

Research Progress on Functional Components and Pharmacological Effects of Red Jujube (*Ziziphus jujuba* Mill.)

Qian SHI*

Guizhou Academy of Testing and Analysis, Guiyang 550000, China

Abstract Red jujube (*Ziziphus jujuba* Mill.), as a traditional Chinese medicine and edible plant, has a long history and extensive uses. Red jujubes are not only widely used in the food industry and traditional Chinese medicine preparations, but also have attracted widespread research interest due to their rich functional components and various pharmacological effects. This paper reviewed the main functional components of jujubes, including polysaccharides, triterpenoid saponins, organic acids and alkaloids, and discussed in detail the pharmacological effects of these components such as blood sugar-regulating, antioxidant, anti-inflammatory and anti-tumor effects. Furthermore, the paper also summarized the safety issues such as drug interactions and toxic side effects of jujubes, and prospected the future development direction of jujube research.

Key words Jujube; Functional components; Pharmacological effects

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Red jujube (*Ziziphus jujuba* Mill.), also known as Chinese date, is a traditional Chinese medicinal material with a long history, as well as a common edible fruit. Since ancient times, red jujubes have been widely used in the field of traditional Chinese medicine due to their rich nutritional components and medicinal value, and are known as "natural desserts" and "nourishing food". With the continuous development of modern science and technology, research on jujubes has gradually deepened, revealing their rich functional components and diverse pharmacological effects. However, although significant research progress has been made on the pharmacological effects and functional components of jujubes, there are still many issues that need to be further studied, such as the interaction mechanism between various components in jujubes and their optimal use and dosage in clinical applications. Therefore, this paper aimed to review the research progress on the functional components and pharmacological effects of red jujubes, hoping to provide scientific basis for the in-depth development and utilization of red jujubes and promote the modernization of traditional Chinese medicine and the development of the health industry.

Functional Components of Red Jujubes

Red jujubes contain rich functional components, including polysaccharides, triterpenoid saponins, organic acids and alkaloids. Among them, polysaccharides are one of the important components of jujubes, which have immune-regulating, antioxidation and anti-tumor functions. Triterpenoid saponins have pharmacological effects such as blood pressure-lowering, anti-inflammatory, and sedative effects. Organic acids play an important role in

maintaining acid-base balance in the body and promoting gastrointestinal peristalsis. Alkaloids have analgesic and antidepressant effects.

Polysaccharides

The polysaccharides in jujubes are complex molecules composed of multiple sugar molecules, which have received widespread attention in the fields of traditional Chinese medicine and modern medicine. These polysaccharides exist in the form of pectin and hemicellulose in red dates, and have unique structures and physiological functions, making them a research hotspot.

Polysaccharides have been found to have significant immunomodulatory effects in jujubes. Polysaccharides can increase the activity and quantity of immune cells by enhancing the body's immune response, thereby effectively enhancing the body's ability to fight diseases. In addition, polysaccharides can also regulate the secretion of immune factors, promote interactions between different cells, and achieve the effect of balancing the immune system. It makes the polysaccharides in jujubes have potential clinical application prospects in immune regulation.

Antioxidant effect is another important physiological function of polysaccharides in jujubes. In modern life, oxidative stress is a common mechanism of various diseases. However, polysaccharides in jujubes have antioxidant capacity, which can neutralize free radicals, inhibit oxidative reactions, and thus reduce cellular oxidative damage^[1]. The antioxidant effect is of great significance for maintaining cell health and reducing the risk of chronic diseases. In addition, research has shown that polysaccharides in jujubes may have the potential to regulate blood sugar. Polysaccharides are expected to regulate blood glucose levels and provide beneficial auxiliary effects for the treatment of diabetes by affecting insulin secretion and cell sensitivity to glucose. It has opened up a new way for the application of jujubes as a natural medicine or food supplement in the management of diabetes^[2].

