Study on the Effects of Hawthorn Products on Gut Microbiota

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Abstract: *This study investigates the effects of hawthorn products on gut microbiota, aiming to reveal their potential health benefits. By administering hawthorn products to experimental animals and analyzing changes in gut microbiota using high-throughput sequencing technology, the results show that hawthorn products significantly improved gut microbiota diversity, promoted the growth of beneficial bacteria, and inhibited the proliferation of harmful bacteria. Additionally, hawthorn products enhanced the production of short-chain fatty acids, further supporting their beneficial effects on gut health. This study provides scientific evidence for the application of hawthorn products in functional foods and offers new perspectives for future gut health research.*

Keywords: *Hawthorn products, gut microbiota, short-chain fatty acids, functional foods, high-throughput sequencing*

Introduction

The gut microbiota plays a crucial role in maintaining human health, being involved in nutrient metabolism, immune regulation, inflammatory responses, and even mental health. In recent years, the regulatory effects of functional foods on gut microbiota have garnered widespread attention. Hawthorn products, a traditional Chinese medicine and food, have attracted interest due to their rich bioactive components. However, research on how hawthorn products influence gut microbiota remains limited. This study not only provides new scientific evidence for the health effects of hawthorn products but also expands the field of gut microbiota regulation research.

1. Nutritional Components and Bioactivity of Hawthorn Products

1.1 Chemical Composition and Nutritional Properties of Hawthorn

1.1.1 Flavonoids: Structure and Function

Hawthorn (Crataegus spp.) is a rich source of flavonoids, which play a key role in its bioactivity. The primary flavonoids in hawthorn include quercetin, hawthorn flavonoids, and rutin. Quercetin, as a major flavonoid, exhibits significant antioxidant and anti-inflammatory activities. Its chemical structure, characterized by hydroxyl groups and aromatic rings, enables it to effectively neutralize free radicals, reduce oxidative stress, and thereby protect cells from oxidative damage. Additionally, hawthorn flavonoids enhance cardiovascular health by inhibiting platelet aggregation and dilating blood vessels, showing potential applications in the prevention of cardiovascular diseases.[1]

1.1.2 Antioxidant Effects of Polyphenols

Hawthorn contains polyphenolic compounds such as procyanidins and tannins, which have important health implications due to their antioxidant properties. Polyphenols can scavenge free radicals in the body through their phenolic hydroxyl structures, reducing lipid peroxidation and effectively mitigating oxidative stress-related damage to cells and tissues. Studies have shown that hawthorn polyphenols have potential in preventing chronic diseases, delaying aging processes, and improving gut health, with their antioxidant mechanisms playing a vital role in maintaining overall health.

1.1.3 Organic Acids and Hawthorn's Digestive-Promoting Function

Hawthorn is rich in organic acids, such as malic acid and citric acid, which promote digestive health. Organic acids enhance gastric acid secretion, increase the digestive capacity of the gastrointestinal tract,

and improve food digestion and absorption. Hawthorn's organic acids also promote bile secretion, aiding in fat digestion and absorption, thereby alleviating issues like indigestion and bloating. Further research has found that hawthorn's organic acids can regulate gut pH and inhibit the growth of harmful bacteria, maintaining the balance of gut microbiota.

1.1.4 Mineral and Vitamin Content in Hawthorn

Hawthorn is rich in various minerals and vitamins, including calcium, potassium, magnesium, vitamin C, and vitamin E. Calcium and magnesium play important roles in bone health and nerve function, while potassium helps maintain electrolyte balance in the body. Vitamins C and E possess antioxidant properties, further enhancing hawthorn's health benefits. Studies show that the combined effects of these minerals and vitamins in hawthorn not only increase its nutritional value but also have positive impacts on preventing various nutritional deficiencies and improving overall health.

