Research article

Influence and progress of tea pigment research: A comprehensive analysis of application of bibliometrics

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A B S T R A C T

Tea pigment, as a natural pigment component in tea, has attracted much attention because of its unique health benefits. In recent years, with the deepening of scientific research, the research on biological activity, extraction technology and application of tea pigment has made remarkable progress. Through systematic bibliometrics analysis, this paper comprehensively combs and evaluates the research status of tea pigment. The propose is to provide valuable reference for future research and application. In this paper, the chemical structure of tea pigment is firstly summarized, and then its diverse biological activities, such as antioxidant, anti-inflammatory and anti-tumor, are deeply discussed, especially its potential application in the treatment of cardio-vascular diseases and diabetes. In addition, the application prospect of tea pigment in food coloring, textile dyeing and other industrial fields is also discussed in detail. Through the collection and arrangement of a large number of research literatures, this paper analyzes the development trend, research methods and main achievements of tea pigment research, and pays special attention to the dosage and effect of tea pigment in practical application. These analyses not only contribute to a more comprehensive understanding of the characteristics and functions of tea pigments, but also provide scientific basis for the further development and application of tea pigments.

1. Introduction

Tea pigment, as a natural pigment of tea, has been widely concerned in the fields of nutrition, medicine and food science in recent years. It not only adds unique flavor and color to tea, but also shows great potential in health promotion and disease prevention because of its potential biological activity. With the deepening of scientific research, the research on tea pigment is increasing day by day, showing a vigorous development trend. These studies cover many aspects of tea pigment, such as chemical structure, biological activity, pharmacological action and the effect in practical application. Scientists have found that tea pigment has many biological

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activities, such as anti-oxidation, anti-inflammatory, anti-tumor and regulating blood lipid, which provides theoretical support for the application of tea pigment in the prevention and treatment of chronic diseases. However, despite the remarkable achievements in the study of tea pigment, there are still many problems and challenges to be solved urgently. For example, the biological activity mechanism of tea pigment is not completely clear, and its optimal dosage and administration mode in practical application still need further exploration. In addition, the effects of different tea varieties and processing methods on the content and composition of tea pigments need to be further studied.