Triterpenoid saponins

Triterpenoid saponins are a natural product that has attracted research attention due to its rich biological activity and pharmacological

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Qian SHI (1994 –), female, P. R. China, junior research fellow, devoted to research about food and drugs.

* Corresponding author.

effects, making red jujubes a precious plant resource with potential medicinal value. The triterpenoid saponins contained in jujubes have broad application prospects in the medical field.

Triterpenoid saponins in jujubes have been found to have significant blood pressure-lowering effects due to their unique chemical structures and physiological effects^[3]. Multiple studies have found that these compounds can effectively lower blood pressure levels by reducing blood flow resistance through mechanisms such as dilating blood vessels and reducing peripheral vascular resistance. Triterpenoid saponins have important therapeutic potential for hypertensive patients, providing them with a natural method of reducing blood pressure. In addition to their blood pressure-lowering effect, triterpenoid saponins in jujubes also have anti-inflammatory and sedative effects^[4]. These compounds can regulate inflammatory responses in the body, inhibit the release of inflammatory mediators, and thereby alleviate discomfort and symptoms caused by inflammation. Meanwhile, they also have an impact on the central nervous system. They produce sedative and soothing effects, help to alleviate anxiety and tension, and provide support for mental and physical health^[5]. Triterpenoid saponins in jujubes have also been found to have antioxidant activity. In modern life, oxidative stress is a common factor in many diseases, but these triterpenoid saponins can neutralize free radicals and inhibit oxidative stress reactions, thereby protecting cells from oxidative damage. Such antioxidant effect has important health benefits for delaying cell aging and slowing down disease development.

Organic acids

Organic acids are a class of compounds rich in carbon elements, and their presence in red dates adds unique brilliance to their medicinal and health value^[6]. The organic acids in jujubes play an important role in maintaining acid-base balance. These organic acids play a role in regulating acid-base balance in the body, thereby maintaining the stability of the internal environment. Such balance is crucial for cell metabolism, enzyme activity, and many biochemical reactions. The presence of organic acids helps to prevent high or low pH in the body, thereby maintaining a healthy physiological state^[7].

Organic acids play a crucial role in promoting gastrointestinal peristalsis, and the organic acids in jujubes can stimulate the movement of the gastrointestinal tract, thereby promoting food digestion and absorption. They have a significant effect in improving problems such as indigestion and bloating. Organic acids help to mix food more evenly by enhancing the peristalsis of the gastrointestinal tract, thereby improving food utilization and reducing the risk of adverse reactions. Organic acids also have the effect of enhancing nutrient absorption. Organic acids can promote the absorption of important nutrients such as vitamins and minerals by regulating the gastrointestinal environment. It is crucial for maintaining normal metabolic processes and maintaining health in the body^[8]. The human body can more effectively utilize the nutrients in food by increasing the absorption rate of nutrients, thereby enhancing immunity and overall health levels.

The organic acids in jujubes not only play an important role in maintaining acid-base balance, promoting gastrointestinal peristalsis, and enhancing nutrient absorption, but also endow this fruit with more medicinal and health value. With in-depth research on these organic acids and their mechanisms of action, the health benefits of jujubes will be further explored and utilized, bringing more benefits to human health.

Alkaloids

Alkaloids are a class of organic compounds containing nitrogen elements that possess diverse biological activity. They add new dimensions to the medicinal and health value of red dates.

