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Effects of several culinary herbs and spices on gut microbiota

Ahmad ALHOMSI[1], **Mukaddes KILIÇ BAYRAKTAR**[2]

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[1] Karabuk University, The Institute of Graduate Programs, Department of Food Toxicology, Karabuk, Türkiye

[2] Karabuk University, Faculty of Health Sciences, Department of Nutrition and Dietetics, Karabuk, Türkiye

ORCID IDs of the authors:

A.A. 0009-0000-8198-0167

M.K.B. 0000-0002-8871-8820

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Correspondence:
Ahmad ALHOMSI
E-mail: alhomsia48@gmail.com

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ABSTRACT

The microbiome of human beings, especially the gut microbiota, appears to be the most potent element of the human body responsible for health and disease. Various herbs and spices often used in cooking and exceptionally high in bioactive substances like polyphenols, terpenes, and flavonoids are getting more attention for their proposed effect on gut health. This study aims to examine the links between culinary herbs and spices and the gut microbiome and to review the latest research findings. Human microbiota has a variable number of bacteria, and the composition and properties of their microbiomes depend on diet, lifestyle, and environmental factors. The current literature demonstrates that phytochemicals in spices and herbs can modify gut microbiota, which may result in lower inflammation, better digestion, and prevention of non-communicable diseases. It has been proven with further studies that herbs such as cinnamon, ginger, turmeric and rosemary are beneficial for the intestines and have shown positive results in animal and human studies. In conclusion, adding culinary herbs and spices to the diet provides a straightforward but powerful means to preserve a healthy gut microbiota, and supports overall better health.

Keywords: Culinary herbs, Gut microbiota, Prebiotic, Spices

Introduction

Bacteria are among the most important microorganisms that inhabit the human body, although viruses, protozoa, fungi, and archaea are also present. All together, they are known as the human microbiome. The bacteria in the digestive system are known as the gut flora or gut microbes. The human body contains more bacterial cells than human cells, with around 40 trillion bacterial cells compared to 30 trillion human cells (Sasso et al., 2023). The collective genome of gut bacteria is more than 100 times larger than the human genome. Given the microbiota's tremendous genetic potential, it is expected to play a role in almost every physiological activity in the human body (Cénit et al., 2014; Hasan & Yang, 2019). The human microbiome is critical for both health and disease. It works close to the digestive tract significantly (Jandhyala, 2015). The gastrointestinal tract is regularly influenced by various environments, significantly affecting the structure, functioning and metabolism of each individual's gut microbiome (Kolodziejczyk et al., 2019). Diet is the main factor in the development of the environment in the human gut. Hence, host diet changes are responsible for microbiome alterations. Gut bacteria perform these functions by digesting complex carbohydrates and amino acids, fermenting food, digesting proteins and lipids, and producing Short-chain fatty acids (SCFAs) – acetate, propionate, and butyrate (Cani et al., 2021).

Using spices and herbs in cooking and medicine can benefit the stomach and other health issues. They have recently gained attention in assessing gut microbes because of their high concentrations of polyphenols, antioxidants, and anti-inflammatory properties. These components provide scope for positive health impacts, which may include a reduction in inflammatory disorders, proper for cardiovascular diseases and obesity in some cases, and prevent incidents of dementia (Kim et al., 2017; Vamanu et al., 2019). The plant leaf is a culinary herb, and any other dried part of the plant is termed a spice. Spices can come from various parts of plants: buds like cloves, bark like cinnamon, roots like ginger, berries like peppercorns, seeds like cumin, and even the stigma of flowers like saffron (Tapsell et al., 2006). Ancient medical systems like Ayurveda, traditional African medicine, and traditional Chinese medicine combine medicinal plants for enhanced biological effects over individual herbs (Mussarat et al., 2021).

