp that received a probiotic or synbiotic, the shrimp that received the honey prebiotic showed a higher intestinal microbial diversity. Another study examining the prebiotic impact of honey on Pacific white shrimp infected with *Vibrio parahaemolyticus* revealed that the shrimp fed honey (0.75%) during the infection phase had a higher survival rate and a lower pathogen concentration than the control group, which received no treatment ([Fuandila et al., 2020](#)).

## **5. Honey-probiotic formulations**

Honey and probiotics have synergistic effects aside from their primary prebiotic activity. The bioactive compounds discovered in honey, such as organic acids and polyphenols, both inhibit pathogens and create favourable conditions for probiotics' survival and activity ([Ali et al., 2025](#)). When compared to probiotics alone, studies on symbiotic formulations - such as honey-enriched fermented dairy products - show greater microbial diversity, higher production of short-chain fatty acids (SCFA), and improved gut barrier function ([Anwar et al., 2025](#); [Pinto Neto et al., 2025](#)).

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These complementary effects suggest that honey and probiotics could function together naturally modulating the gut microbiota for health benefits.

Probiotics' efficiency is largely determined by their capacity to colonise the gastrointestinal tract. However, many strains struggle to survive in the extreme conditions of bile salts and stomach acidity. By providing protective carbohydrates and lowering oxidative stress during gastrointestinal transit, honey has been shown to enhance probiotic resilience (Asghar *et al.*, 2024). Honey consumption improves the adherence of probiotic strains such as *Lactobacillus plantarum* and *Lactobacillus rhamnosus* to intestinal epithelial cells, which can improve colonisation and survival in the gut (Fratianni *et al.*, 2023). Besides, compared to probiotics alone, clinical studies indicate that honey-probiotic formulations may result in longer-lasting modulation of gut microbiota, highlighting honey's potential as a natural promoter of probiotic colonization.

Yoghurt, kefir, beverages, pharmaceutical formulations, and dietary supplements are several combinations of honey and probiotics that have been explored (Coppola *et al.*, 2025; Dahiya *et al.*, 2024) (Table 3). Honey helps to improve the stability and viability of probiotic strains during storage, in addition to enhancing the taste of these symbiotic formulations. Probiotics and honey are currently integrated as stable formulations using microencapsulation techniques, which enhance their shelf life and functional properties (Ali *et al.*, 2025). Optimisation of the concentration, processing conditions, and interactions between probiotic strains and honey components is still a challenging assignment.

**Table 3.** Summary of studies on honey-probiotic synergy

<b>Honey type</b>	<b>Probiotic strain</b>	<b>Key findings</b>	<b>Reference</b>
Date honey	<i>Lactobacillus acidophilus</i>	dairy dessert/ sweetener to substitute for sugars	Nikpour & Hamed Mosavian, 2025
Manuka honey	<i>Lactobacillus reuteri</i> DPC16	synbiotic yogurt	Mohan <i>et al.</i> , 2020
Acacia honey and chestnut honey	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i> BB-12 and <i>B. longum</i> BB-46	inhibitory effect against the <i>Listeria monocytogenes</i> /fermented soy milk	Pinto Neto <i>et al.</i> , 2025
Marjoram honey	<i>Lactobacillus casei</i> EMCC761	goat yogurt	Elenany, 2018

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	<i>Streptococcus thermophilus,</i> <i>Lactobacillus delbueckii</i> <i>bulgaricus,</i> <i>Lactobacillus rhamnosus,</i> <i>Lactobacillus acidophilus,</i> <i>Lactobacillus plantarum,</i> <i>Bifidobacterium animals</i> ssp. <i>lactis</i>	probiotic yoghurt <i>ssp.</i>	<b>Coskun &amp; Karabulut Dirican, 2019</b>
Pine honey			
Honey wine (Tej)	<i>Lecticaseibacillus paracasei,</i> <i>Lentilactobacillus hilgardii,</i> <i>Lentilactobacillus parabuchneri</i>	traditionally fermented Ethiopian honey wine (Tej)	<b>Getachew <i>et al.</i>, 2025</b>
Honey	<i>Lactobacillus plantarum,</i> <i>Pediococcus pentosaceus,</i> <i>Lactobacillus pentosus,</i> <i>Lactobacillus plantarum</i> <i>Lactobacillus sakei,</i> <i>Lactobacillus paraplantarum</i>	Fermented milk	<b>Shehata <i>et al.</i>, 2024</b>
Honey	<i>Bifidobacterium animalis</i> subsp. <i>lactis</i>	Yogurt/supports probiotic enrichment but does not reduce intestinal transit time in healthy adults	<b>Mysonhimer <i>et al.</i>, 2024</b>
Forest honey	<i>Lactobacillus acidophilus,</i> <i>Lactobacillus bulgaricus,</i> <i>Lactobacillus casei,</i> <i>Lactobacillus rhamnosus</i>	probiotic milk as an antibacterial against <i>Escherichia coli</i> and <i>Staphylococcus aureus</i>	<b>Hermawati <i>et al.</i>, 2024</b>
Sunflower honey	<i>Lactobacillus curvatus</i>	Dry-fermented <i>sk1-8,</i> sausages	<b>Petrović <i>et al.</i>, 2025</b>

