Advances in Food Science and Human Nutrition (2025)
Clausius Scientific Press, Canada

DOI: 10.23977/afshn.2025.070101
ISSN 2616-258X Vol. 7 Num. 1

Antioxidant Properties of Pear Polyphenols and Their Application in the Development of Functional Foods

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Keywords: Pear Polyphenols; Antioxidant Properties; Functional Food; Food Development; Biological Activity

Abstract: Pear polyphenols are a class of natural active substances widely found in pear fruits, and have remarkable antioxidant properties. In recent years, with the increasing demand for functional foods, pear polyphenols have shown broad application prospects in the development of functional foods due to their unique biological activity and health benefits. This paper summarizes the chemical composition, antioxidant mechanism and their application of pear polyphenols in functional foods, and discusses their stability and future development direction in food processing, in order to provide theoretical basis for further research and application of pear polyphenols.

1. Introduction

With the improvement of people living standards and the enhancement of health awareness, functional food has attracted much attention because of its effect of regulating human physiological function and preventing diseases. Oxidative stress, as an important factor leading to many chronic diseases, promotes the development of antioxidant functional food ingredients. As a fruit rich in polyphenols, pear polyphenols have significant antioxidant, anti-inflammatory, anti-cancer and other biological activities, which show great potential in the development of functional food. This study aims to explore the antioxidant properties of pear polyphenols and their application in functional foods. Through the extraction, separation, and identification of pear polyphenols, it evaluates their antioxidant properties and investigates the underlying mechanism. Additionally, the study explores the practical application of pear polyphenols in beverages, yogurt, and biscuits. The ultimate goal is to develop pear polyphenol-enriched foods with significant antioxidant functions, thereby meeting the diversified demands of consumers for healthy food options.

2. Chemical composition and source of pear polyphenols

As a class of natural compounds with a wide range of biological activities, pear polyphenols play important roles in plants. They not only provide defense mechanisms for plants against environmental stresses and pests, but also have significant benefits for human health, especially in antioxidants. The main chemical composition of pear polyphenols, their distribution and content in pear fruit, and their extraction and purification methods will be explored in detail below.

2.1 Main polyphenols

The chemical composition of pear polyphenols is complex and diverse, which mainly includes flavonoids, phenolic acids, and other polyphenolic compounds. Flavonoids are the most important class of pear polyphenols, which have a unique C6-C3-C6 structure, conferring rich antioxidant properties. Common flavonoids include quercetin, rutin, and luteolin, which are widely found in pear fruits and show strong antioxidant activity. Phenolic acid compounds are also an important part of pear polyphenols, and chlorogenic acid is one of the most representative phenolic acids. Chlorogenic acids not only have significant antioxidant properties, but also participate in diverse physiological processes in plants. In addition, phenolic acid compounds such as catechins and caffeic acid were also detected in pear fruits, which together constitute the antioxidant system of pear polyphenols. In addition to flavonoids and phenolic acids, pear polyphenols also include many other polyphenolic compounds, such as resveratrol, proanthocyanidins, etc. The content and distribution of these compounds in pear fruits varied according to the variety, maturity, and growth environment, but they all had important effects on the antioxidant properties of pear fruits.

2.2 Distribution and content of polyphenols in pear fruit

The distribution and content of polyphenols in pear fruit are significantly diverse. Studies have shown that the polyphenols in pear fruit are mainly distributed in the peel, pulp, fruit heart and seed parts, but there are significant differences in the content and species of polyphenols in each part. The peel is one of the highest polyphenols in pear fruit. The polyphenols in the peel are not only rich in species, but also high in content, which makes it an important raw material for the extraction of pear polyphenols. The polyphenols in the flesh are relatively low, but they also contain a variety of polyphenolic compounds with antioxidant activities. The polyphenols in fruit centers and seeds are also high, but because these sites are usually discarded during consumption, the polyphenol resources are relatively few. The content and distribution of polyphenols also varied among different varieties of pear fruit. For example, the early crisp pear and Nanguo pear two pear varieties have significant differences in the content and species of polyphenols. A variety of flavonol compounds, such as rutin and quercetin, were detected in the pear, while more phenolic acids, such as chlorogenic acid, were detected in the pear. This difference makes different varieties of pear fruit show different characteristics in their antioxidant properties [1].

