

# Research Progress on the Antioxidant Activity of Oolong Tea

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**Abstract:** Oolong tea, a unique type of semi-fermented tea, has garnered widespread attention in recent years due to its distinctive production process and nutritional composition. Particularly, its antioxidant capacity has become a focal point for numerous researchers. This study systematically reviews the latest research advances in antioxidant compounds in oolong tea, discusses their potential applications in food preservation, processing, and functional food development, and anticipates future developments in the antioxidant activity of oolong tea.

## 1. Introduction

In the process of delving into the profound cultural essence of the East, Oolong tea has gradually emerged on the global stage with its unique flavor profile and rich nutritional content. As a splendid gem of Chinese tea culture, Oolong tea stands out with its distinctive semi-fermentation process, blending the freshness of green tea with the robustness of black tea to create its own unique taste and aroma. In recent years, with the increasing pursuit of healthier eating habits among consumers, the abundant antioxidant compounds in Oolong tea and their potential health benefits have become a hot topic in the field of scientific research.

Antioxidants act as a natural barrier against oxidative stress, playing an essential role in maintaining human health. In the fast-paced context of modern life, factors such as environmental pollution and stress can lead to elevated levels of free radicals within the body, creating a growing demand for antioxidants. Oolong tea, as a natural source of antioxidants, not only holds significant importance for unveiling its health effects but also carries practical implications for guiding consumers towards making informed choices about healthy beverages.

## 2. Antioxidant Composition Analysis of Oolong Tea

### 2.1. Major Constituents and Its Antioxidant Properties

Antioxidants in oolong tea mainly include catechins, polyphenols, flavonoids, and other natural antioxidants[1]. These components endow oolong tea with strong antioxidant capacity, effectively removing free radicals and inhibiting oxidative stress, thereby exerting beneficial effects on human health.

Catechins are important antioxidant compounds in oolong tea, belonging to the category of polyphenols. They are characterized by high stability and strong antioxidant capacity. Studies have shown that catechins can remove free radicals through two main mechanisms: one is directly binding to free radicals and converting them into stable molecules; the other is activating the body's antioxidant enzyme system, such as superoxide dismutase (SOD) and glutathione peroxidase (GPx), to play an antioxidant role[2]. Among various catechins, EGCG (epigallocatechin gallate) is the most prominent type, with the most significant antioxidant capacity[3].

Polyphenols are another important class of antioxidant compounds, referring to a series of compounds with polyphenol structures. Apart from catechins, they also include theophylline, thearubigin, and other compounds. These compounds have strong reducing properties and can effectively eliminate peroxides and free radicals, preventing lipid peroxidation and DNA damage. Moreover, polyphenols can regulate the expression of antioxidant enzymes in the body through influencing cell signaling pathways, thus playing an antioxidant role. The types and content of polyphenols directly affect the antioxidant performance of oolong tea.

Flavonoids are a class of important natural antioxidants, best known for their strong antioxidant capacity. These compounds can exert antioxidant effects through various mechanisms, including directly removing free radicals, inhibiting lipid peroxidation, enhancing the antioxidant defense system of cells, etc. In oolong tea, flavonoid compounds mainly include catechins, flavonols, and flavonol glycosides, and their content and proportion significantly affect the overall antioxidant performance of oolong tea. High-performance liquid chromatography (HPLC) can be used for quantitative analysis of these flavonoid compounds, helping to further understand the antioxidant mechanism of oolong tea[4].

Apart from the above main antioxidant components, oolong tea also contains other natural antioxidants, such as vitamin C, vitamin E, and beta-carotene. Although

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these components have relatively low content in oolong tea, together with the main antioxidant components such as catechins, polyphenols, and flavonoids, they form a complex antioxidant network. This synergistic effect makes the antioxidant capacity of oolong tea more comprehensive and lasting, providing a solid defense line for the human body against oxidative stress.