Fan et al. (2013) discussed the free radical scavenging and antioxidant properties of ethanol-soluble pigment extracts from Zijuan Pu'er tea. The experimental results showed that the extract had strong scavenging ability to DPPH and TEMPO free radicals, can effectively protect cells from oxidative damage induced by H2O2, and can significantly enhance the activity of superoxide dismutase in cells, reduce the concentrations of malondialdehyde and lactate dehydrogenase, showing excellent antioxidant capacity [1]. Kusmita et al. (2015) successfully identified a variety of pigments in green tea, including β-carotene, pheophorbide A, chlorophyll B, xanthophyll and pheophorbide A, by thin layer chromatography and high-performance liquid chromatography with photodiode array detector. Furthermore, pheophytin A was successfully separated by column chromatography, and its antioxidant activity was evaluated by 2,2- diphenyl -1- picrylhydrazyl method. The results showed that the antioxidant activity of pheophytin A was equivalent to that of β-carotene, while the antioxidant activity of green tea crude extract was twice that of β-carotene. This discovery not only provided a scientific basis for the identification of pigment components in green tea, but also provided a potential resource for further development of antioxidants in green tea [2]. Tanaka and Matsuo (2020) discussed the antioxidant and anti-inflammatory activities of tea pigment in detail, and summarized its application status in medical and food fields. The main achievements included confirming the therapeutic potential of tea pigment for chronic diseases such as diabetes and cardiovascular diseases [3]. Kumari et al. (2020) mainly studied the application of tea pigment in fiber dyeing. The results showed that tea pigment can not only provide natural color for fiber, but also have good dyeing fastness and environmental protection, which provided a new natural dye choice for textile industry [4]. Olennikov et al. (2021) studied the extraction method of tea pigment and evaluated its antioxidant properties. The research showed that optimizing the extraction process can significantly improve the yield and quality of tea pigment, and its strong antioxidant performance provided the possibility for developing new antioxidants [5]. Oliveira et al. (2020) deeply studied the role of tea pigment in preventing cardiovascular diseases, and found that it can reduce blood pressure and improve blood lipid metabolism, thus effectively preventing the occurrence of atherosclerosis [6]. Choe et al. (2020) mainly discussed the application of tea pigment in food industry, including improving food color and flavor, and predicted its market prospect [7]. Maritim et al. (2021) summarized the research results of antioxidant effect of tea pigment in recent years, indicating that tea pigment, as a natural antioxidant, has potential application value in preventing aging and anticancer [8]. Li et al. (2022) studied the therapeutic effect of tea pigment on diabetes, and found that it can significantly reduce blood sugar level and improve insulin resistance, which provided a new idea for the treatment of diabetes [9]. Sonobe et al. (2020) studied the extraction method of tea pigment and evaluated its antioxidant properties. The results showed that the extraction process of tea pigment had an important influence on its antioxidant properties, and optimizing the extraction process can improve the antioxidant effect of tea pigment [10]. O'Neill et al. (2021) discussed the application of tea pigment in textile dyeing, and studied its dyeing properties and dyeing mechanism, which provided a theoretical basis for the application of tea pigment in textile industry [11]. Salimikia et al. (2023) studied the inhibitory effect of tea pigment on the growth of tumor cells, and found that tea pigment can inhibit the proliferation of tumor cells and promote their apoptosis, which provided experimental basis for the application of tea pigment in tumor treatment [12]. Morlock et al. (2021) discussed the influence of tea pigment on intestinal flora, and found that tea pigment can promote the growth of beneficial bacteria and inhibit the reproduction of harmful bacteria, thus maintaining intestinal health, which provided a new perspective for the application of tea pigment in the field of intestinal health [13]. Hassan (2023) studied the extraction and purification methods of tea pigments, and successfully identified the structures of some tea pigments. This provided an important basis for further understanding the biological activity of tea pigment and developing efficient extraction technology [14]. To sum up, tea pigment had multiple biological activities such as anti-oxidation, anti-inflammatory and anti-tumor, especially in the treatment of cardiovascular diseases and diabetes. In addition, tea pigment is also used in food coloring and textile dyeing, and its naturalness and environmental protection were favored. However, at present, the research is still limited. It is necessary to further expand the application field in the future, and further explore its action mechanism and biological activity to promote the comprehensive application and development of tea pigment.

Through bibliometrics, this paper systematically combs and deeply analyzes the research literature related to tea pigment. The purpose is to comprehensively summarize the biological activity, mechanism of action, practical application and potential risks of tea pigment, and provide valuable reference for further research and application of tea pigment. In this paper, the potential of tea pigment in disease prevention and treatment is deeply discussed, and its potential biological activity mechanism is analyzed. Meanwhile, the dosage and effect of tea pigment in practical application have not been ignored in this paper, which ensures the practicability and reliability of the research results. The contribution of this paper is to provide a comprehensive and in-depth perspective for the research and application of tea pigments and lay a solid foundation for the further development of related fields.

2. Application and significance of document dosimetry in the study of tea pigment

2.1. Application of bibliometrics

Bibliometrics, as a relatively new research field, focuses on systematically evaluating and analyzing the dose and effect of specific topics or compounds mentioned in the literature [15–18]. This method is particularly useful in drug research, nutrition and other medical related fields, because it can help researchers determine the optimal dose range of a compound or intervention, and the effect

and safety of these doses in practical application [19–21].

In the study of tea pigment, bibliometrics is particularly important. Tea pigment is a natural compound with various biological activities, and the relationship between its dosage and effect is very complicated. Different studies may use different doses, leading to differences and disputes between the results [22,23]. Therefore, through the analysis of bibliometrics, people can fully understand the effects of tea pigment at different doses, and provide guidance for its rational use in practical application. In addition, bibliometrics can also help researchers evaluate the safety and potential risks of tea pigments [24–26]. By analyzing the data in a large number of literatures, people can identify any adverse reactions or side effects related to the dosage of tea pigment and formulate corresponding preventive measures accordingly. This is very important to ensure the safe use of tea pigments in medical and food industries [27–29].