In jujubes, alkaloids have shown significant analgesic effects. These compounds can interfere with the release and action of neurotransmitters, thereby reducing pain^[9]. Traditional Chinese medicine often uses alkaloids of red dates to alleviate discomfort such as headaches and muscle pain. Such effect provides a theoretical basis for jujubes as a natural analgesic. On the other hand, the alkaloids in jujubes also play an important role in anti-depression and sedation. Research has shown that these compounds can regulate the balance of neurotransmitters, affect emotions and psychological states, and thus alleviate depression and anxiety to a certain extent. In addition, these alkaloids also have the characteristic of producing sedative effects and help to alleviate tension and anxiety, thereby promoting peace and relaxation of the mind and body. The alkaloids in jujubes have also been found to have antioxidant activity. In modern life, oxidative stress is a common mechanism of various diseases. However, these alkaloids can neutralize free radicals in the body, alleviate oxidative stress, and protect cells from oxidative damage, maintaining overall health of the body^[10]. Recent studies have also shown that alkaloids in jujubes may have anti-tumor potential. Although relevant research is still in the preliminary stage, some alkaloids are believed to inhibit the development of tumors by influencing pathways such as tumor cell proliferation, apoptosis, and invasion. It provides a new exploration direction for the application of red dates in cancer treatment.

Pharmacological Effects of Jujubes

Blood sugar regulation

As a traditional Chinese medicine and edible plant, jujube has attracted much attention in its pharmacological role in regulating blood sugar, especially for its polysaccharides and triterpenoid saponins, which have important potential in the field of diabetes treatment^[11].

Polysaccharides are important functional components in jujubes, playing a positive role in regulating blood sugar. Research has shown that polysaccharides in jujubes can stimulate pancreatic islet cells to secrete more insulin, which is an important hormone that regulates blood sugar. Polysaccharides help improve the utilization of glucose in the body by increasing insulin secretion, thereby lowering blood sugar levels. Moreover, polysaccharides in jujubes can also enhance the sensitivity of tissues to glucose,

which is a mechanism that promotes cell absorption and utilization of glucose. Polysaccharides, by increasing the sensitivity of tissues to glucose, help to more effectively convert glucose into energy, reduce the accumulation of excessive glucose in the blood, and thus lower blood sugar levels. These effects make polysaccharides in jujubes a potential blood glucose regulator. On the other hand, triterpenoid saponins in jujubes also participate in the process of regulating blood sugar. These compounds can affect the secretion and action of insulin, thereby regulating blood sugar levels. Some studies have shown that triterpenoid saponins can enhance the sensitivity of pancreatic islet cells to glucose stimulation, promote more insulin release, and thus help reduce the occurrence of hyperglycemia. Such regulatory mechanism makes triterpenoid saponins in red dates another potential regulatory factor of blood glucose^[12]. Therefore, polysaccharides and triterpenoid saponins in jujubes, as important bioactive components, have significant hypoglycemic effects^[13]. These compounds are expected to become useful auxiliary means for the treatment of diabetes and blood glucose management by promoting insulin secretion and increasing cell sensitivity to glucose.

Antioxidation

Red jujubes, as a traditional medicinal and edible fruit, have attracted much attention for their antioxidant effects in their pharmacological effects. Polysaccharides, organic acids and other components in jujubes have significant antioxidant effects, which provide potential pathways for preventing the occurrence of various chronic diseases.

Polysaccharides are one of the important functional components in jujubes and are believed to have significant antioxidant effects. In the body, metabolic processes produce a large number of free radicals, which can trigger oxidative stress, leading to cell damage and inflammatory reactions, thereby promoting the occurrence of various chronic diseases. The polysaccharides in jujubes can neutralize free radicals in the body, thereby reducing oxidative stress, protecting cells from oxidative damage, maintaining cell homeostasis, and preventing the development of chronic diseases. The organic acids in jujubes also contribute to their antioxidant effect. Organic acids are a class of compounds that can react with free radicals, thereby reducing oxidative damage caused by free radicals. Organic acids in jujubes have such ability to clear free radicals in the body and maintain cell health^[14]. Organic acids can also regulate the redox balance within cells, thereby enhancing the antioxidant defense mechanism of cells. Such antioxidant effect makes jujubes have important potential in preventing various chronic diseases. Chronic inflammation, cardiovascular diseases and neurodegenerative diseases are all related to oxidative stress. Consuming red dates rich in antioxidant components can reduce the level of oxidative stress in the body, slow down the progression of diseases, and improve the quality of life.