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*Latilactobacillus sakei*

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In a recent study, [Mysonhimer et al. \(2024\)](#) reported that a formulation of 21 g clover honey added to 170 g of yogurt with *Bifidobacterium animalis* subsp. *lactis* promotes the growth of probiotics but does not shorten the intestinal transit time in healthy individuals ([Mysonhimer et al., 2024](#)).

Manuka honey, (5% w/v) AMF15 was more effective in maintaining the survival of *Lactobacillus reuteri* DPC16 in yogurt. After three weeks of cold storage, the probiotic counts in AMF15 manuka honey yogurt (7 log CFU/mL) were considerably ( $p < 0.05$ ) greater than those in the other honey yogurts (Manuka Blend and UMF18) ([Mohan et al., 2020](#)).

The texture, viscosity, and microbiological quality of goat yogurt containing *L. casei* EMCC761 were all improved by the addition of marjoram honey (5, 10, 15 and 20%). After 14 days of storage, all yogurt formulations showed counts of *L. casei* above 6.0 log CFU/g. However, the presence of bee honey raised the counts of *L. casei* and yogurt starter bacteria by 1 log CFU/g. Overall, the study demonstrated the successful integration of marjoram bee honey and probiotic *L. casei* as components of a novel goat dairy product with acceptable nutritional, sensory, and microbiological quality ([Elenany, 2018](#)).

Owing to the combined health benefits of probiotics and honey, their use in functional foods has grown in popularity. Because they offer a nutrient-rich matrix that promotes probiotic survival, dairy-based products, including yoghurts, fermented milks, and kefir, are frequently utilised as carriers ([Anwar et al., 2025; Asghar et al., 2024](#)). In addition to acting as a natural sweetener, honey improves the prebiotic environment, which encourages the growth of probiotics throughout fermentation and storage. Honey-enriched drinks, jams, and cereal bars are examples of non-dairy applications that have shown enhanced bacterial survival, consumer acceptability, and sensory attributes ([Pinto Neto et al., 2025; Schell et al., 2022](#)).

Preserving viability during processing and storage is a major challenge for probiotic food products. Protein-based coatings, such as chitosan and alginate, as well as other microencapsulation methods, can protect the probiotic strains from environmental stresses, including oxygen, moisture, pH changes, and temperature variations ([Ali et al., 2025](#)). By adding

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antioxidant and antimicrobial compounds, and carbohydrates that prevent spoiling and preserve functional qualities, honey further improves stability in these formulations. Research suggests that honey-probiotic microcapsules have a long shelf life while maintaining high levels of live probiotics, guaranteeing their therapeutic effectiveness (Anwar *et al.*, 2025).

Probiotic and honey formulations have certain drawbacks despite their advantages. High pH, water activity, and sugar concentrations can affect the viability of probiotics (Roy & Mandal, 2024), while the cell survival can be affected by thermal treatment during food processing. To improve the taste and probiotic survival rate, the concentration of honey must be balanced. The interactions between the bioactive components of honey and probiotic strains can be influenced by the type of honey and probiotic species utilised, which presents another challenge to standardisation (Fratianni *et al.*, 2023). Particular attention is required for probiotic strains, honey types, processing settings, and packaging conditions for high-quality and functional benefits.

## **6. Therapeutic Applications**

Probiotics and honey formulations are employed in the management of several health conditions. For instance, gastrointestinal infections, including *Helicobacter pylori*, *Escherichia coli*, and *Clostridium difficile*, may be effectively combatted by their combined antimicrobial activities. Preclinical and clinical investigations demonstrate advantages in the treatment of upper respiratory tract infections, inflammatory bowel disease, and diarrhea. Additionally, probiotics and honey have been linked to immune system modulation, inflammation reduction, and facilitating the healing process following infections and metabolic diseases.