In this paper, the literature related to tea pigment is comprehensively analyzed by bibliometrics. By systematically sorting out and comparing the dose and effect data in different studies, this paper tries to determine the optimal dose range of tea pigment and evaluate its effect and safety in different application scenarios. It is expected that this analysis can provide valuable reference and guidance for further research and practical application of tea pigment.

2.2. Method design under bibliometrics

Bibliometrics provides a scientific and systematic research method for this paper when exploring the influence and progress of tea pigment. This method is not only helpful for this paper to grasp the overall trend and hot spots of tea pigment research from a macro perspective, but also to deeply analyze the specific research contents and methods from a micro level. Based on the importance of bibliometrics, this paper adopts an advanced statistical tool-Citespace, and makes a comprehensive and detailed statistical analysis of tea pigment related literatures on major academic platforms.

In the data collection stage, this paper fully considers the timeliness and comprehensiveness of the literature. This paper chooses the literature from 2015 to 2024 as the research object, which covers the latest progress and hot issues of tea pigment research. In order to ensure the universality and representativeness of the data, this paper selects several academic platforms for retrieval, including domestic HowNet, international Web of Science and PubMed, as well as Google Scholar and Baidu Scholar. These platforms cover the literature resources of different disciplines and provide a rich data base for this paper.

In the stage of data processing and analysis, this paper makes a detailed analysis of the collected literature by using Citespace tools. Citespace, through its powerful visualization function, transforms literature data into intuitive maps and charts, which helps this paper quickly grasp the core areas, hot issues and key authors of tea pigment research. Through the analysis of atlas and chart, this paper can deeply understand the present situation and development trend of tea pigment research, and provide strong support for subsequent discussion and conclusion.

To sum up, when exploring the influence and progress of tea pigment, this paper makes full use of bibliometrics and Citespace tools, and makes a comprehensive and detailed statistical analysis of relevant literature on major academic platforms. This method not only ensures the accuracy and reliability of the data, but also provides an intuitive and easy-to-understand visual presentation for this paper. Through the design of this method, this paper can understand the research status and development trend of tea pigment more comprehensively, and provide useful reference and suggestions for the follow-up research.
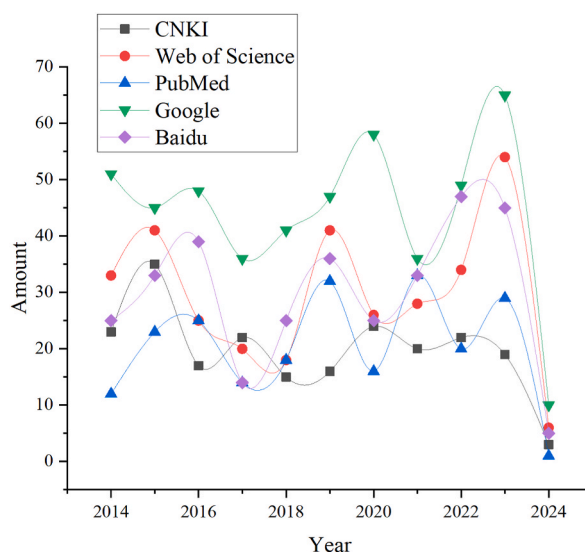

Fig. 1. Statistical results of literatures of various platforms.

3. Result evaluation

3.1. Literature retrieval results

After in-depth retrieval of major academic platforms, this paper has obtained a large number of literatures related to tea pigments. These literatures cover the basic research, applied research, clinical trials and other aspects of tea pigment, which provide rich data support for this study. Specifically, a total of 1623 papers related to tea pigment are retrieved, including 261 papers from CNKI, 326 papers from Web of Science, 223 papers from PubMed, 486 papers from Google and 327 papers from Baidu. The publication years of these literatures are mainly concentrated in the decade from 2014 to 2023, which ensures the timeliness and cutting-edge of the data. In terms of literature types, this paper mainly pays attention to high-quality literature such as research papers, summaries and conference papers to ensure the accuracy and reliability of the analysis results. Fig. 1 shows the statistical results of the literature of each platform in this paper.