Anti-inflammatory effect

Triterpenoid saponins and alkaloids in jujubes, as active ingredients, have been widely studied and found to have certain

anti-inflammatory effects, which brings potential value in the field of inflammatory disease treatment.

Triterpenoid saponins are an important active component in jujubes, and their anti-inflammatory effects have received much attention. Inflammation is a common feature of various diseases, and triterpenoid saponins can intervene in the occurrence and development of inflammatory reactions. Research has shown that triterpenoid saponins in jujubes can inhibit the production and release of inflammatory mediators, reducing the intensity of inflammatory reactions^[15]. These compounds regulate the activity of immune cells by affecting inflammatory signaling pathways, thereby achieving the effect of inhibiting inflammation. The anti-inflammatory mechanism of triterpenoid saponins has potential application prospects in the treatment of inflammatory diseases.

On the other hand, alkaloids in jujubes also play a role in anti-inflammatory effects. These compounds are believed to affect the activity of inflammatory cells and inhibit the secretion of inflammatory factors. Alkaloids in jujubes have the characteristic of regulating immune response. They can balance the inflammatory process and reduce tissue damage caused by inflammation. This regulatory effect makes jujubes have certain potential in the treatment of inflammatory diseases. Inflammatory diseases such as rheumatoid arthritis, inflammatory bowel disease and skin inflammation are associated with abnormal inflammatory reactions. Consuming red dates rich in anti-inflammatory ingredients can reduce the level of inflammation in the body, alleviate discomfort caused by inflammation, and improve disease symptoms. The anti-inflammatory effects of triterpenoid saponins and alkaloids in jujubes provide a natural healthy choice for people, and are expected to play a positive role in preventing and alleviating inflammatory diseases^[16].

Antitumor effect

As a common Chinese medicinal material, jujubes not only have rich nutritional value, but also contain various medicinal components. Some of these components have been found to have anti-tumor potential and exhibit pharmacological effects on inhibiting tumor cell proliferation and invasion. An in-depth exploration of the pharmacological properties of jujubes is conducted as blow from the perspective of anti-tumor effect.

Firstly, jujubes are rich in various antioxidant substances, such as polyphenols, vitamin C, and carotenoids. These antioxidant substances can neutralize free radicals in the body, reduce oxidative stress in cells, and thus reduce the risk of cell mutation and tumor occurrence^[17]. The accumulation of free radicals can lead to damage and mutation of cellular DNA, which may trigger the formation of tumors. The antioxidant components in jujubes help maintain cell stability and reduce the possibility of tumor occurrence. Secondly, polysaccharides in red dates have immunomodulatory effects. They can enhance the body's immune system and help control and inhibit tumor growth. The immune system plays an important role in monitoring and suppressing abnormal cells, and polysaccharide components in jujubes can activate

immune cells, and enhance their recognition and attack ability against tumor cells. Jujubes can assist the body in combating the invasion and growth of tumor cells by increasing the activity of immune cells. Thirdly, some bioactive substances in jujubes, such as triterpenoids and polyphenols, have been found to have direct inhibitory effects on tumor cells^[18]. These substances can interfere with the signaling pathways of tumor cells, and inhibit their proliferation and survival ability. These components can inhibit the further development of tumors by affecting the normal function of tumor cells. Fourthly, jujubes also contain some anti-inflammatory components, such as flavonoids and polysaccharides. Inflammation plays an important role in the occurrence and development of tumors, and inhibiting inflammation can reduce the deterioration of the tumor microenvironment, thereby inhibiting tumor growth and metastasis^[19]. Anti-inflammatory components in jujubes can help reduce inflammation levels and create an environment that is not conducive to tumor cell growth.