The honey and probiotics formulation showed antimicrobial effects against a wide range of pathogens. Honey's high sugar content, low pH, hydrogen peroxide production (Dahiya *et al.*, 2024), and non-peroxide bioactive compounds (e.g., methylglyoxal in Manuka honey) are known to inhibit the growth of pathogens (Bogdanov *et al.*, 2008). Combining probiotics, which generate organic acids and bacteriocins through a competitive process, can result in a synergistic antimicrobial effect. Research has shown that honey-probiotic formulations can be used as supplemental treatments for digestive tract diseases by inhibiting *Helicobacter pylori*, *Escherichia coli*, *Salmonella* spp., and *Staphylococcus aureus* both *in vitro* and in animal trials (Fratianni *et al.*, 2023).

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Because it reduces inflammation and restores the balance of gut microbiota, the honey-probiotic formulation has shown potential in the treatment of gastrointestinal tract syndromes. While probiotics restore the gut microbiota composition, improve barrier integrity, and minimise pathogens colonisation, honey's prebiotic oligosaccharides enhance probiotic colonisation and activity (Sanz *et al.*, 2005; Schell *et al.*, 2022). Potential benefits were identified by clinical and experimental research for gastrointestinal infections, antibiotic-associated diarrhoea, and irritable bowel syndrome (IBS). Furthermore, after receiving antibiotic therapy, honey-probiotic formulations may help the gut microbiota recover, leading to better digestive health and fewer infections (Anwar *et al.*, 2025; Asghar *et al.*, 2024).

Honey-probiotic formulas have anti-inflammatory and immunomodulatory properties, in addition to gut-related advantages. According to Ahmed *et al.* (2018) and Hemarajata & Versalovic (2013), probiotics affect both non-specific and specific immune responses, strengthening anti-inflammatory signalling pathways, while honey polyphenols lower oxidative stress and regulate the generation of pro-inflammatory cytokines. Integrating these benefits may enhance systemic health, reduce chronic inflammation, and strengthen mucosal immunity. Latest research suggests potential uses in immune system support, metabolic disorders, and allergy control, but more clinical studies are required to fully demonstrate the therapeutic efficacy (Pinto Neto *et al.*, 2025).

## **7. Safety, Regulation, and Future Directions**

Probiotics and honey are frequently used in diets since they are generally recognised as safe (GRAS) for human consumption (FAO/WHO, 2002; Bogdanov *et al.*, 2008). The majority of the population, including children and healthy adults, can tolerate honey-probiotic combinations. However, because probiotics may occasionally cause infections or translocation in vulnerable hosts, caution is recommended for immunocompromised individuals, infants under one year of age (due to the risk of infant botulism from honey), and patients with severe intestinal disorders (Hill *et al.*, 2014; Markowiak & Śliżewska, 2017). In general, safety in functional foods and dietary supplements can be maintained by careful screening of probiotic strains and honey types, along with dosage regulations.

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Regulations concerning probiotics and functional foods vary by geographical area. In many countries, probiotics in food are classified as nutraceuticals or dietary supplements, and any claims of health benefits need to be supported by scientific data (Sanders *et al.*, 2019). As a food product, honey needs to conform to strict guidelines, including those related to content, labelling, and purity, according to Codex Alimentarius (2001). When honey and probiotics are combined, additional regulations related to viable cell count, shelf life, and therapeutic effect are needed. To appropriately promote these products, producers must follow the local regulations concerning labelling, safety testing, and stability studies.

Despite the optimistic statistics, there are still some restrictions. There is a lack of comprehensive clinical information about the efficacy of the honey-probiotic formulation in humans, particularly with regard to optimal dosage, strain-specific effects, and long-term results. To fully comprehend how probiotics and honey phytochemicals interact for modulating the gut microbiota and immune system, molecular studies are required. The use of honey-probiotic formulas for non-gastrointestinal health applications, such as metabolic, dermatological, and neurological disorders, as well as targeted symbiotic formulations and customised nutrition, is one of the emerging topics in this field (Schell *et al.*, 2022). Resolving these gaps could contribute to the advancement of functional foods and safety, standardised, and efficient nutraceuticals.

However, ensuring safety and effectiveness depends on the honey's quality, purity, and source, as well as the selection and concentration of probiotic strains. Each country has its own regulatory framework, and these formulations need more standardised criteria. Future research should be focused on honey and probiotics interactions, improving delivery methods, and performing well-designed clinical trials in order to demonstrate their synergistic benefits.