1.2 Pharmacological Activity and Health Effects of Hawthorn

1.2.1 Protective Effects of Hawthorn on the Cardiovascular System

Hawthorn is widely used for maintaining cardiovascular health, with its main mechanisms including improving blood circulation, lowering blood pressure, and reducing blood lipids. The flavonoids and polyphenols in hawthorn can effectively dilate blood vessels, lower blood pressure, and reduce the risk of heart disease and stroke. Additionally, hawthorn has anti-platelet aggregation effects, which can reduce the risk of thrombosis, thereby protecting cardiovascular health. Clinical studies have shown that long-term consumption of hawthorn products can significantly improve cardiovascular function and have a marked protective effect on the heart.[2]

1.2.2 Mechanisms of Hawthorn in Metabolic Regulation

The effects of hawthorn products on metabolic regulation are mainly reflected in the regulation of blood glucose and lipid metabolism. The active ingredients in hawthorn can help lower blood glucose levels by improving insulin sensitivity and inhibiting gluconeogenesis, and they can effectively regulate lipid metabolism. Studies have found that hawthorn has a beneficial effect on symptoms of metabolic syndrome, including hyperglycemia, hyperlipidemia, and obesity, providing new insights for the treatment of diabetes and hyperlipidemia.

1.2.3 Anti-Inflammatory and Immunomodulatory Functions

Hawthorn's anti-inflammatory effects are primarily derived from its flavonoids and polyphenols, which can reduce chronic inflammation by inhibiting the release of inflammatory mediators and lowering levels of inflammatory markers. Additionally, hawthorn has immunomodulatory functions, enhancing immune cell activity and boosting the body's immune capacity. Studies show that hawthorn's anti-inflammatory and immunomodulatory effects are not only important for preventing and treating inflammatory diseases but also crucial for maintaining normal immune system functions.

1.2.4 Antibacterial and Antiviral Properties of Hawthorn

Hawthorn's antibacterial and antiviral properties are mainly reflected in its inhibitory effects on various pathogenic microorganisms. Research indicates that hawthorn extracts have significant inhibitory effects on bacteria such as Staphylococcus aureus and Escherichia coli, as well as on certain viruses like the influenza virus. These antibacterial and antiviral properties make hawthorn a potential natural anti-infective agent with broad application prospects.

1.3 Potential Effects of Hawthorn Products on Gut Health

1.3.1 Probiotic-Promoting Effects of Hawthorn Products

Certain active ingredients in hawthorn products can promote the growth and proliferation of beneficial gut bacteria. These components provide nutritional support for probiotics while also regulating gut pH and increasing the survival rate of beneficial bacteria, helping to maintain a healthy balance of gut microbiota. Research has found that long-term consumption of hawthorn products can significantly increase the number of beneficial bacteria such as lactobacilli and bifidobacteria in the gut, positively impacting gut function.

1.3.2 Role of Hawthorn Products in Gut Microbiota Balance

Hawthorn products help restore gut microbiota balance by regulating the structure and function of

gut microbiota. The bioactive components in hawthorn can inhibit the overgrowth of harmful bacteria while promoting the proliferation of beneficial bacteria, thus maintaining gut microecological stability. Studies show that hawthorn products are effective in improving gut issues such as constipation and diarrhea, and their role in regulating gut microbiota balance is crucial for overall gut health.

1.3.3 Effects of Hawthorn Products on Gut Barrier Function

Hawthorn products have a significant positive impact on gut barrier function. The active ingredients in hawthorn can enhance the integrity of gut epithelial cells, reduce gut permeability, and protect the gut from harmful substances and pathogens. Additionally, hawthorn products can regulate mucus secretion in the gut, enhancing the protective function of the gut barrier. Research indicates that hawthorn products play an active role in preventing and improving inflammatory gut diseases.

1.3.4 Relationship Between Hawthorn Products and Gut Metabolites

The effects of hawthorn products on gut metabolites are mainly reflected in their regulation of short-chain fatty acid (SCFA) production. SCFAs are the primary metabolites of gut microbiota and are crucial for maintaining gut health. Hawthorn products can promote the metabolic activities of beneficial bacteria, increase SCFA production, improve the gut's acid-base environment, and further promote gut health. Studies have shown that the regulatory effects of hawthorn products on SCFA levels help improve gut function and overall metabolic health.

2. Relationship Between Gut Microbiota and Health

2.1 Composition and Function of Gut Microbiota

2.1.1 Basic Structure and Classification of Gut Microbiota

Gut microbiota consists of various microorganisms, including bacteria, archaea, fungi, and viruses. The basic structure of this community presents a complex ecosystem, where different microorganisms exhibit varying abundance and diversity in different regions of the gut. Bacteria are the most predominant component of gut microbiota and can be classified into major phyla based on their morphological and physiological characteristics, such as Firmicutes, Bacteroidetes, Proteobacteria, and Actinobacteria. Each type of microorganism plays a unique role in maintaining gut ecological balance, forming a stable microecological environment through mutual interactions.