## **2.2. Comparison of antioxidant content with other popular teas (green tea, black tea, white tea)**

### *2.2.1 Oolong tea*

Oolong tea is a semi-fermented tea with a tea polyphenol content between green tea and black tea. Studies have shown that the total amount of tea polyphenols in oolong tea can reach about 20% to 30% of the dry weight of tea leaves. Among them, catechins are one of the major antioxidants in oolong tea, especially epigallocatechin (EGC) and epigallocatechin gallate (EGCG), which occupy a significant proportion of the total catechins.

### *2.2.2 Green tea*

Green tea is a non-fermented tea and its tea polyphenol content is usually high. In particular, EGCG, the major catechin component in green tea, can account for about 3% to 5% of the dry weight of the tea leaves. This high content of EGCG makes green tea outstanding in antioxidant capacity.

### *2.2.3 Black Tea*

Black tea is a fully fermented tea, and during the fermentation process some of the tea polyphenols are oxidized into compounds such as theaflavin and thearubigin. Therefore, the total amount of tea polyphenols in black tea is relatively low. However, black tea still contains a certain amount of tea polyphenols and other antioxidant substances.

### *2.2.4 White Tea*

White tea is an under-fermented tea with a moderate amount of tea polyphenols. The tea polyphenols in white tea exist in unoxidized form and have high biological activity. In addition, white tea is also rich in other antioxidant substances such as flavonoids.

The content of tea polyphenols in oolong tea is between that of green tea and black tea, and catechins are its main antioxidant components, especially the high content of EGC and EGCG. This unique combination of catechins makes oolong tea excel in antioxidant capacity. Although green tea has a higher content of EGCG, oolong tea is also rich in other catechin components, providing a more comprehensive antioxidant effect. Black tea has some of its tea polyphenols oxidized during the fermentation process, resulting in a relatively low total amount. And although white tea has a moderate amount

of tea polyphenols, its unique processing method retains more of the original components.

## **2.3. Methods of Extraction and Separation of Antioxidant Compounds**

As a treasure of traditional Chinese tea culture, Oolong tea is rich in various bioactive substances, among which antioxidant compounds are particularly noteworthy. To delve into the types, contents, and bioactivities of antioxidant compounds in Oolong tea, selecting efficient and appropriate extraction and separation methods is crucial.

Traditional extraction methods, such as hot water extraction, ethanol extraction, and ethyl acetate extraction, are the basis for the isolation of natural compounds in oolong tea. The hot water extraction method utilizes water as a solvent and promotes mass transfer between the solvent and the solid tea leaves by heating, thus extracting the soluble components from the tea leaves. This method is simple and inexpensive. However, the hot water extraction method has some limitations, and the high temperature may destroy some heat-sensitive antioxidant components [5], resulting in a decrease in their activity. Compared with the hot water extraction method, ethanol extraction and ethyl acetate extraction have higher extraction efficiency as organic solvent extraction methods. Ethanol is a polar organic solvent that can effectively extract polyphenols from tea. Ethyl acetate, on the other hand, is a non-polar organic solvent, which has a unique advantage in extracting the fat-soluble components in tea. These two organic solvents extraction method can not only improve the extraction rate, but also to a certain extent to retain the active ingredients in tea. However, the use of organic solvents requires consideration of solvent recovery and environmental impact, which is not conducive to sustainable development.

With advancements in technology, modern extraction techniques such as ultrasound-assisted extraction (UAE), microwave-assisted extraction (MAE), and supercritical fluid extraction (SFE) have provided new insights into the extraction of antioxidant compounds from Oolong tea[6]. Ultrasound-assisted extraction takes advantage of the mechanical vibration and cavitation effect generated by ultrasound to disrupt plant cell walls, facilitating solvent penetration and improving extraction efficiency and rate. Microwave-assisted extraction achieves rapid and uniform heating via microwaves, allowing for the effective extraction of compounds from tea within a short time. Supercritical fluid extraction, utilizing supercritical carbon dioxide as a solvent, offers advantages such as strong solvency power, good selectivity, and no residue, especially suitable for extracting heat-sensitive antioxidant compounds in tea.