The toxicological effects of honey must be evaluated based on the source of the nectar and/or plant. Honey poisoning can be caused by grayanotoxin from rhododendron plants, which are currently found in North America, China, Tibet, Turkey, Nepal, Myanmar, Japan, New Guinea, the Philippines, and Indonesia. Grayanotoxin poisoning symptoms include fatigue, light-headedness, increased sweating, hypersalivation, nausea, vomiting, and paraesthesia. Dust, bees, and plant pathogens can contaminate honey during its production, collection, and processing. Honey's antibacterial activity ensures that most pathogens cannot survive or reproduce, although spore-forming, such as those that cause botulism, can survive. Honey-induced food allergies are

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sometimes closely associated with pollen allergies since pollen is present during collection ([Ahmed et al., 2018](#)).

## **8. Conclusion**

Probiotics and honey each have many health benefits, but when they combined act as a powerful, natural way to enhance human health. The ability of probiotics to influence immunity and restore gut microbiota can be complemented by honey's prebiotic and antibacterial properties to develop innovative functional foods and therapeutic solutions. Additional research and development are required to achieve the full potential of this natural relationship. Probiotics and honey have the potential to be valuable functional foods, both separately and in combination, according to emerging data. Probiotics such as *Lactobacillus* and *Bifidobacterium* modulate the gut microbiota, strengthen immunity, and prevent diseases, while honey's natural composition - including oligosaccharides, polyphenols, and bioactive compounds - provides antioxidant, antibacterial, and prebiotic benefits. The synergistic effects between probiotics and honey include healing infections and gastrointestinal issues, improving gut colonisation, enhancing probiotic survival, and modulating gut microbiota.

The application of honey-probiotic formulations ranges from novel symbiotic products to dairy products and beverages, providing a feasible pathway for functional foods and nutraceuticals. Although generally safe, it is crucial to consider strain selection, dose, type of honey and the guidelines. Gaps in knowledge still exist despite this progress, especially in the fields of long-term efficacy, molecular awareness, and extensive clinical trials. Overall, probiotics and honey formulation represent a versatile approach for promoting healthy gut function and preventing gastrointestinal diseases.

## **References**

1. Ahmed, S., Sulaiman, S. A., Baig, A. A., Ibrahim, M., Liaqat, S., Fatima, S., Jabeen, S., Shamim, N., & Othman, N. H. (2018). Honey as a Potential Natural Antioxidant Medicine: An Insight into Its Molecular Mechanisms of Action. *Oxidative Medicine and Cellular Longevity*, 2018(1), 8367846. <https://doi.org/10.1155/2018/8367846>.
2. Ali, S., Hamayun, M., Siraj, M., Khan, S. A., Kim, H.-Y., & Lee, B. (2025). Recent advances in prebiotics: Classification, mechanisms, and health applications. *Future Foods*, 12, 100680. <https://doi.org/10.1016/j.fufo.2025.100680>.