The primary goal of this paper is to review recent research on gut microbiota and culinary herbs and spices. This review focuses on cinnamon, ginger, turmeric, and rosemary due to their well-documented bioactive properties and widespread culinary and medicinal use. Cinnamon is known for its antimicrobial and anti-inflammatory properties, ginger for its digestive benefits, turmeric for its anti-inflammatory and antioxidant effects, and rosemary for its antioxidant and mood-enhancing effects. By exploring these herbs, the paper aims to provide insights into how they can influence gut health and overall well-being.

Role of Culinary Herbs in Traditional Medicine and Cuisine

Herbs and spices have a long history in culinary applications, medicinal properties, and as natural preservatives (Tapsell et al., 2006). Herbs and spices are traditional culinary ingredients used for flavour enhancement, food preservation, aromatic qualities, and most importantly, for medical use, including digestive aid, nausea prevention, and boosting general health in ancient and modern times (Dahl et al., 2023). A papyrus from ancient Egypt, dating back to 1555 BCE, records the use of coriander, fennel, juniper, cumin, garlic, and thyme. The Sumerians utilised thyme for its health benefits starting in 5000 BCE, while Mesopotamian farmers cultivated garlic from 3000 BCE. An ancient trade in spices with Ethiopia lasted from 4500 to 1900 BCE. Egyptians highly regarded garlic, as garlic cloves were discovered in King Tutankhamun's tomb. Mint leaves were found in pyramids in Egypt dating back to approximately 1000 BCE (Block E, 1986; Chevallier A., 1996). Plants were used more often than spices in ancient Greece and Rome. Hippocrates (460 BCE) used over 300 substances, such as locally obtainable garlic and real cinnamon. It has been claimed that garlic can help with uterine cancer. Along with repairing the digestive system, mint was also good to combat all kinds of breath problems. At the same time, liquorice honey was suitable as a dessert to treat all respiratory disorders, even colds, coughs, asthma, and mouth sores. Although centuries before, garlic was also used to improve memory (Sharangi, 2018). Ayurveda, the ancient medical system believed to have originated in the Himalayas over 5000 years ago, was documented in Sanskrit poetry around the Vedas in 1500 BCE. It reached its peak in the seventh century. Ayurveda is a comprehensive medical theory revered as the ultimate health science. It prevents illness by promoting well-being and emphasising good eating habits. Ayurvedic medicine uses various herbs and spices to provide health-promoting benefits. Such herbs and spices include turmeric, used to treat jaundice; basil, which protects the cardiovascular system; mace, which helps with gastrointestinal infections; cinnamon, which enhances blood

circulation; and ginger, which is multipurpose and significantly helps in the treatment of nausea. An anecdote elaborates on an individual taking up to 50 grams of garlic per week (Vladirmirescu, 2011).

Composition and Properties of Gut microbiota

The gut microbiota is a rich ecosystem of numerous microorganisms, including bacteria, viruses, and eukaryotes. It is estimated to carry about ~3.8 × 10^13 microbes, most residing in the lower digestive tract, particularly in the large intestine or colon (Dahl et al., 2023). The state of the host may be linked to the composition of the gut microbiota, which is affected by direct and indirect factors, as shown by Sekirov et al. (2010). The indirect influence of certain factors evidences this fact. Various factors in the intestinal canal are affected by transit time and the nutrients present in the intestine. These factors can vary for individuals based on their health status, medication use, dietary habits, smoking status, and levels of physical activity (Figure 1). All these mentioned factors are strongly interconnected. Many components that account for the variability of gut microbiota have been discovered; however, 80% or more of these factors still lack explanation (Rothschild et al., 2018; Zhernakova et al., 2016).