2.3 Methods of extraction and purification

The extraction and purification of pear polyphenols is a key step in the development of their antioxidant properties and their application in functional foods. At present, the commonly used extraction methods include solvent extraction, ultrasonic extraction, microwave extraction. Among them, the solvent extraction method is one of the most commonly used methods, which uses the solubility difference of polyphenols in the solvent for extraction. Ultrasonic extraction method and microwave extraction method can accelerate the release and dissolution of polyphenols from the pear fruit and improve the extraction efficiency. During the extraction process, the selection of extraction solvent, material-liquid ratio, extraction time and extraction temperature will affect the extraction effect of pear polyphenols [2]. Therefore, these conditions need to be optimized to achieve optimal extraction results. The extracted crude extract of pear polyphenols usually contains many impurities and requires further purification to obtain a high purity of pear polyphenols. Common purification methods include macroporous resin adsorption, membrane separation, chromatography, etc. Among them, the macroporous resin adsorption method is widely used because of its advantages of simple operation, low cost and good purification effect. By selecting

the appropriate macroporous resin model and elution conditions, impurities can be effectively removed and the purity of pear polyphenols can be improved. For example, NKA-9 macropore resin can be used during the purification of pear juvenile polyphenolsLine of adsorption and desorption. The optimal flow rate condition [3] can be determined by comparing the loading adsorption and desorption at different flow rates. Meanwhile, the influence of the elution agent type, volume fraction and elution flow rate on the desorption rate can also be examined to optimize the purification process. The resulting purified products of pear polyphenols have high purity and antioxidant properties, which provides strong support for the development of functional food.

In conclusion, pear polyphenols, as a class of natural compounds with a wide range of biological activities, exhibit remarkable antioxidant properties. An in-depth understanding of the chemical composition, distribution and content in pear fruit, and extraction and purification methods, can provide scientific basis and technical support for the development of functional foods with antioxidant function.

3. The antioxidant properties of pear polyphenols

As a kind of widely eaten fruit, pear is not only sweet and juicy, but also rich in nutrients, especially polyphenols. These polyphenols give pears a unique antioxidant properties, allowing them to play an important role in the maintenance of human health. In this paper, the antioxidant mechanism, in vitro antioxidant experiment and in vivo antioxidant effect will be discussed in detail.

3.1 Antioxidation mechanism

The antioxidant properties of pear polyphenols are mainly due to their multiple mechanisms of action, including free radical scavenging, metal ion chelation, and inhibition of oxidase activity.

First, pear polyphenols have excellent free radical scavenging ability. Free radicals are highly active molecules or atomic groups produced during oxidation reactions in the body that can attack biological macromolecules, such as proteins, lipids and DNA, thus triggering cellular damage and aging. The phenol-hydroxyl structure in pear polyphenols is like a "scavenger", which can effectively neutralize these free radicals and reduce their damage to cells. Many studies have confirmed that pear polyphenols show significant scavenging effect on free radicals such as DPPH radical, ABTS free radicals and nitrite group, and this scavenging ability will gradually increase [4] with the increase of polyphenols concentration.

Secondly, pear polyphenols are able to chelate the metal ions, thereby reducing the level of oxidative stress. In living organisms, metal ions such as iron ions and copper ions often serve as catalysts to accelerate the generation of free radicals, thus exacerbating the oxidative stress response. However, the phenolic groups in pear polyphenols are able to form stable coordination bonds with these metal ions to generate the metal ion-polyphenols complex, thus effectively reducing the catalytic activity of the metal ions and reducing the amount of free radical formation.