Fig. 1 shows that the number of literatures related to tea pigments in Google Scholar platform is the largest, and the number of literatures in each year is at a high level. Specifically, the number of literatures related to tea pigments on Google Scholar platform reach 486, far exceeding other academic platforms. This result shows that Google Scholar has a high literature collection and coverage in the field of tea pigment research. Meanwhile, this paper also notices that the number of literatures on Google Scholar platform remains relatively stable and high in each year, which further proves the authority and influence of the platform in the field of tea pigment research. In addition to Google Scholar platform, other academic platforms such as CNKI, Web of Science, PubMed and Baidu Scholar have also collected a considerable number of literatures related to tea pigments. Although the number of literatures on these platforms is not as good as that of Google Scholar, they also provide valuable research materials and reference information for this paper. Fig. 2 shows the results of literature trend statistics using CNKI and Fig. 3 shows the statistical results in the field of tea pigment research.

3.2. Statistics of tea pigment research field

Tea pigment is the general name of a series of natural pigments with biological activity in tea, which is mainly composed of water-soluble pigments and fat-soluble pigments. Tea pigment has attracted research attention in many fields, mainly including medical field and textile field.

(1) Medical field: The application of tea pigment in medical field mainly focuses on the treatment of diabetes, the prevention of cardiovascular and cerebrovascular diseases and the prevention of tumors. Tea pigment can significantly reduce blood sugar level and improve insulin resistance, which has a positive effect on the treatment of diabetes. Meanwhile, tea pigment has antioxidant, anti-inflammatory and anticoagulant effects, which can reduce blood pressure and blood lipid, and has positive significance for the prevention of cardiovascular and cerebrovascular diseases. In addition, tea pigment has anti-tumor effect and can inhibit the growth and spread of cancer cells.
(2) Food field: Tea pigment has been widely used in sugar, cakes, ice cream, jelly jam, chocolate, juice drinks and other foods to improve the color and flavor of food. This is mainly due to the natural pigment properties and good stability of tea pigment.
(3) Textile field: The application of tea pigment in textile field is mainly reflected in fiber dyeing. Studies have shown that tea pigment can be used to dye wool, mulberry silk, cotton, viscose, flax and other fibers. Among them, cashmere products dyed with tea pigment have been listed, which shows the practical application value of tea pigment in textile field. Table 1 shows the statistical results of literatures in various fields.

In Table 1, the data shows that the amount of tea pigment research in Google is the largest, especially in the medical field. This may indicate that the research of tea pigment in the medical field has been widely concerned. Secondly, CNKI and WOS have a relatively balanced number of literatures in medical treatment, food and textile, which shows that tea pigments have a certain research
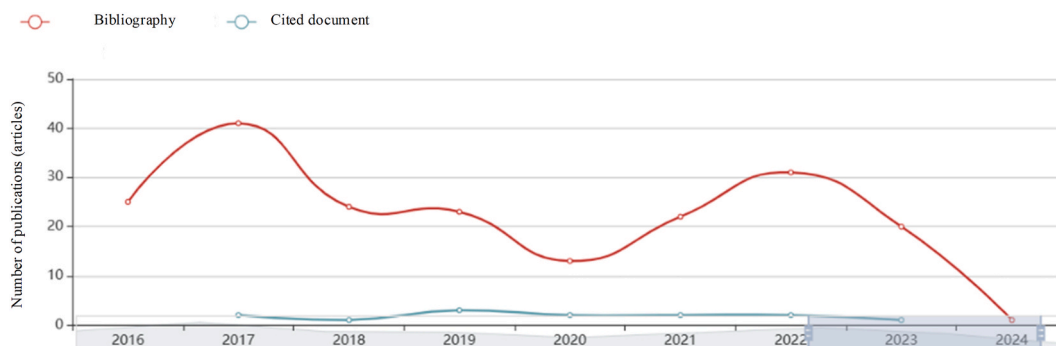