After extracting antioxidant compounds from Oolong tea, the next step involves separating and purifying these compounds. Common separation techniques include chromatographic techniques, membrane separation technology, and electrophoresis technology, among others[7]. Chromatographic techniques, particularly

HPLC (High-Performance Liquid Chromatography) due to its high resolution, sensitivity, and broad applicability, have become an essential tool for separating polyphenolic compounds in Oolong tea. Membrane separation technology, a physical separation method, employs selective membranes to separate components in mixtures, offering advantages such as simplicity of operation, low energy consumption, and no solvent residue, making it suitable for separating macromolecular and small molecular antioxidant compounds in tea. Electrophoretic techniques, especially Capillary Electrophoresis (CE), stand out for their high efficiency, high resolution, and low sample consumption, demonstrating unique advantages in separating complex mixtures of natural products.

### **3. Application Studies of Antioxidant Activity in Oolong Tea**

#### **3.1. Research Progress on Health Benefits**

The antioxidant characteristics are at the core of the health benefits associated with Oolong tea. Antioxidants such as catechins and flavonoids in Oolong tea effectively mitigate oxidative stress-induced cellular damage through mechanisms such as direct radical scavenging and enhanced antioxidant enzyme activity[8]. This property positions Oolong tea as a promising preventive agent against cardiovascular diseases, cancer, and other oxidative stress-related conditions.

##### *3.1.1 Cardiovascular health*

In terms of cardiovascular health, the antioxidant components of oolong tea can lower blood pressure, inhibit platelet aggregation, and reduce blood lipid levels, thus exerting a protective effect on the cardiovascular system. It has been shown that the incidence of cardiovascular diseases in people who drink oolong tea for a long time is lower than those who do not drink tea[9]. In addition, oolong tea improves vascular function, enhances vascular elasticity and reduces the risk of atherosclerosis. It improves the endothelial function of blood vessels by promoting vasodilation and reducing vascular inflammatory response, thus maintaining the normal physiological function of blood vessels.

##### *3.1.2 Cancer prevention*

Cancer is a complex multifactorial disease, in which inflammatory response and oxidative DNA damage are one of the important factors leading to the development of cancer. In terms of cancer prevention and treatment, the antioxidant component of oolong tea reduces the risk of cancer by inhibiting the inflammatory response and reducing oxidative DNA damage. Oolong tea extracts have been found to inhibit the proliferation of certain cancer cells and promote their apoptosis, showing potential in fighting cancer. This provides a scientific basis for the use of oolong tea in cancer control.

#### **3.1.3 Metabolic disorders**

In addition, oolong tea also has certain preventive and therapeutic effects on metabolic diseases such as obesity and diabetes. Obesity and diabetes are major public health problems facing the current society, and they are closely related to metabolic disorders. Oolong tea extract can positively affect these diseases through mechanisms such as regulating fat metabolism and improving insulin sensitivity. For example, oolong tea can promote lipolysis and increase energy expenditure, thus helping to control body weight; at the same time, it can also improve insulin resistance and insulin sensitivity, thus lowering blood glucose levels[10].

### **3.2. Health benefits compared to other popular teas (green, black, white)**

#### *3.2.1 Antioxidant and Anti-Aging*

The antioxidants in oolong, green, black and white teas are able to scavenge free radicals and inhibit oxidative cellular damage, resulting in significant antioxidant and anti-aging effects. These antioxidants can protect cells from the external environment and slow down the aging process.

#### *3.2.2 Reducing the risk of cardiovascular diseases*

The antioxidants in these teas are also able to reduce blood lipids, blood pressure and blood glucose levels, thus helping to prevent the occurrence of cardiovascular diseases. Oolong and green teas, in particular, show a more prominent role in this regard. The tea polyphenols and catechins in oolong tea can effectively block the production and absorption of cholesterol, thus lowering blood cholesterol levels. Green tea, on the other hand, is particularly effective in lowering LDL cholesterol. In addition, these ingredients promote vasodilation and help lower blood pressure. For people with high blood pressure, moderate daily consumption of green tea can significantly improve blood pressure. At the same time, the active substances in tea can also improve insulin sensitivity and promote glucose metabolism, thus helping to maintain stable blood sugar. Both from animal experiments and clinical trials, oolong tea and green tea show positive effects in controlling blood glucose and improving insulin resistance.