In addition, pear polyphenols are able to inhibit the activity of some oxidases, further reducing the rate and degree of oxidative reaction. Oxidases are enzymes that catalyze oxidative reactions, and if their activity is too high, they can cause persistently elevated levels of oxidative stress in the body. Pear polyphenols can "inhibit" the activity of these oxidases, such as polyphenol oxidase (PPO), thus slowing down the process of the oxidation reaction [5].

3.2 In vitro antioxidant experiment

In order to scientifically verify the antioxidant properties of pear polyphenols, the researchers

carefully designed and implemented a series of in vitro antioxidant experiments, covering DPPH radical scavenging experiments, ABTS radical scavenging experiments and ferrous iron reduction capacity (FRAP) experiments. In the DPPH free radical scavenging experiment, the researchers used DPPH, a stable free radical, as the experimental object. The DPPH solution originally appeared purple, but when its free radicals are cleared by the antioxidant—pear polyphenols, the solution becomes significantly lighter and the absorbance decreases accordingly. By accurately measuring the change of absorbance of DPPH solution before and after the addition of pear polyphenols, the researchers successfully calculated the clearance rate of DPPH radical [6]. The experimental results showed that pear polyphenols showed the strong scavenging ability of DPPH free radicals. The principle of the ABTS radical clearance assay is similar to the DPPH radical clearance assay, and also that the antioxidant efficacy of the antioxidants was assessed by observing the changes in the absorbance of the solution. The experimental data clearly show that pear polyphenols also have a very significant scavenging effect on ABTS free radicals.

In addition, the ferrous iron reduction capacity (FRAP) experiments were also used to further assess the antioxidant properties of pear polyphenols. In this experiment, pear polyphenols, as an antioxidant, successfully reduced the Fe 3 + -TPTZ (tripyridyl triazine iron ion) complex to Fe2 +, and thus formed the blue Fe2 + -TPTZ complex. By accurately measuring the absorbance of the blue complex, researchers can accurately calculate the reducing capacity of pear polyphenols. The experimental results show that the ferrous iron reduction capacity of pear polyphenols is also not negligible for [7].

In conclusion, this series of in vitro antioxidant experiments fully validate the excellent antioxidant properties of pear polyphenols and provide a solid scientific basis for their widespread application in the functional food and health industries.

3.3 Antioxidant effects in vivo

In addition to in vitro antioxidant experiments, scientists have also studied in animal models to comprehensively evaluate the antioxidant effects of pear polyphenols in living organisms. In choosing animal models, scientists tend to use mice as subjects. Rice not only reproduce rapidly and have relatively low feeding costs, but also have many similarities in their physiological structure and metabolic mechanisms with humans, which makes them an ideal model to study the efficacy of antioxidants in vivo. In the way of administration, the scientists used gavage to introduce pear polyphenols into mice. As a commonly used means of administration, gavage can ensure that pear polyphenols directly enter the digestive system of mice and are smoothly absorbed into the blood circulation, so as to give full play to their antioxidant effect. In order to scientifically evaluate the antioxidant effect of pear polyphenols in vivo, the scientists collected blood and tissue samples from mice and measured a number of biochemical indicators. These indicators include the activity of superoxide dismutase (SOD), malondialdehyde (MDA) content, and the activity of alanine aminotransferase (ALT) and alanine aminotransferase (AST). These biochemical indicators can sensitively reflect the dynamic changes of oxidative stress level and antioxidant capacity in mice. The experimental results showed that the pear polyphenols were significant. Enhance the activity of SOD in mouse serum and liver, kidney, intestine and other tissues, while effectively reducing the content of MDA, and reducing the release of ALT and AST. These positive changes fully indicate that pear polyphenols are also able to exert significant antioxidant effects in vivo, helping to alleviate the tissue damage of oxidative stress and maintaining the integrity of cellular structure and function [8].

In conclusion, with their excellent antioxidant properties, pear polyphenols show strong antioxidant effects in vitro and in vivo through multiple mechanisms such as free radical scavenging,

chelating metal ions and inhibition of oxidase activity. Through the dual validation of in vitro antioxidant experiments and animal model research, the scientists have provided a solid scientific basis for the wide application of pear polyphenols in food, health care products and medicine.