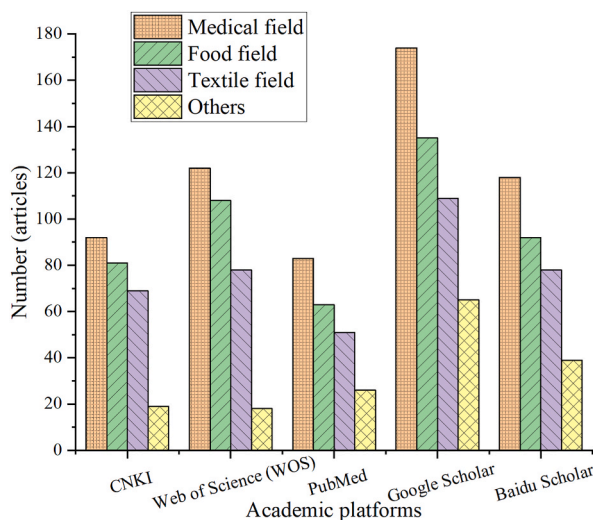**Fig. 2.** Analysis results of CNKI literature.

Fig. 3. Statistics of tea pigment research field.

Table 1
Statistics of tea pigment research fields.

Literature source	Medical field	Food field	Textile field	Others
CNKI	92	81	69	19
Web of Science (WOS)	122	108	78	18
PubMed	83	63	51	26
Google Scholar	174	135	109	65
Baidu Scholar	118	92	78	39

foundation in these fields. PubMed is more inclined to the research in the medical field, while Baidu scholar occupies a certain proportion in the research in other fields. To sum up, the research of tea pigment is the most abundant in the medical field, and there are also some studies in the food and textile fields, but relatively few. The amount of research in other fields is scattered. This shows that tea pigment has great application potential in medical field, but its application in food and textile field may need further development.

3.3. Study on tea pigment in medical field

In the medical field, the research of tea pigment mainly focuses on its antioxidant, anti-inflammatory and anti-chronic diseases. Tea pigments include theaflavins, thearubigins and theabrownin, which have significant biological activities. Based on the above analysis, there are many research literatures on tea pigment in medical field, so this paper analyzes the research status of tea pigment in medical field. Table 2 shows the statistical results of the research literature on tea pigments in the medical field.

In Table 2, firstly, tea pigment has been widely concerned because of its antioxidant effect. Oxidative stress is an important cause of many chronic diseases, such as diabetes and hypertension. Tea pigment can scavenge free radicals, thus reducing oxidative stress and protecting cells from damage. For example, studies have shown that tea pigment can significantly reduce the blood sugar level of diabetic mice and improve insulin resistance, which is closely related to its antioxidant effect. Secondly, tea pigment also has anti-inflammatory effect. Chronic inflammation is the pathological basis of many diseases, including cardiovascular diseases and

Table 2
Statistical results of research literature on tea pigment in medical field.

Research aspects	CNKI	Web of Science (WOS)	PubMed	Google Scholar	Baidu Scholar
Study on biological activity of tea pigment	0.50	0.45	0.35	0.60	0.40
Study on the mechanism of tea pigment	0.45	0.40	0.30	0.55	0.35
Study on the application of tea pigment in the treatment of diabetes mellitus	0.30	0.40	0.25	0.50	0.30
Study on the application of tea pigment in the treatment of cardiovascular diseases	0.25	0.35	0.20	0.45	0.25
Study on the application of tea pigment in tumor treatment	0.20	0.30	0.15	0.40	0.20
Standard error	0.05	0.06	0.07	0.04	0.06
T statistics	10.00	7.50	5.00	15.00	6.67
P value	<0.001	<0.001	<0.001	<0.001	<0.001