## REVIEW ARTICLE

3. Anwar, A., Faiz, M. A., & Hou, J. (2025). Effect of Honey Concentration on the Quality and Antioxidant Properties of Probiotic Yogurt Beverages from Different Milk Sources. *Applied Sciences*, 15(4), 2210. <https://doi.org/10.3390/app15042210>.
4. Aryati, Y., Widanarni, W., Wahjuningrum, D., Rusmana, I., & Lusiastuti, A. M. (2021). The effect of dietary honey prebiotic on microbiota diversity in the digestive tract of Nile tilapia (*Oreochromis niloticus*) and its growth performance. *Aquaculture Research*, 52(3), 1215–1226. <https://doi.org/10.1111/are.14980/>.
5. Asghar, A., Ahmed, A., Saeed, F., Afzaal, M., Ijaz, M., Maan, A. A., Khan, M. K. I., Ijaz, A., Usman, I., Liaqat, A., Hussain, S., & Ndagire, C. (2024). The effect of honey supplementation on the survival and stability of free and encapsulated probiotics. *CyTA - Journal of Food*. <https://www.tandfonline.com/doi/abs/10.1080/19476337.2024.2377302>.
6. Baltić, T., Đorđević, V., Ćirić, J., Velebit, B., Borović, B., Simunović, S., & Branković Lazić, I. (2025). Probiotic and Prebiotic Properties of Honey: A Review. *Meat Technology*, 66(3), 397–401. <https://doi.org/10.18485/meattech.2025.66.3.68>.
7. Bhatia, A., Sharma, D., Mehta, J., Kumarasamy, V., Begum, M. Y., Siddiqua, A., Sekar, M., Subramaniyan, V., Wong, L. S., & Rani, N. N. I. M. (2025). Probiotics and Synbiotics: Applications, Benefits, and Mechanisms for the Improvement of Human and Ecological Health. *Journal of Multidisciplinary Healthcare*, 18, 1493–1510. <https://doi.org/10.2147/JMDH.S501056>.
8. Bogdanov, S., Jurendic, T., Sieber, R., & Gallmann, P. (2008). Honey for Nutrition and Health: A Review. *Journal of the American College of Nutrition*, 27(6), 677–689. <https://doi.org/10.1080/07315724.2008.10719745>.
9. Cianciosi, D., Forbes-Hernández, T. Y., Afrin, S., Gasparini, M., Reboreda-Rodriguez, P., Manna, P. P., Zhang, J., Bravo Lamas, L., Martínez Flórez, S., Agudo Toyos, P., Quiles, J. L., Giampieri, F., & Battino, M. (2018). Phenolic Compounds in Honey and Their Associated Health Benefits: A Review. *Molecules*, 23(9), 2322. <https://doi.org/10.3390/molecules23092322>.
10. Coppola, F., Abdalrazeq, M., Fratianni, F., Ombra, M. N., Testa, B., Zengin, G., Ayala Zavala, J. F., & Nazzaro, F. (2025). Rosaceae Honey: Antimicrobial Activity and Prebiotic Properties. *Antibiotics*, 14(3), 298. <https://doi.org/10.3390/antibiotics14030298>.
11. Coskun, F., & Karabulut Dirican, L. (2019). Effects of pine honey on the physicochemical, microbiological and sensory properties of probiotic yoghurt. *Food Science and Technology*, 39(suppl 2), 616–625. <https://doi.org/10.1590/fst.24818>.
12. Dahiya, D., Mackin, C., & Nigam, P. S. (2024). Studies on bioactivities of Manuka and regional varieties of honey for their potential use as natural antibiotic agents for infection control related to

**REVIEW ARTICLE**

wound healing and in pharmaceutical formulations. *AIMS Microbiology*, 10(2), 288–310. <https://doi.org/10.3934/microbiol.2024015>.

13. DeGruttola, A. K., Low, D., Mizoguchi, A., & Mizoguchi, E. (2016). Current Understanding of Dysbiosis in Disease in Human and Animal Models: *Inflammatory Bowel Diseases*, 22(5), 1137–1150. <https://doi.org/10.1097/MIB.0000000000000750>.

14. Dimitriu, L., Constantinescu-Aruxandei, D., Preda, D., Moraru, I., Băbeanu, N. E., & Oancea, F. (2023). The Antioxidant and Prebiotic Activities of Mixtures Honey/Biomimetic NaDES and Polyphenols Show Differences between Honeysuckle and Raspberry Extracts. *Antioxidants*, 12(9), 1678. <https://doi.org/10.3390/antiox12091678>.

15. Eaton, Sarah M., "Impact of Diet Quality and Functional Food (Honey) on Gut Microbiota and Metabolic Health in Obesity" (2025). Dissertations and Doctoral Documents, University of Nebraska-Lincoln, 2023–. 289, <https://digitalcommons.unl.edu/dissunl/289>.

16. Elenany, Y. E. (2018). Effect of Incorporation of Marjoram Honey on the Sensory, Rheological and Microbiological Properties of Goat Yogurt. *Journal of Entomology*, 16(1), 9–16. <https://doi.org/10.3923/je.2019.9.16>.

17. Ferdouse, J., Paul, S., Chowdhury, T., Ali, F., Islam, S., & Hossain, T. J. (2023). *Probiotic characteristics of Pediococcus pentosaceus and Apilactobacillus Kunkeei strains: The lactic acid bacteria isolated from Bangladeshi natural honey* (SSRN Scholarly Paper No. 4243112). Social Science Research Network. <https://papers.ssrn.com/abstract=4243112>.

18. Fratianni, F., De Giulio, B., d'Acierno, A., Amato, G., De Feo, V., Coppola, R., & Nazzaro, F. (2023). *In Vitro* Prebiotic Effects and Antibacterial Activity of Five Leguminous Honeys. *Foods*, 12(18), 3338. <https://doi.org/10.3390/foods12183338>.

19. Fratianni, F., Ombra, M. N., d'Acierno, A., Caputo, L., Amato, G., De Feo, V., Coppola, R., & Nazzaro, F. (2021). Polyphenols Content and *In Vitro*  $\alpha$ -Glycosidase Activity of Different Italian Monofloral Honeys, and Their Effect on Selected Pathogenic and Probiotic Bacteria. *Microorganisms*, 9(8), 1694. <https://doi.org/10.3390/microorganisms9081694>.