2.1.2 The Role of Gut Microbiota in Nutrient Absorption

Gut microbiota plays a critical role in nutrient absorption. Through their metabolic activities, these microorganisms break down indigestible substances like dietary fibers into short-chain fatty acids (SCFAs) such as acetate, propionate, and butyrate, which can be directly absorbed by intestinal epithelial cells to provide energy for the body. Additionally, gut microbiota is involved in the synthesis of vitamins, such as vitamin K and certain B vitamins, which are essential for maintaining normal physiological functions. The metabolic products of gut microbiota not only influence nutrient absorption but also regulate the nutritional environment within the gut, supporting healthy metabolic processes.[3]

2.1.3 Interaction Between Gut Microbiota and the Immune System

There is a close interaction between gut microbiota and the immune system. The microorganisms in the gut interact with the gut immune system to regulate the intensity and type of immune responses. Probiotics can enhance the body's immune defense by activating intestinal immune cells and promoting the secretion of immune factors. Furthermore, the gut microbiota helps maintain the integrity of the gut barrier, preventing the invasion of pathogens and playing a crucial role in balancing and functioning of the immune system. Dysregulation of the immune system is closely related to gut microbiota imbalance, making the maintenance of a healthy microbiota essential for normal immune function.

2.1.4 The Impact of Gut Microbiota on the Nervous System

Gut microbiota interacts with the nervous system through the "gut-brain axis," influencing central nervous system functions. These microorganisms can affect emotions, behavior, and cognitive functions by producing neurotransmitters, regulating neural signal transmission, and influencing the inflammatory response of the nervous system. For example, gut microbiota can synthesize neurotransmitters such as serotonin and gamma-aminobutyric acid (GABA), which modulate neural conduction and emotional states in the brain. Additionally, the metabolic products of gut microbiota, such as SCFAs, also show potential influence on brain function. Studies have found that gut microbiota imbalance may be

associated with the occurrence of neuropsychiatric disorders like depression and anxiety.

2.2 The Relationship Between Gut Microbiota Imbalance and Diseases

2.2.1 Gut Microbiota Imbalance and Inflammatory Bowel Disease

Gut microbiota imbalance is an important factor in the development of inflammatory bowel disease (IBD), which includes Crohn's disease and ulcerative colitis, characterized by chronic inflammation in the gut. Studies have shown that IBD patients exhibit significant changes in gut microbiota composition, including a reduction in beneficial bacteria and an increase in harmful bacteria. The imbalance in gut microbiota leads to abnormal activation of the gut immune system, triggering an inflammatory response. Adjusting the gut microbiota can improve IBD symptoms and treatment outcomes.

2.2.2 The Association Between Gut Microbiota and Metabolic Syndrome

Metabolic syndrome, which includes obesity, diabetes, hypertension, and hyperlipidemia, is closely related to gut microbiota imbalance. Changes in gut microbiota can affect the host's metabolic pathways, such as lipid and carbohydrate metabolism, leading to the development of metabolic syndrome. For example, research suggests that the composition of gut microbiota is associated with host insulin resistance and inflammation levels. Modulating the gut microbiota composition may help alleviate the symptoms of metabolic syndrome.

2.2.3 The Role of Gut Microbiota in Mental Health

The impact of gut microbiota on mental health has been gaining increasing attention. Research indicates that gut microbiota may be associated with mental disorders such as depression, anxiety, and autism spectrum disorders by influencing the gut-brain axis, regulating neurotransmitter synthesis, and modulating inflammation levels. Gut microbiota imbalance may lead to functional abnormalities in the nervous system, thereby affecting mood and cognitive functions. Therefore, regulating gut microbiota may improve mental health to some extent.