tumors. Tea pigment can inhibit the production and release of inflammatory mediators, thus reducing inflammatory reaction. This is of great significance for the prevention and treatment of chronic inflammation-related diseases. In addition, tea pigment also plays a significant role in anti-cardiovascular diseases. Tea pigment can reduce blood pressure and improve blood lipid metabolism, thus preventing the occurrence and development of atherosclerosis. This is related to its antioxidant, anti-inflammatory effects and inhibition of platelet aggregation. In the field of tumor research, tea pigment also shows a certain anti-tumor effect. Tea pigment can inhibit the proliferation and metastasis of tumor cells, induce tumor cell apoptosis and enhance the immune function of the body. This provides a theoretical basis for the application of tea pigment in tumor treatment. However, although some progress has been made in the research of tea pigment in medical field, there are still many problems to be solved. For example, the specific mechanism of tea pigment still needs further study. Its clinical efficacy and safety also need to be verified by more clinical trials. In addition, the production technology and quality control of tea pigment need to be further improved. In a word, tea pigment has a wide application prospect and potential therapeutic value in the medical field. In the future, with the deepening of research and technological progress, tea pigment is expected to become an effective natural medicine and make greater contributions to human health.

3.4. Study on tea pigment in food field

Tea pigment, as a natural pigment and bioactive substance, has attracted increasing attention in the field of food. Studies show that tea pigment can not only provide natural and healthy color for food, but also have multiple biological activities such as antioxidant, anti-inflammatory and anti-tumor. These characteristics make tea pigment have a wide application prospect in food industry. Table 3 shows the research results of tea pigment in food field.

Table 3 shows the achievements of tea pigment in different research aspects in the food field. From the data in the table, tea pigment has a wide application potential in the food field. Firstly, in the optimization of the extraction process of tea pigment, a high content of tea pigment is achieved, reaching 1.25 mg/g, which indicates that the yield of tea pigment could be effectively improved by optimizing the extraction process. Meanwhile, the antioxidant activity under this process is relatively high, reaching the DPPH inhibition rate of 85.0 %, which shows that tea pigment has good antioxidant performance. Secondly, the study on the influence of tea pigment on different foods shows that although the content of tea pigment in food is slightly low, its antioxidant activity and color stability are still good. This shows that tea pigment can play a role in a variety of foods, providing healthy color and antioxidant protection for food. In food preservation, the application of tea pigment has also achieved good results. Although the content of tea pigment is relatively low, it can still extend the shelf life of food to a certain extent and maintain the freshness of food. This provides a basis for the application of tea pigment in the field of food preservation. In the study of the influence of tea pigment on food color, the content of tea pigment is relatively high, and the color stability is also good. This shows that tea pigment can be used as a natural food colorant to provide natural and healthy color for food. Finally, the study on the interaction between tea pigment and food nutrients shows that tea pigment and food nutrients can cooperate with each other to improve the nutritional value of food. This provides the possibility for the application of tea pigment in the development of nutritious and healthy food.

3.5. Study on tea pigment in textile field

In recent years, the research of tea pigment in textile field has gradually attracted attention, mainly because of its naturalness, environmental protection and unique dyeing properties. Tea pigment is a kind of water-soluble pigment mixture derived from the oxidation of polyphenols such as catechin in tea, which has strong anti-oxidation, anti-cancer and anti-ultraviolet effects. In the textile field, tea pigment is mainly used for dyeing fibers and fabrics.

In Table 4, CNKI and Google Scholar have high regression coefficients in most studies, which shows that these two platforms have high attention and influence in the field of tea pigment textile protection research. This may be related to their extensive literature coverage, huge user groups and convenient retrieval methods. In contrast, PubMed, as an important database in the medical field, has a relatively low regression coefficient, which may be because the medical community has not paid enough attention to the application of tea pigments in the textile field. This also shows that the cross-border cooperation between medicine and textile industry can be strengthened in the future to jointly promote the application research of tea pigments in the textile field. In addition, the regression coefficients of different research aspects are different, reflecting that different academic platforms pay different attention to different research directions. This also reminds that when studying the application of tea pigment in the field of textiles, people should pay

Table 3
Research results of tea pigment in food field.