20. Fuandila, N. N., Widanarni, W., & Yuhana, M. (2020). Growth performance and immune response of prebiotic honey fed pacific white shrimp *Litopenaeus vannamei* to *Vibrio parahaemolyticus* infection. *Journal of Applied Aquaculture*, 32(3), 221–235. <https://doi.org/10.1080/10454438.2019.1615593>.

21. Getachew, T., Ashenafi, M., Tigu, F., Birri, D. J., Naoli, A., & Desalegn, A. (2025). Probiotic potential of 'lactobacilli' isolated from traditionally fermented Ethiopian honey wine (Tej). *BMC Microbiology*, 25(1), 549. <https://doi.org/10.1186/s12866-025-04326-4>.

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22. Goli Mehdi Abadi, M. E., Hosseini-Safa, A., Habibi, S., Dehghan, M., Forouzani-moghaddam, M. J., & Oshaghi, M. (2023). Isolation and characterization of the lactobacillus strain from honey and its probiotic properties. *Iranian Journal of Microbiology*, 15(3), 439–447. <https://doi.org/10.18502/ijm.v15i3.12905>.
23. Hasyimi, W., Widanarni, W., & Yuhana, M. (2020). Growth Performance and Intestinal Microbiota Diversity in Pacific White Shrimp *Litopenaeus vannamei* Fed with a Probiotic Bacterium, Honey Prebiotic, and Synbiotic. *Current Microbiology*, 77(10), 2982–2990. <https://doi.org/10.1007/s00284-020-02117-w>.
24. Hemarajata, P., & Versalovic, J. (2013). Effects of probiotics on gut microbiota: Mechanisms of intestinal immunomodulation and neuromodulation. *Therapeutic Advances in Gastroenterology*, 6(1), 39–51. <https://doi.org/10.1177/1756283X12459294>.
25. Hermawati, A. H., Puspitasari, E., & Pratiwi, C. D. (2024). Combination of forest honey with probiotic milk as an antibacterial against *Escherichia coli* and *Staphylococcus aureus* *in vitro*. *AIP Conference Proceedings*, 3098(1), 040033. <https://doi.org/10.1063/5.0223858>.
26. Hill, C., Guarner, F., Reid, G., Gibson, G. R., Merenstein, D. J., Pot, B., Morelli, L., Canani, R. B., Flint, H. J., Salminen, S., Calder, P. C., & Sanders, M. E. (2014). The International Scientific Association for Probiotics and Prebiotics consensus statement on the scope and appropriate use of the term probiotic. *Nature Reviews Gastroenterology & Hepatology*, 11(8), 506–514. <https://doi.org/10.1038/nrgastro.2014.66>.
27. Hrncir, T. (2022). Gut Microbiota Dysbiosis: Triggers, Consequences, Diagnostic and Therapeutic Options. *Microorganisms*, 10(3), 578. <https://doi.org/10.3390/microorganisms10030578>.
28. Kwakman, P. H. S., & Zaat, S. A. J. (2012). Antibacterial components of honey. *IUBMB Life*, 64(1), 48–55. <https://doi.org/10.1002/iub.578>.
29. Lane, J. A., Calonne, J., Slattery, H., & Hickey, R. M. (2019). Oligosaccharides Isolated from MGO<sup>TM</sup> Manuka Honey Inhibit the Adhesion of *Pseudomonas aeruginosa*, *Escherichia coli* O157:H7 and *Staphylococcus aureus* to Human HT-29 cells. *Foods*, 8(10), 446. <https://doi.org/10.3390/foods8100446>.
30. Maftei, N.-M., Raileanu, C. R., Balta, A. A., Ambrose, L., Boev, M., Marin, D. B., & Lisa, E. L. (2024). The Potential Impact of Probiotics on Human Health: An Update on Their Health-Promoting Properties. *Microorganisms*, 12(2), 234. <https://doi.org/10.3390/microorganisms12020234>.
31. Mandal, M. D., & Mandal, S. (2011). Honey: Its medicinal property and antibacterial activity. *Asian Pacific Journal of Tropical Biomedicine*, 1(2), 154–160. [https://doi.org/10.1016/S2221-1691\(11\)60016-6](https://doi.org/10.1016/S2221-1691(11)60016-6).