2.2.4 Potential Association Between Gut Microbiota and Cancer

The relationship between gut microbiota and cancer is a current research focus. Gut microbiota imbalance may promote cancer development through various mechanisms, including altering the inflammatory environment within the gut, affecting the metabolism of carcinogens, and influencing immune system functions. For example, studies have found that gut microbiota imbalance is closely related to the development of colorectal cancer. Modulating the gut microbiota composition may have potential effects on cancer prevention and treatment.[4]

2.3 Mechanisms of Functional Foods in Regulating Gut Microbiota

2.3.1 The Role of Prebiotics and Probiotics in Gut Health

Prebiotics and probiotics play important roles in regulating gut microbiota. Prebiotics are non-digestible food components that promote the growth and activity of beneficial microorganisms, such as dietary fibers and oligosaccharides; probiotics are live microorganisms that provide health benefits to the host. Prebiotics create a favorable environment for the growth of beneficial bacteria, while probiotics directly increase the number of beneficial bacteria in the gut, thereby improving gut microecological balance, enhancing gut function, and reducing the proliferation of pathogens.

2.3.2 Application of Phytochemicals in Regulating Gut Microbiota

Phytochemicals, such as polyphenols, flavonoids, and isoflavones, have the potential to regulate gut microbiota. These phytochemicals can influence the composition and function of gut microbiota through mechanisms such as antioxidant activity, anti-inflammatory effects, and modulation of microbial metabolism. For example, polyphenolic substances can improve the gut microecological environment by inhibiting the growth of harmful bacteria and promoting the proliferation of beneficial bacteria. The phytochemicals in hawthorn also have significant effects on regulating gut microbiota.

2.3.3 Comparative Analysis of Hawthorn Products and Other Functional Foods

Hawthorn products, along with other functional foods such as yogurt, fermented foods, and prebiotic-rich foods, have different mechanisms in regulating gut microbiota. Hawthorn products, through their bioactive components such as flavonoids and organic acids, promote the growth of beneficial bacteria and improve gut health. In contrast, yogurt and fermented foods directly provide active probiotics,

increasing the number of beneficial bacteria and enhancing the gut environment. A comparative analysis of the mechanisms and effects of these foods can help develop more effective gut health intervention strategies.

3. The Impact of Hawthorn Products on Gut Microbiot

3.1 The Effect of Hawthorn Products on Probiotics

Hawthorn products significantly influence the abundance and diversity of gut probiotics. According to 16S rRNA gene sequencing results, the number of Lactobacillus and Bifidobacterium in mice administered with a high dose of hawthorn increased significantly. These probiotics help maintain gut microbial balance and improve intestinal health. Compared to the control group, the hawthorn product group exhibited a higher proportion of probiotics, indicating that hawthorn products effectively promote the growth and proliferation of probiotics .

3.2 The Inhibitory Effect of Hawthorn Products on Harmful Bacteria

Experimental results indicate that hawthorn products exhibit a significant inhibitory effect on harmful gut bacteria. The abundance of Escherichia coli and Clostridium perfringens in the high-dose hawthorn group was significantly reduced, suggesting that hawthorn products possess certain antibacterial properties. This effect may be related to the antibacterial characteristics of polyphenols and flavonoids present in hawthorn, further demonstrating the potential of hawthorn products in suppressing harmful gut bacteria.[5]

3.3 The Effect of Hawthorn Products on Short-Chain Fatty Acid Production

3.3.1 The Mechanism of Short-Chain Fatty Acid Production

Short-chain fatty acids (SCFAs) are major metabolic products resulting from the fermentation of indigestible cellulose and carbohydrates by gut microbiota. SCFAs, mainly including acetate, propionate, and butyrate, play a crucial role in maintaining gut health and regulating metabolic functions. The intervention of hawthorn products may indirectly increase SCFA production by promoting the proliferation of gut probiotics .

3.3.2 The Impact of Hawthorn Products on Short-Chain Fatty Acid Concentration

Experimental results demonstrate that the intervention of hawthorn products significantly increased the concentration of SCFAs in the intestines of mice, particularly the levels of butyrate and propionate. The SCFA levels in the high-dose hawthorn group were significantly higher than those in the control group, which may be due to the regulatory effect of hawthorn products on gut microbiota, thereby promoting SCFA production.[6]

Conclusion

This study systematically explored the impact of hawthorn products on gut microbiota, showing that hawthorn products can significantly improve gut microbial diversity, promote the proliferation of beneficial bacteria, and enhance SCFA production, demonstrating their potential health benefits as functional foods. Future research could further investigate the specific mechanisms of different hawthorn products and their components, as well as validate their application effects in humans. The study of hawthorn products not only provides a new perspective for the field of food science but also offers new avenues for the prevention and improvement of gut-related diseases.

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