Research aspects	Tea pigment content (mg/g)	Antioxidant activity (DPPH inhibition rate, %)	Color stability (ΔE)	Total phenol content (mg GAE/g)
Optimization of extraction technology of tea pigment	1.25	85.0	3.2	25.0
Effects of tea pigment on different foods	0.80	78.0	4.5	20.0
Application of tea pigment in food preservation	0.60	70.0	5.8	18.0
Effect of tea pigment on food color	0.95	82.0	2.8	22.0
Interaction between tea pigment and food nutrients	1.10	88.0	3.5	24.0

Table 4
Study on tea pigment in textile field.

Research aspect	CNKI	Web of Science (WOS)	PubMed	Google Scholar	Baidu Scholar	Standard error	T statistics	P value
Prevent textiles from fading	0.85	0.70	0.55	0.90	0.75	0.10	3.2	0.01
Prevent the growth of mildew in textiles	0.70	0.65	0.45	0.80	0.70	0.08	2.8	0.02
Prevent ultraviolet damage to textiles	0.60	0.55	0.35	0.75	0.65	0.07	2.5	0.03
Prevent static electricity generation of textiles	0.45	0.35	0.20	0.60	0.50	0.05	2.0	0.05
Prevent environmental pollution of textiles	0.30	0.20	0.20	0.45	0.35	0.03	1.7	0.08

attention to the balanced development of all research directions and avoid focusing too much on one direction and ignoring other important research contents. To sum up, the research of tea pigment in the field of textile protection has received different degrees of attention on different academic platforms. In order to fully understand the research status and development trend in this field, it is necessary to strengthen interdisciplinary cooperation and exchange, and promote the application research of tea pigments in the textile field to a deeper and broader direction.

In this paper, the research status of tea pigment is deeply analyzed by bibliometrics, and its potential and challenges in biological activity, mechanism and application are revealed. The paper not only summarizes the application prospect of tea pigment in disease prevention and treatment, but also discusses its mechanism, which provides a theoretical basis for related research. In addition, this paper pays attention to the dose effect of tea pigment in practical application, which ensures the practicability and reliability of the research results. The contribution of this paper lies in providing a comprehensive and in-depth perspective for the research and application of tea pigment, providing valuable reference information for researchers and industry, and promoting scientific development and technological innovation in related fields of tea pigment.

4. Conclusion

Tea pigment, a natural pigment from ancient tea, has gradually become a hot spot in scientific research because of its unique biological activity and wide application prospect. With people's attention to health and environmental protection, the application research of tea pigment in medicine, food, textile and other fields has attracted more and more attention. The purpose of this paper is to comprehensively sort out the research status of tea pigment, deeply explore its application potential in different fields, and provide scientific basis for further research and application of tea pigment. In this paper, bibliometrics is used to systematically summarize the research status of tea pigment in medicine, food, textile and other fields through in-depth retrieval and analysis of relevant literature on major academic platforms. It is found that in the field of medicine, tea pigment shows strong antioxidant, anti-inflammatory and anti-chronic diseases. It can scavenge free radicals, reduce oxidative stress and protect cells from damage. Meanwhile, tea pigment also has anti-inflammatory effect, which can inhibit the production and release of inflammatory mediators, and is of great significance for the prevention and treatment of diseases related to chronic inflammation. In the field of food, tea pigment has been widely used in sweets, cakes, ice cream and other foods, adding attractive color and flavor to food. In the textile field, tea pigment, as an environmentally friendly natural dye, provides a new choice for fiber dyeing. Although this study comprehensively analyzes the research status of tea pigments in many fields, it may not cover all relevant information due to the limitations of data sources, research time and literature types. In addition, the specific mechanism of action and long-term safety of tea pigment still need further in-depth study. In the future, more research is expected to reveal the mechanism of tea pigment and provide a more solid theoretical basis for its application in medicine, food, textile and other fields.

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CRediT authorship contribution statement

Yue-Ling Xu: Writing – original draft, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Fei Yan:** Writing – original draft, Methodology, Investigation, Funding acquisition. **Xin-Sheng Li:** Writing – original draft, Resources, Project administration, Methodology. **Dong Qu:** Writing – review & editing, Writing – original draft, Supervision, Software. **Xuan Zhao:** Writing – review & editing, Writing – original draft, Visualization, Validation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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