Conclusions and Prospects

Red jujube, as a common edible plant and medicinal material, has various pharmacological effects and is widely used in traditional Chinese medicine and the food industry^[20]. Their functional components mainly include polysaccharides, triterpenoid saponins, organic acids, and alkaloids. Polysaccharides play a significant role in immune regulation, antioxidation and blood glucose regulation, providing a potential way to enhance immune function, reduce oxidative stress and treat diabetes. Triterpenoid saponins play important roles in blood pressure-lowering, anti-inflammatory, sedative, and antioxidant properties, contributing to cardiovascular health, inflammation control, and the reduction of oxidative damage. Organic acids play a crucial role in maintaining acid-base balance, promoting gastrointestinal peristalsis, and enhancing nutrient absorption, further increasing the medicinal and health value of red dates. Alkaloids exhibit unique pharmacological effects in terms of analgesic, antidepressant, antioxidant, and potential anti-tumor effects. These functional components together constitute the multiple pharmacological effects of jujubes, providing multifaceted support for human health.

For red jujube, as a traditional Chinese herbal medicine and edible plant, the research progress on its functional components and pharmacological effects has provided a solid foundation for its application in the fields of medicine and health care. In the future, further in-depth research can be conducted on the relationship between the active ingredients and pharmacological effects of jujubes, and the mechanism of action can be explored. In addition, the pharmacological effects of red jujubes have potential value in multiple disease treatment and health maintenance fields, which can further expand their clinical applications, especially in immune regulation, antioxidation, and inflammation control. In future research, the impact of different jujube varieties, processing methods and other factors on their functional components and pharmacological effects can also be explored, providing people with a more diverse selection of

jujube products. With comprehensive utilization of modern technological means and deep exploration of the pharmacological potential of jujubes, it is expected to bring more benefits to human health and promote the further development and application of jujubes in the fields of medicine and health care.

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modern urbanites forget to leave. To build an ecologically livable new countryside, we need to take the rural ecological environment into account in agricultural development, ensure food security, promote resource recycling and clean agricultural production, and promote the green development of rural agriculture.

Ecological livability and green agricultural development are coordinated and symbiotic

Ecological livability is to strengthen the protection of rural resources and the environment, coordinate the management of mountains, rivers, forests, farmland, lakes and grasslands, and create a beautiful Chinese new countryside. The goal of green agricultural development is also to promote the formation of green agricultural production model and make contributions to the construction of beautiful countryside with the guidance of friendly ecological environment and sustainable utilization of resources. The focus and goals of the two are consistent, and the common objective requirement of ecological livability and green development is to focus on solving the prominent problems in the current agriculture and rural areas, significantly improve the rural ecosystem, significantly improve the rural ecological service function, and build a harmonious and beautiful beautiful rural picture scroll.

Epilogue

General Secretary Xi Jinping has said that man and nature are a community of life. In fact, what is ecological livable, in many ancient poems has given us the answer, should be Tao Yuanming's "picking chrysanthemum under the east hedge, leisurely see the South mountain", is Su Shi's "water light clear good, mountain empty rain is also strange", is Wang Wei's "the moon between the pine, spring stone upper". These ancient poems depict elegantly vivid, fascinating scene. The future ecological livable country has a beautiful ecological environment, green

and healthy vegetables, convenient life facilities, also can let people have the wind quietly elegant, carefree state of mind. Urban life will no longer be the best choice of modern people, while the country will become people most yearning life place.

The goal of ecological livability puts forward higher requirements for green agricultural development. In the process of green agricultural development, we should fully respect the objective law of rural development, adapt measures to local conditions, base on regional characteristics, and adhere to the guidance of scientific and technological innovation, so as to make a good rural ecological environment become the growth point of people's living quality. We will have a deep understanding of the significance of green agricultural development for the realization of the goal of ecological and livable development, and under the guidance of Xi Jinping Thought on Socialism with Chinese Characteristics for a New Era, we will solve prominent problems in agriculture and rural areas, and build a beautiful new rural home where people live and work in peace and contentment.

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