4. Application of pear polyphenols in the development of functional foods

4.1 Definition and development trend of functional foods

Functional foods are those that have specific health benefits in addition to providing basic nutritional needs. This type of food is designed to improve physical condition, prevent disease, or enhance physical function. With peoples growing pursuit of healthy life, the functional food market shows a booming trend. At present, the development trend of functional food is diversified, personalized, scientific and technological, to meet the health needs of different consumers.

4.2 Application form of pear polyphenols in food

As a natural ingredient with significant antioxidant properties, pear polyphenols show great application potential in the development of functional foods. Pear polyphenols can be used in food in various forms, including but not limited to beverages, dairy products, baked goods, etc.

In the field of beverage, pear polyphenols can be added as antioxidants to fruit juice and tea drinks, so as to improve the antioxidant performance of products and meet the demand of consumers for healthy drinks. In addition, the addition of pear polyphenols can also add a unique fruit aroma and taste to the drink, and improve the overall quality of the product. In terms of dairy products, pear polyphenols can be combined with milk, yogurt and other dairy products to develop products with antioxidant, anti-aging and other functions. This combination not only enriches the taste and flavor of dairy products, but also provides consumers with more healthy choices.

In baked goods, pear polyphenols can be used as natural preservatives or antioxidants, extending the shelf life of the products, while maintaining the color and texture of the food. In addition, the addition of pear polyphenols can also add a certain nutritional value to baked goods and improve the health attributes of the products.

4.3 Specific case analysis

Take antioxidant drinks as an example, a brand has launched antioxidant juice drinks containing pear polyphenols. The drink used fresh pear juice as the main ingredient and was supplemented with appropriate amounts of pear polyphenol extract. Through scientific matching and technological processing, the beverage not only retains the original flavor and nutritional composition of pears, but also enhances its antioxidant performance. After drinking, consumers can effectively resist the infringement of free radicals, slow down the aging process, and improve their health level. In terms of anti-aging food, a company has launched health care capsules containing pear polyphenols. The capsule uses advanced extraction technology to extract high-purity polyphenols from pears, combined with other natural ingredients, such as vitamin E and grape seed extract, to jointly play an anti-aging role. Consumers take the capsule for a long time, can significantly improve the skin state, reduce the production of wrinkles and spots, maintain youthful vitality [9].

In conclusion, pear polyphenols are widely used in the development of functional foods. Through reasonable formula design and process treatment, pear polyphenols can be effectively applied in beverages, dairy products, baked goods and other food forms, to provide more healthy choices for consumers. In the future, with the progress of science and technology and the continuous improvement of consumers demand for health, the application of pear polyphenols in

the field of functional food will be more extensive and deeper.

5. Stability of pear polyphenols in food processing

As a natural ingredient with many biological activities, pear polyphenols show great application potential in food processing. However, its stability is susceptible to various factors during processing, such as temperature, pH, and illumination. To ensure the effective use of pear polyphenols in food processing, we need to deeply understand the influence of these factors on their stability and adopt the methods to improve their stability accordingly [10].

5.1 Effect of processing conditions on the stability of pear polyphenols

High temperature conditions may adversely affect pear polyphenols, leading to their degradation and inactivation. In food processing processes, the high temperatures involved in these processes, such as heat treatment or baking, may significantly reduce the content of pear polyphenols and weaken their bioactivity. Moreover, the pH of the solution plays a crucial role in the stability of pear polyphenols. Too acidic or alkaline environment may damage the structure of pear polyphenols, and then reduce its bioactivity [11]. Therefore, the pH of the products must be strictly monitored and adjusted to ensure the stability of pear polyphenols. On the other hand, long light exposure may also have a negative impact on pear polyphenols, leading to their degradation. Light exposure accelerates the process of oxidation reaction, which destroys the structure of pear polyphenols and reduces its bioactivity. Therefore, prolonged light exposure should be avoided during storage and processing to protect the integrity and efficacy of pear polyphenols.