#### *3.2.3 Improvement of brain function*

The catechin component of green tea can improve brain function, concentration and memory. In addition, the caffeine in green tea also helps to refresh the mind and improve work efficiency.

#### *3.2.4 Enhancement of immunity*

A variety of nutrients in white tea such as tea polyphenols and flavonoids help to improve the body's immunity and prevent diseases. These antioxidants can enhance the

function of the immune system and improve the body's resistance to disease.

Antioxidants such as tea polyphenols and catechins in oolong tea can scavenge free radicals and inhibit oxidative cell damage, which has significant antioxidant and anti-aging effects. Not only that, the tea polyphenols in oolong tea can reduce blood lipids, blood pressure and blood glucose levels, which can help prevent the occurrence of cardiovascular diseases. In addition, tea polyphenols and caffeine in oolong tea can stimulate gastrointestinal peristalsis, promote food digestion and fat metabolism, which helps to lose weight. At the same time, Oolong tea is also rich in a variety of nutrients, such as flavonoids, which help to improve the body's immunity. Compared to green tea, oolong tea is superior in promoting digestion and weight loss; while black tea stands out with its unique advantages of invigorating and refreshing the mind and keeping warm; and white tea shines in boosting immunity and antibacterial and antiviral properties. However, when it comes to antioxidant capacity, oolong tea still holds an irreplaceable position.

### **3.3. Antioxidants in the Food Industry**

In recent years, with the improvement of people's living standards and increasing pursuit of healthy diet, the role of natural antioxidants in food preservation, processing, and the development of functional foods has gained significant importance. As a beverage rich in natural antioxidants, the potential applications of Oolong tea in the food industry cannot be overlooked.

#### **3.3.1 Food preservation area**

Oolong tea antioxidants play a remarkable role in food preservation. During the processing and storage of food products, oxidation can lead to quality degradation and loss of nutritional value. Traditional chemical preservatives are effective in extending shelf life but are increasingly being resisted by consumers due to safety concerns. The natural antioxidants in Oolong tea, such as catechins, polyphenols, and flavonoids, can effectively neutralize free radicals and inhibit lipid peroxidation, thereby slowing down the oxidation process of food[11]. Studies have shown that Oolong tea extracts can significantly enhance the antioxidant capacity of perishable food items like meat products and dairy products, prolonging their shelf life while maintaining their original color and flavor. This approach of using natural plant extracts as an alternative to traditional chemical preservatives not only meets consumer demands for food safety and naturalness but also provides new ideas for the development of food preservation technology.

#### **3.3.2 Food processing area**

In the field of food processing, Oolong tea antioxidants also exhibit great potential. During the processing of food products, various additives are often added to improve appearance, texture, and nutritional value[12]. However, some additives may cause oxidative reactions, affecting

the quality of the food. The use of Oolong tea extracts as a natural additive can enhance the antioxidant performance of food. For instance, in the processing of fruits and vegetables, Oolong tea extracts can effectively prevent browning and maintain freshness and nutritional content; in oil-based food products, adding Oolong tea extracts can delay oxidation and rancidity, improving product stability. This method reduces reliance on traditional chemical additives and enhances the nutritional value and market competitiveness of food products.

#### **3.3.3 Functional food development**

The application of Oolong tea antioxidants in the development of functional foods is equally promising. Functional foods are defined as those that have regulatory effects on bodily functions, benefit specific physiological conditions, and are not intended for the treatment of diseases. With growing public interest in health, the market for functional foods is expanding. The abundant antioxidants in Oolong tea not only provide antioxidant protection but also offer multiple health benefits, including anti-tumor, anti-inflammatory, and cardiovascular protection. Therefore, incorporating Oolong tea antioxidants as functional factors in the development of various functional foods and beverages is a significant research direction in the field of food science. For example, creating health drinks, nutrition bars, yogurt, and other products rich in Oolong tea extracts can meet consumer demand for healthy food options and drive the deep processing and industrialization of Oolong tea. Additionally, through research on the synergistic effects between Oolong tea antioxidants and other nutrients, the range of applications in functional foods can be further expanded, offering consumers a wider variety of personalized and diversified healthy food choices.