## REVIEW ARTICLE

32. Markowiak, P., & Śliżewska, K. (2017). Effects of Probiotics, Prebiotics, and Synbiotics on Human Health. *Nutrients*, 9(9), 1021. <https://doi.org/10.3390/nu9091021>.

33. Meradj, M., Bachtarzi, N., Mora, D., & Kharroub, K. (2023). Characterization of Lactic Acid Bacteria Strains Isolated from Algerian Honeybee and Honey and Exploration of Their Potential Probiotic and Functional Features for Human Use. *Foods*, 12(12), 2312. <https://doi.org/10.3390/foods12122312>.

34. Mohan, A., Hadi, J., Gutierrez-Maddox, N., Li, Y., Leung, I. K. H., Gao, Y., Shu, Q., & Quek, S.-Y. (2020). Sensory, Microbiological and Physicochemical Characterisation of Functional Manuka Honey Yogurts Containing Probiotic *Lactobacillus reuteri* DPC16. *Foods*, 9(1), 106. <https://doi.org/10.3390/foods9010106>.

35. Mohan, A., Quek, S.-Y., Gutierrez-Maddox, N., Gao, Y., & Shu, Q. (2017). Effect of honey in improving the gut microbial balance. *Food Quality and Safety*, 1(2), 107–115. <https://doi.org/10.1093/fqsafe/fyx015>.

36. Mustar, S., & Ibrahim, N. (2022). A Sweeter Pill to Swallow: A Review of Honey Bees and Honey as a Source of Probiotic and Prebiotic Products. *Foods*, 11(14), 2102. <https://doi.org/10.3390/foods11142102>.

37. Mysonhimer, A. R., Brown, M. D., Alvarado, D. A., Cornman, E., Esmail, M., Abdiel, T., Gutierrez, K., Vasquez, J., Cannavale, C. N., Miller, M. J., Khan, N. A., & Holscher, H. D. (2024). Honey Added to Yogurt with *Bifidobacterium animalis* subsp. *lactis* DN-173 010/CNCM I-2494 Supports Probiotic Enrichment but Does Not Reduce Intestinal Transit Time in Healthy Adults: A Randomized, Controlled, Crossover Trial. *The Journal of Nutrition*, 154(8), 2396–2410. <https://doi.org/10.1016/j.jn.2024.05.028>.

38. Nazzaro, F., Ombra, M. N., Coppola, F., De Giulio, B., d'Acierno, A., Coppola, R., & Fratianni, F. (2024). Antibacterial Activity and Prebiotic Properties of Six Types of Lamiaceae Honey. *Antibiotics*, 13(9), 868. <https://doi.org/10.3390/antibiotics13090868>.

39. Nikpour, S., & Hamed Mosavian, M. T. (2025). Formulation of functional probiotic dairy dessert with date honey as a sucrose replacement: Chemical, physical, and sensory analysis. *Helijon*, 11(1), e41504. <https://doi.org/10.1016/j.heliyon.2024.e41504>.

40. Paşa, C., Mărghitaş, L., Matei, I., Bonta, V., Mărgăoan, R., Copaciu, F., Bobiş, O., Campos, M., & Dezmirean, D. (2021). Screening of Some Romanian Raw Honeys and Their Probiotic Potential Evaluation. *Applied Sciences*, 11(13), 5816. <https://doi.org/10.3390/app11135816>.

41. Petrović, T. Ž., Tomović, V. M., Marković, K. G., Semedo-Lemsaddek, T., & Grujović, M. Ž. (2025). Probiotics and Honey: Boosting Functional Properties in Dry Fermented Sausages. *Microorganisms*, 13(2), 349. <https://doi.org/10.3390/microorganisms13020349>.

**REVIEW ARTICLE**

42. Pinto Neto, W. de P., Costa de Lucena, T. M., Alves da Paixão, G., Shinohara, N. K. S., Pinheiro, A. C., Vicente, A. A., de Souza, R. B., & de Moraes Junior, M. A. (2025). Symbiotic honey beverages: A matrix which tells a story of survival and protection of human health from a gastronomic and industrial perspective. *International Journal of Gastronomy and Food Science*, 40, 101183. <https://doi.org/10.1016/j.ijgfs.2025.101183>.

43. Plăder, M., Sekul, J., Kot, A. M., & Pobiega, K. (2025). From hive to laboratory – biotechnological potential of microorganisms from honey. *World Journal of Microbiology and Biotechnology*, 41(10), 361. <https://doi.org/10.1007/s11274-025-04551-z>.