5.2 Methods to improve the stability

Microencapsulation provides an efficient strategy for improving the stability of pear polyphenols. By encapsulating pear polyphenols in tiny capsules, this technology builds a solid barrier to effectively isolate the intrusion of temperature fluctuations, pH changes and illumination and other external adverse factors. This method not only significantly enhances the stability of pear polyphenols, but also greatly facilitates its flexible application in the field of food processing. In addition, in the food processing process, the scientific and reasonable addition of protective agents can also help to improve the stability of pear polyphenols. The addition of antioxidants can effectively inhibit the process of oxidation reaction, and then slow down the degradation rate of pear polyphenols, while the introduction of stabilizer and thickening agent can further optimize the product texture and enhance its stability.

In conclusion, the stability of pear polyphenols faces multiple challenges during food processing. In order to fully tap its potential value and ensure its effective application, we must take targeted measures to enhance its stability. Through the clever use of microencapsulation technology and the reasonable addition of protective agents, we can effectively build a solid defense line for pear polyphenols, making it free from the external environment, so as to show more excellent stability and biological activity in food processing. This will lay a solid foundation for the wide application of pear polyphenols in the functional food and health industry, and promote the continuous development of this field.

6. Challenges and future development directions

Although pear polyphenols have shown great application potential and value in the functional food and health industry, there are still some limitations and problems to be solved in the current

research field. The first problem is that the extraction efficiency and purity of pear polyphenols still need to be further improved. Traditional extraction processes are generally faced with problems such as high energy consumption, long time consuming and low extraction efficiency, which greatly hinder the large-scale production of pear polyphenols and their application in a wider field. In addition, the current research on the biological activity mechanism and functional characteristics of pear polyphenols is still not in-depth, and lack of comprehensive and systematic exploration and verification. We have not fully revealed the precise mechanism by which pear polyphenols function within organisms and have not fully defined their diverse functional properties [12].

To address these challenges, future research can work in several directions:

First, the research, development and application of new extraction technology. We can actively develop more efficient and environmentally friendly pear polyphenols extraction methods, such as ultrasonic assisted extraction, microwave extraction and high pressure extraction and other advanced technologies. These new technologies are not only expected to significantly improve the extraction efficiency and reduce the energy consumption, but also can better maintain the biological activity of pear polyphenols, providing strong support for the large-scale production of pear polyphenols.

The second is to deeply study the mechanism of synergistic action between pear polyphenols and other active components. We should pay more attention to the interaction relationship between pear polyphenols and other active ingredients such as vitamins, minerals, dietary fiber, and explore their synergistic patterns in the functional food and health industries. This will help us to develop functional foods with multiple health benefits and rich mouthfeel, and to better meet the diverse needs of consumers.

In conclusion, despite the research challenges, through continuous innovation and exploration, we are expected to make new breakthroughs in extraction technology, bioactivity mechanisms, and functional properties. This will lay a solid foundation for promoting the wide application of pear polyphenols in the functional food and health industries, provide consumers with more healthy and delicious food choices, and promote the vigorous development of related industries.

7. Conclusion

With their excellent antioxidant properties, pear polyphenols have shown a very high application value in the development of functional food. It effectively resists oxidative stress and protects cells from damage through scavenging of free radicals, chelation of metal ions, and inhibition of oxidase activity. In the diversified application forms such as beverages, dairy products and baked goods, pear polyphenols not only enhance the antioxidant characteristics of food, but also enrich the taste and nutritional value of products, satisfying consumers pursuit of healthy food. The research and application of pear polyphenols have profound implications for the development of functional food. It encourages us to explore more natural antioxidant components and innovate extraction and protection technologies to efficiently retain and enhance the biological activities of these components. At the same time, the successful application of pear polyphenols also indicates that functional foods will pay more attention to the synergy between ingredients, committed to the development of innovative products with comprehensive health benefits, leading the food industry to a healthier and more sustainable direction.

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