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# HONEY AS A PREBIOTIC, PROBIOTIC AND SYNBIOTIC 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 aims to offer a brief overview of recent studies on the synergistic benefits of probiotics and honey, focusing on enhancing the immune system, improving gut microbiome health, and promoting overall wellness.

**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 β-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, 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).

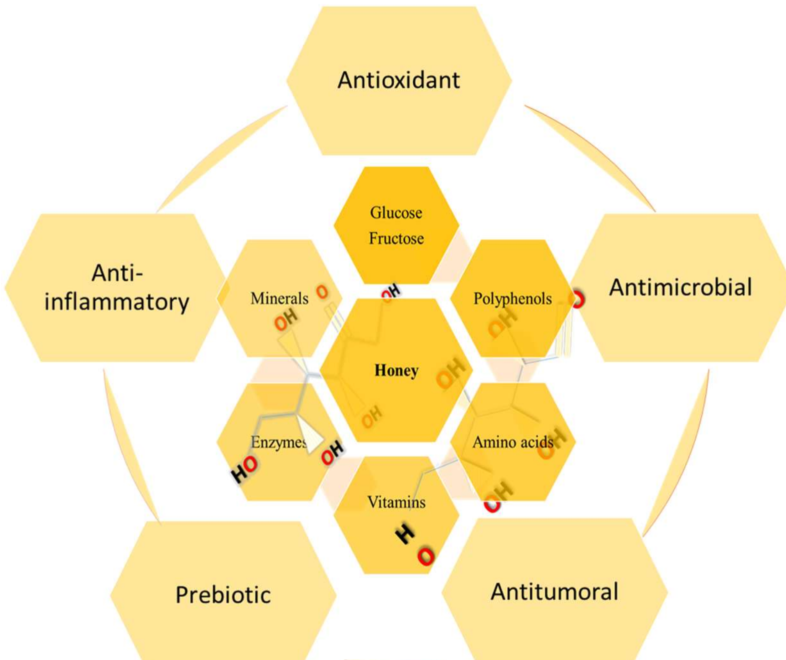


**Fig. 1.** Bioactivity properties of honey

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 & Zaat, 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 flavu*s, *Penicillium chrysogenum*, *Candida albicans*, *Saccharomyce*s 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 $H_2O_2$ 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 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

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

| **Honey type and source** | **Key findings** | **Reference** |
|---|---|---|
| *in vitro* studies | | |
| Honey, Spain | increase in beneficial lactobacilli and bifidobacteria, reduction in enteric bacteria and Bacteroides/ *in vitro* fermentation system | Sanz *et al*., 2005 |

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

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| Honey type and source | Key findings | Reference |
|---|---|---|
| Manuka, New Zealand | 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 | Schell *et al*., 2022 |
| Manuka honey, USA | increased abundance of *Akkermansia* and *Faecalibacterium*/ in individuals with overweight and obesity, daily consumption of one tablespoon of Manuka honey, 4-week trial | Eaton, 2025 |

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 or shrimp that received a probiotic or synbiotic, shrimp that received the honey prebiotic revealed 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). These complementary effects suggest that honey and probiotics could function together naturally modulating the gut microbiota for health benefits.

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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 which has 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

| Honey type | Probiotic strain | Key findings | Reference |
|---|---|---|---|
| Date honey | *Lactobacillus acidophilus* | dairy dessert/ sweetener to substitute for sugars | Nikpour & Hamed Mosavian, 2025 |
| Manuka honey | *Lactobacillus reuteri* DPC16 | synbiotic yogurt | Mohan *et al.*, 2020 |
| Acacia honey and chestnut honey | *Bifidobacterium animalis* subsp. *lactis* BB-12 and *B. longum* BB-46 | inhibitory effect against the *Listeria monocytogenes* /fermented soy milk | Pinto Neto *et al*., 2025 |
| Marjoram honey | *Lactobacillus casei* EMCC761 | goat yogurt | Elenany, 2018 |
| Pine honey | *Streptococcus thermophilus, Lactobacillus* | probiotic yoghurt | Coskun & Karabulut Dirican, 2019 |

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

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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 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).

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.

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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.

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,

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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 a number of 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 pathogens cannot survive or reproduce, even though bacteria that can proliferate through spores, like those that cause botulism, can survive. Honey-induced food allergies are sometimes closely associated with pollen allergies since pollen is present during collecting (Ahmed *et al*., 2018).

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## 8. Conclusion

Probiotics and honey each have many health benefits, but when they are 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.

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