Application of extracts from different sources with natural preservative properties in daily chemical products

Qingdi Luo[1], Song Zhang[1], Qiulin Yue[1], Chen Zhao[4], Xin Sun[1], Li Tian[1], Baojun Li[4], Kunlun Li[4], Le Su[1,3,a*], Lin Zhao[1,2,b*]

[1]Qilu University of Technology, Jinan, Shandong, 250000, China
[2] Shandong Chenzhang Biotechnology Co., Ltd., Jinan, P.R. China
[3] Shengsheng Xiangrong Biotechnology (Shandong) Co., Ltd, Jinan, P.R. China
[4] Shandong ZhuoRan Biotechnology Co., Ltd., Jinan, P.R. China

Abstract: This article discusses the importance of the use of natural preservatives in cosmetics and personal care products, especially in the context of the search for alternatives to chemical preservatives in order to reduce health risks. The article summarizes the effects of different extraction and preparation methods on the yield and purity of natural preservatives and discusses strategies to improve their stability. By carefully classifying and analyzing the inhibition mechanisms of natural preservatives, their value and potential in practice are highlighted. The aim is to provide researchers and industry practitioners with insights into the research and application of natural preservatives and to promote their widespread use in the industry.

1. Introduction

In the field of daily chemical products, preservatives are essential auxiliary materials that play a key role in inhibiting the growth of microorganisms, extending the shelf life of products, and ensuring user safety and quality[1]. Traditional preservatives such as nipagin esters, benzyl alcohol and benzoic acid have been widely used, but not without concern. There is growing evidence that these chemicals can be serious allergens, causing contact dermatitis in cosmetic users, and in severe cases, chronic toxicity or aggravation of skin conditions[2].

With growing consumer awareness and demand for safer, more sustainable alternatives, the focus has shifted to natural preservatives[3]. Natural preservatives are substances derived from plants, animals or microorganisms with antimicrobial properties[4]. They are promising alternatives that are safe and effective without affecting the aesthetic properties of the product such as color and aroma[3]. This review delves into the burgeoning field of natural preservatives, exploring their extraction and preparation methods, stability challenges, and functional applications in various industries.

The paper begins by elucidating extraction and preparation techniques for natural preservatives, focusing on methods to ensure the potency and purity of these compounds. The discussion then transitions to stabilization strategies for maintaining the integrity of natural preservatives in product formulations and extending their lifespan. Finally, the article categorizes these preservatives into botanical, animal-derived, and microbial classes, examining their unique antimicrobial mechanisms and practical applications. By providing a comprehensive overview, this article aims to emphasize the significance of natural preservatives in the cosmetic and broader household chemicals industry, and to advocate for greater adoption of natural preservatives from a safety and environmental perspective.

2. Extraction and preparation of natural preservatives

Through a review of the available literature, natural preservatives of plant, animal and microbial origin, each possess unique extraction methods. The extraction and preparation methods of the three different sources of natural preservatives are shown in Table 1.

Table 1. Extraction and preparation of natural preservatives from three different sources.

Natural preservatives from different sources	Extraction and Preparation Methods
Plant sources	The extraction of essential oils from plants is conducted using steam distillation[1].

*Corresponding author's e-mail: [a]sule@sdu.edu.cn, [b]sdilizhaolin@163.com

	An extraction method is used to extract active compounds, such as phenols and flavonoids, from solid plant material[5].
Animal origin	Methods such as alcohol extraction are used to isolate flavonoids and phenolic compounds from propolis[6].
	Chitosan extraction, on the other hand, involves the extraction of chitin from the shells of crustaceans, which is converted to chitosan through a series of chemical reactions[7].
Microbial sources	Usually obtained through a fermentation process[6].

3. Stabilization of natural preservatives

Stability is essential to maintain the efficacy and longevity of natural preservatives, whether they are of plant, animal or microbial origin. Key strategies include the use of antioxidants, particularly plant preservatives, to combat oxidative degradation and the incorporation of preservatives into carrier systems or encapsulation to protect them from environmental factors such as air and light[8]. For animal- and microbial-derived preservatives, specific stabilization methods, such as controlled storage conditions, chemical modification, and microencapsulation, are essential to maintain their antimicrobial activity and prevent degradation[9]. These stabilization measures are essential to ensure that natural preservatives maintain their effectiveness and shelf life, supporting their reliable use in various industries to maintain product quality and safety[8].