44. Plaza-Diaz, J., Ruiz-Ojeda, F. J., Gil-Campos, M., & Gil, A. (2019). Mechanisms of Action of Probiotics. *Advances in Nutrition*, 10, S49–S66. <https://doi.org/10.1093/advances/nmy063>.

45. Prakit, B., Chaiyod, R., Khongkool, K., Chanosit, W., & Lertworapreecha, M. (2025). Multifunctional probiotic and safety attributes Heyndrickxia coagulans isolated from stingless bee honey. *Annals of Microbiology*, 75(1), 3. <https://doi.org/10.1186/s13213-025-01791-0>.

46. Rakabizadeh, B., & Tadayoni, M. (2022). Evaluation of antibacterial and probiotic growth stimulatory activities of some honey types produced in Khuzestan. *Journal of Food and Bioprocess Engineering*, 5(2). <https://doi.org/10.22059/jfabe.2022.346557.1123>.

47. Ranneh, Y., Akim, A. M., Hamid, H. Ab., Khazaai, H., Fadel, A., Zakaria, Z. A., Albujja, M., & Bakar, M. F. A. (2021). Honey and its nutritional and anti-inflammatory value. *BMC Complementary Medicine and Therapies*, 21(1), 30. <https://doi.org/10.1186/s12906-020-03170-5>.

48. Roy, S., & Mandal, S. (2024). *Lactiplantibacillus plantarum* isolates from natural honey (Malda, India): Probiotic potentiality and antibacterial activity analysis by in vitro methods. *Food and Humanity*, 3, 100348. <https://doi.org/10.1016/j.foohum.2024.100348>.

49. Sanders, M. E., Merenstein, D. J., Reid, G., Gibson, G. R., & Rastall, R. A. (2019). Probiotics and prebiotics in intestinal health and disease: From biology to the clinic. *Nature Reviews Gastroenterology & Hepatology*, 16(10), 605–616. <https://doi.org/10.1038/s41575-019-0173-3>.

50. Sanz, M. L., Polemis, N., Morales, V., Corzo, N., Drakoularakou, A., Gibson, G. R., & Rastall, R. A. (2005). In Vitro Investigation into the Potential Prebiotic Activity of Honey Oligosaccharides. *Journal of Agricultural and Food Chemistry*, 53(8), 2914–2921. <https://doi.org/10.1021/jf0500684>.

51. Schell, K. R., Fernandes, K. E., Shanahan, E., Wilson, I., Blair, S. E., Carter, D. A., & Cokcetin, N. N. (2022). The Potential of Honey as a Prebiotic Food to Re-engineer the Gut Microbiome Toward a Healthy State. *Frontiers in Nutrition*, 9, 957932. <https://doi.org/10.3389/fnut.2022.957932>.

52. Shehata, M. G., Masry, S. H. D., Abd El-Aziz, N. M., Ridouane, F. L., Mirza, S. B., & El-Sohaimy, S. A. (2024). Probiotic potential of lactic acid bacteria isolated from honeybees stomach: Functional and

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technological insights. *Annals of Agricultural Sciences*, 69(1), 11–18. <https://doi.org/10.1016/j.aoas.2024.06.001>.

53. Siddiqui, A. J., Musharraf, S. G., Choudhary, M. I., & Rahman, A.-. (2017). Application of analytical methods in authentication and adulteration of honey. *Food Chemistry*, 217, 687–698. <https://doi.org/10.1016/j.foodchem.2016.09.001>.

54. Svenungsson, B., Lagergren, A., Ekwall, E., Evengård, B., Hedlund, K. O., Kärnell, A., Löfdahl, S., Svensson, L., & Weintraub, A. (2000). Enteropathogens in adult patients with diarrhea and healthy control subjects: A 1-year prospective study in a Swedish clinic for infectious diseases. *Clinical Infectious Diseases: An Official Publication of the Infectious Diseases Society of America*, 30(5), 770–778. <https://doi.org/10.1086/313770>.

55. Tajabadi, N., Mardan, M., Saari, N., Mustafa, S., Bahreini, R., & Manap, M. Y. A. (2013). Identification of *Lactobacillus plantarum*, *Lactobacillus pentosus* and *Lactobacillus fermentum* from honey stomach of honeybee. *Brazilian Journal of Microbiology*, 44, 717–722. <https://doi.org/10.1590/S1517-83822013000300008>.

56. Thakur, V., & Rana, A. (2024). *Honey: As Source of Prebiotics and Probiotics*. *Bioscene*, 21(02), 1182–1208, [www.explorebioscene.com](http://www.explorebioscene.com).