### **3.4. Challenges to the commercialization of oolong tea extracts**

Although oolong tea extracts show great potential for application in the food industry, they still face many challenges in the commercialization process. First, cost control is an important issue. The production and extraction costs of oolong tea extracts are relatively high, which may affect the market competitiveness of the products. Therefore, it is necessary to explore ways to reduce the cost, such as optimizing the extraction process and improving the utilization of raw materials. Secondly, the balance of taste and flavor is also a challenge. Oolong tea has a unique aroma and taste, but the balance between taste and flavor needs to be fully considered when combining with other food ingredients. The R&D process requires continuous experimentation and adjustment of formulations to ensure that the overall taste and flavor of the product meets consumer demand. In addition, factors such as consumer acceptance, regulations and standards, and market competition are also concerns in the commercialization of oolong tea extracts.

## 4. Conclusion

The antioxidant compounds in Oolong tea, such as catechins and polyphenols, primarily exert their action through multiple mechanisms, including scavenging reactive oxygen species, enhancing the activity of antioxidant enzymes, and reducing lipid peroxidation levels[13]. These compounds' antioxidant abilities have been validated not only in vitro but also in vivo models, showing significant protective effects against oxidative stress-induced cellular damage. Furthermore, the antioxidants present in Oolong tea also exhibit potent anti-cancer, anti-inflammatory, and cardiovascular protective effects, providing scientific evidence for its applications in health and disease prevention.

However, despite the fact that a series of important discoveries have been made in the study of antioxidant components of oolong tea, there are still some challenges and limitations. First, the current understanding of antioxidant components in oolong tea is not comprehensive enough, and many potential active components have not yet been identified or studied in detail. Second, relatively few studies have been conducted on the absorption, metabolism and bioavailability of antioxidant components in oolong tea in vivo, which limits our in-depth understanding of their health benefits. In addition, the antioxidant mechanisms of the antioxidant components of oolong tea have not been fully clarified, and further exploration of their mechanisms of action and signaling pathways is needed.

Looking ahead, the research on the antioxidant components of oolong tea should be explored in depth from the following aspects: first, through in-depth study of the chemical composition and biological activity of oolong tea, the antioxidant mechanism should be revealed, so as to provide a scientific basis for the development of oolong tea products with specific functions. Secondly, the research on the absorption, metabolism and bioavailability of the antioxidant components of oolong tea should be strengthened, so as to clarify the mechanism of their action and health effects in the human body, and to provide a more solid scientific basis for the health functions of oolong tea. In addition, a comprehensive system for evaluating the antioxidant activity of oolong tea should be established, taking into account a variety of influencing factors, including tea varieties, production processes, additives and so on. This will help to more accurately evaluate the antioxidant properties of oolong tea and provide consumers with more valuable choices of healthy beverages.

In terms of application, the prospects for the use of Oolong tea and its antioxidant compounds in the food, pharmaceutical, and cosmetic industries are promising. By extracting and purifying high-activity antioxidant components from Oolong tea, novel natural antioxidants can be developed for use in food preservation, disease prevention, and skin care. Moreover, with the aid of modern biotechnology, such as genetic engineering and cell engineering techniques, the production efficiency and effectiveness of Oolong tea antioxidants can be improved, leading to the development of more functional foods and drugs. As research on Oolong tea antioxidants deepens,

we believe that Oolong tea and its extracts will play a greater role in health maintenance and disease prevention.

As a naturally rich source of antioxidant compounds, Oolong tea's health benefits have been widely recognized by the scientific community. Through in-depth research into the chemical composition, biological activities, and mechanisms of action of Oolong tea, not only can we provide a more robust scientific foundation for its health-promoting effects but also open up new avenues for its broader application in product development. With the progress of technology and ongoing research, Oolong tea and its antioxidant compounds will undoubtedly play a more significant role in human health and disease prevention.

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