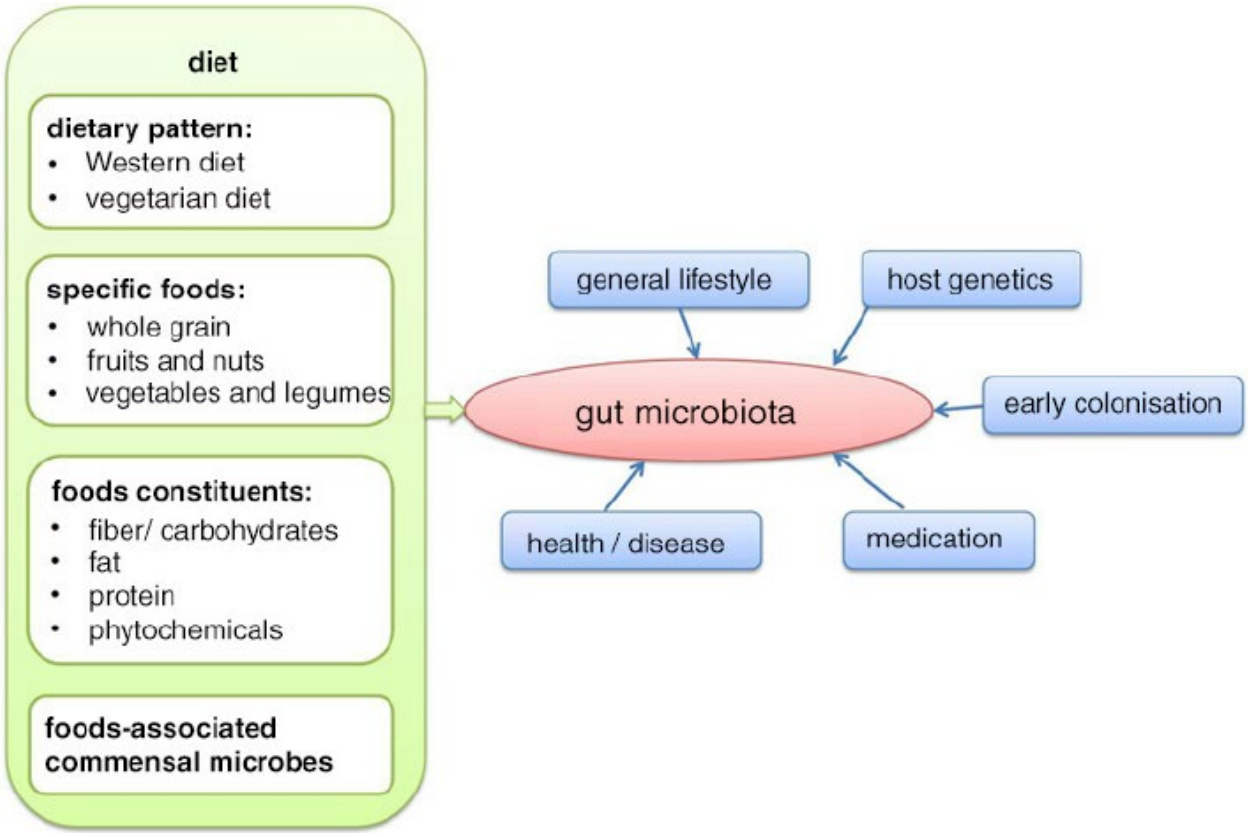

Figure 1. Factors affecting the structure of the human gut microbiota, especially emphasising the role of diet (Graf et al., 2015)

Understanding the prerequisites that cause changes in gut microbiota composition is essential for developing interventions to improve health. Individuals consume foods rich in various nutrients with different proportions of bioavailability, not relying solely on individual nutrients. Thus, the concentration of some of these nutrients depends on the consistency of the ingested food and the interaction of its components. Moreover, research has shown that some eating patterns are associated with similar groups; for instance, people who consume a lot of soda or sweets also tend to eat more snacks and fried potatoes (Huseinovic et al., 2019). On the other hand, to determine which dietary patterns are truly beneficial, future nutrition research should focus more on how individual foods are combined (known as dietary patterns) rather than on the consumption of specific nutrients to explore health outcomes (Cespedes & Hu, 2015). Researchers have investigated variations in gut microbiota composition among people depending on diet types, such as vegan/vegetarian and omnivore diets, and adherence levels to the Mediterranean diet. Nevertheless, the fact that the studies reflect only vegans or vegetarians who strictly observe their diet does not necessarily mean that their diet is intrinsically superior to that of non-vegetarians, especially if the studies show only a small gap (only 4.5%) in the Healthy Eating Index between vegans/vegetarians and non-vegetarians (Parker & Vadiveloo, 2019).

Gut Microbiome and Health

The modulation of the gut microbiome can be achieved by gradually adding new, particular bacteria to a person's diet, for example, through prebiotics (Gibson et al., 2017). Regarding short-chain fatty acids (SCFAs), anaerobic gut microorganisms ferment indigestible carbohydrates—substances that can be potentially beneficial for health—and release gases (including SCFAs) and organic acids into the gut (Rastall & Gibson, 2015). These SCFAs, like butyrate, propionate, and acetate, positively influence gene expression, physiological functions, and a range of health outcomes, including relieving obesity indicators, managing the progression of type 2 diabetes, and potentially acting as anticancer agents. As the primary energy source for colonic epithelial cells, butyrate can be involved in apoptosis regulation, suggesting it can help prevent colon cancer (Canfora et al., 2015; Zeng et al., 2019). Acetate and propionate may contribute to fighting obesity and weight management by releasing satiety hormones and controlling satiety, as Canfora et al. (2019) suggested. Butyrate can reduce fat accumulation in obese individuals, potentially improving insulin sensitivity (Vrieze et al., 2012).

Culinary Herbs and Spices and Their Effects on Gut Health

Culinary herbs are primarily fresh leaves and flowers. On the other hand, the rest of the parts, including roots, seeds, bark, stems, berries, and buds, are categorised as culinary spices and are typically dried (Tapsell et al., 2006). Culinary spices and herbs are rich in micronutrients and other bioactive components such as polyphenols, terpenes, alkaloids, and flavonoids (Chandrababu & Bastola, 2019; Mukherjee & Chakraborty, 2021; Opara & Chohan, 2014). Despite their influence on the gut microbiome among human groups, a detailed investigation of these dietary components is still lacking, making them an important element to consider in studies on diet and the microbiome. Many pre-clinical research works indicate the capability of cooking herbs and spices, or their vital components, to impact the microbiota of the intestinal system (Rosca et al., 2020; Yang et al., 2020).

For centuries, people have utilised herbs and spices to preserve food, enhance taste, enrich aroma, and provide medicinal benefits such as aiding digestion, treating nausea, and promoting overall health (Böck, 2012). Several herbs and spices used in the past are still important for culinary and medicinal purposes. For instance, liquorice root is commonly used as a natural sweetener to aid digestion. The Mediterranean diet uses garlic, mint, rosemary, thyme, and basil. Individuals with irritable bowel syndrome often use mint supplements to control their symptoms, while allicin, a compound in garlic, is known to reduce cholesterol and high blood pressure.

Despite this evidence, these plants are suggested to contribute to the health benefits of the Mediterranean diet, which reduces the likelihood of non-communicable diseases such as stroke, heart disease, and various cancers (Martinez-Lacoba et al., 2018; Tapsell et al., 2006).

Specific Culinary Herbs and Their Effects on Gut Health

Cinnamon

It has been increasingly proven that cinnamon's antimicrobial properties and ability to reduce inflammation are responsible for its protective impact against inflammatory bowel diseases (Li et al., 2020). Cinnamon essential oil (CEO), a natural plant-based extract, is considered safe as it is often used in food seasoning and traditional herbal remedies. Recently, the number of research papers describing the therapeutic properties of one of cinnamon's chemical components, cinnamaldehyde, has increased (Chao et al., 2008).

Hou (2015) conducted a study on pigs who were given 50 mg/kg of cinnamon oil in their diets, which reduced the incidence of diarrhoea in pigs post-weaning. Cinnamon oil, which contains antioxidant properties, also helps reduce intestinal damage and enhance intestinal absorption by improving the integrity of mucosal healing. Cinnamon oil can protect the gut against damage from inflammation, infections, and oxidative injuries. In another study carried out by Li et al. (2020), mice that were given cinnamon oil exhibited better variability and quantity of bacteria, with a reduction in Helicobacter and Bacteroides and a rise in Bacteroidales and bacteria generating short-chain fatty acids like Alloprevotella and Lachnospiraceae (Table 1).

Ginger

Ginger is from the Zingiberaceae plant family, and its scientific name is Zingiber officinale Roscoe. Although it originated in Asia, it is now grown in the West Indies, Africa, India, and other tropical areas. The underground rhizome is used to produce powdered ginger or spice. It comes in a range of colours, from white to brown. The rhizome can be processed into various products, including powder, syrup, and volatile oil. Ginger has been widely utilised in the culinary world since the 13th century (Singletary, 2010).

Ginger contains several bioactive substances responsible for its known biological processes. These substances include phenolic compounds, terpenes, lipids, and carbohydrates, which are believed to provide numerous health benefits (Jafarzadeh et al., 2021; Kiyama, 2020). The four main phenolic components obtained from ginger are gingerol, shogaols, paradols, and zingerone. These compounds are known for their potent anti-inflammatory and antioxidant properties in vitro (Black et al., 2010; Prasad & Tyagi, 2015). Ginger root is often used in cooking as a seasoning or supplement (Mohd Yusof, 2016). It can enhance the performance of gut bacteria and restore their diversity without causing any harmful effects on the stomach (Y. Lu et al., 2018; Ballester et al., 2022).

Research conducted by Wang et al. (2021) studied the effects of fresh ginger juice consumption on gut microorganisms in healthy individuals. The study involved 123 participants who consumed either ginger juice or a control solution daily. The results showed increased intestinal flora species diversity following ginger juice intervention, accompanied by alterations in specific bacterial taxa. Notably, there was a decrease in pro-inflammatory bacteria and a rise in species with anti-inflammatory properties.

Another study by Shen et al. (2024) analysed the changes in pain-related behaviour caused by the separate and combined use of gingerol-enriched ginger (GEG) in diabetic neuropathic pain (DNP) in rats. The study focused on alterations in physical constructs of inhibition and pain sensitivity and the definite role of the microbiome in neuropathic pain. Additionally, the researchers investigated mitochondrial function. The study involved 33 male rats divided into three groups: controls, DNP, and GEG. Rats treated with GEG during drug withdrawal showed elevated levels of certain gut microbiota and reduced levels of others. Furthermore, GEG induced changes not only in the development of mechanical hypersensitivity but also in anxiety and depressive behaviours.

Table 1. Effects of culinary herbs and spices on gut microbiota

Herb or Spice	Study Type	Effects on Gut Microbiota	References
Cinnamon	Animal (mice)	Decrease *Helicobacter* and *Bacteroides*, increase *Alloprevotella* and *Lachnospiraceae* (SCFA producers)	Li et al., 2020
Ginger	Human (clinical trial); Animal (rats)	Increase bacterial diversity, decrease pro-inflammatory bacteria	Wang et al., 2021; Shen et al., 2024
Turmeric	Animal (broilers); Human (clinical trial)	Increase beneficial bacteria in the ileum, minimal changes in overall gut microbiota composition	Ji et al., 2024; Lopresti et al., 2021
Rosemary	Animal (mice)	Increased Lactobacillus and Firmicutes decrease Bacteroidetes and Proteobacteria, which are associated with antidepressant effects and reduced inflammation in mice.	Guo et al., 2018

Turmeric

Turmeric, also known as Curcuma longa, belongs to the ginger family. These plants are common in the southern and southwestern Asia regions. In many countries around the globe, turmeric is a common spice. This natural spice generally acts to suppress inflammation, kill microorganisms, scavenge for oxidative radicals, and block the entrance of cancerous cells. It is used as a spice and adds colour, taste, and character to food products. Turmeric has been well-established in India and China for ages and has been confirmed to be a medicine used to cure diseases such as infections, depression, and stress. Curcumin, a lipophilic polyphenol compound, is the primary focus of turmeric's health benefits because it is derived from the herb's roots (Kocaadam & Şanlier, 2017; Vaughn et al., 2016). Curcumin is extracted from the turmeric plant using a solvent and crystallised for purity (Zam, 2018).

An experiment by Ji et al. (2024) researched the impact of supplementing broiler diets with Lonicerae flos and turmeric extract (LTE) on intestinal health and growth performance. Three groups of broilers were studied: a control group (CON), a group containing LTE at a concentration of 300 g/t (LTE300), and another group containing LTE at a concentration of 500 g/t (LTE500). According to the outcomes, LTE supplementation dramatically enhanced gut health and growth performance, improved body and bone weight, and decreased serum endotoxin levels. Additionally, LTE improved the structure of the intestinal and immune systems. Analysis of the data related to microorganisms showed that the probiotic strain LTE300 was favourable for the human ileum.

Another study conducted by Lopresti et al. (2021) investigated the impact of curcumin extract (Curcuge) on gut symptoms and mood in adults diagnosed with self-reported digestive problems. The study was conducted for eight weeks with 79 randomly assigned to two groups: one receiving curcumin and the other a placebo. The findings showed that curcumin significantly reduced gastrointestinal symptoms and anxiety levels compared to the placebo. These findings indicated that the change in intestinal microbiota due to curcumin was minimal; the effect on small intestinal bacterial overgrowth was non-significant. The study suggests that curcumin could aid in relieving digestive symptoms and anxiety, although this mechanism of action might not be linked to changes in gut bacteria. More research is required to discover other mechanisms of curcumin's action on gastrointestinal health.

Rosemary

Rosemary is a plant from the Lamiaceae family, renowned for its use as an herb and seasoning (Sánchez-Camargo & Herrero, 2017). A component of the well-known Mediterranean diet, it can add distinctive organoleptic characteristics (taste, aroma, and texture) to food. Rosemary has been an important part of traditional medicine for treating various minor issues, such as indigestion and common colds, as well as more serious or lethal conditions (González-Vallinas et al., 2015; Ulbricht et al., 2010). Polyphenols in rosemary extracts are noteworthy because their high phenolic content endows them with hepatoprotective, antibacterial, antifungal, and antioxidant qualities (Alizadeh et al., 2016). Despite its food value, rosemary is less commonly used due to its strong taste, odour, and colour. Small industries use chemical methods to remove these characteristics from antioxidants (Aziz et al., 2022).

A study conducted by Guo et al. (2018) found that extracts from rosemary (RE) have antidepressant properties in mice exposed to long-term constant stress, a model for depression in animals. The researchers examined how RE affected depressive-like symptoms, inflammation, and gut microbiota in chronic restraint stress (CRS) mice. The treatment with RE altered the gut microbiota's composition, increasing the proportion of beneficial microorganisms such as *Lactobacillu*s and *Firmicute*s while decreasing the percentage of potentially harmful bacteria such as *Bacteroidetes* and *Proteobacteria* (Table 1).

Conclusion

Culinary spices and herbs are strong candidates for balancing the microbiota and restoring gut health. Bioactive substances, with their variety of physiological activities, may possess the potential to protect from inflammation, improve digestion, and lower the risk of chronic diseases. The value of herbs and spices in traditional medicine underscores their significance in human health across different populations and centuries. The gut microbiome resides in the gastrointestinal tract, and various factors such as diet, cooking methods, and existing microbes can influence it. Recent research has demonstrated that culinary herbs and spices can modify the microbiota in the intestinal tract. Adequate and properly conducted clinical trials are essential to validate that herbal remedies are sustainable methods of maintaining gut health and preventing gastrointestinal diseases. The widespread use of adding different herbs and spices to the diet can be an easy and effective strategy for bowel health and overall well-being. By utilising the natural properties of these compounds on a small scale, we can fine-tune our gut microbiome and help our immune system combat various health threats.

Compliance with Ethical Standards

Conflict of interest: The author(s) declares that they have no actual, potential, or perceived conflict of interest for this article.

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