4. Classification, Inhibitory Mechanisms and Applications of Natural Preservatives

Natural preservatives from different sources have now been extensively studied, such as essential oils and plant extracts from plant sources, propolis and chitosan from animal sources and lactobacilli and bacteriocins from microbial sources[10], all of which have great potential in the field of preservation.

4.1. Natural preservatives of plant origin

Preservatives from plant sources, such as essential oils and plant extracts, are rich in a variety of active compounds, such as phenols, terpenes and alkenes, which have been shown to have powerful antimicrobial and antiseptic effects[11]. These active compounds exhibit their antimicrobial effects by disrupting the cell membranes of microorganisms, inhibiting enzyme activity or interfering with their metabolic pathways[11].The bioactive compounds of Plant extracts and Essential oils studied at this stage can be seen in Table 2.

Table 2. Bioactive compounds of PE and EO studied at this stage.

plants	active compound	Reference
Rhubarb	rhein, emodin, aloe-emodin, physcion and chrysophanol	[12]
Yinxingye	terpene trilactones (ginkgolides A, B, and C) and flavonoids, polysaccharide,	[13]
Rosmarinus officinalis L.	phenolic acids, flavonoids, diterpenoids,	[12]
Cinnamomum cassia Pres	vanillic, caffeic, gallic, protocatechuic, *p*-coumaric, and ferulic acids	[14]
Origanum vulgare L.	mono- and sesquiterpenes, rosmarinic acid, salvianolic acid, luteolin,	[15]

Extracts of plant origin are rich and diverse, and the bacteriostatic mechanism of their active substances varies among different plant extracts, and at present, the bacteriostatic mechanism of some bioactive substances is still unclear, and more in-depth studies are needed. At this stage, the following bacteriostatic mechanisms have been clarified, and the bacteriostatic mechanisms of some plant bacteriostatic active compounds are shown in Figure 1.

(a) Inhibition of adhesion of pathogenic bacteria;
(b) Altering the permeability of cell membranes;
(c) Inhibition of the synthesis of genetic material and proteins in the bacterium;
(d) Inhibition of bacterial respiratory metabolism.

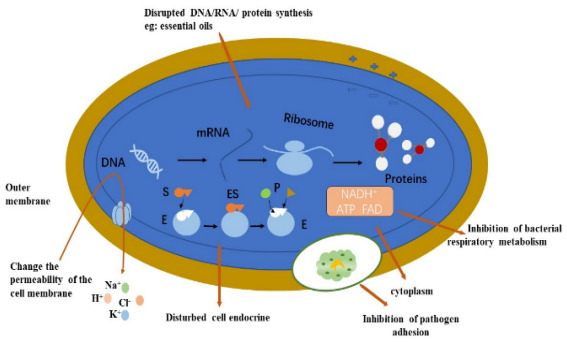

Figure 1. Mechanism of action of bacteriostatic components in PE and EO.

The use of plant extracts and essential oils as natural preservatives in cosmetic applications is receiving increasing attention. Dadashi et al. found a high incidence of bacterial and fungal contamination in shared cosmetic kits provided by women's beauty salons [16], whereas, the water extract of Aspergillus violaceus prevents the germination of conidia from Aspergillus flavus and Aspergillus parasiticus idia[17], it is an ideal natural anti-bacterial agent.

4.2. Natural preservatives of animal origin

Among preservatives of animal origin, substances such as propolis and chitosan exhibit their antibacterial properties through different mechanisms. Propolis is rich in flavonoids and phenolic compounds that inhibit microbial protein synthesis and cell division. Chitosan, on the other hand, achieves its inhibitory effect by enhancing the permeability of cell walls and interfering with the normal physiological functions of microorganisms[18]. The antibacterial mechanism of propolis and chitosan is shown in Figure 2.

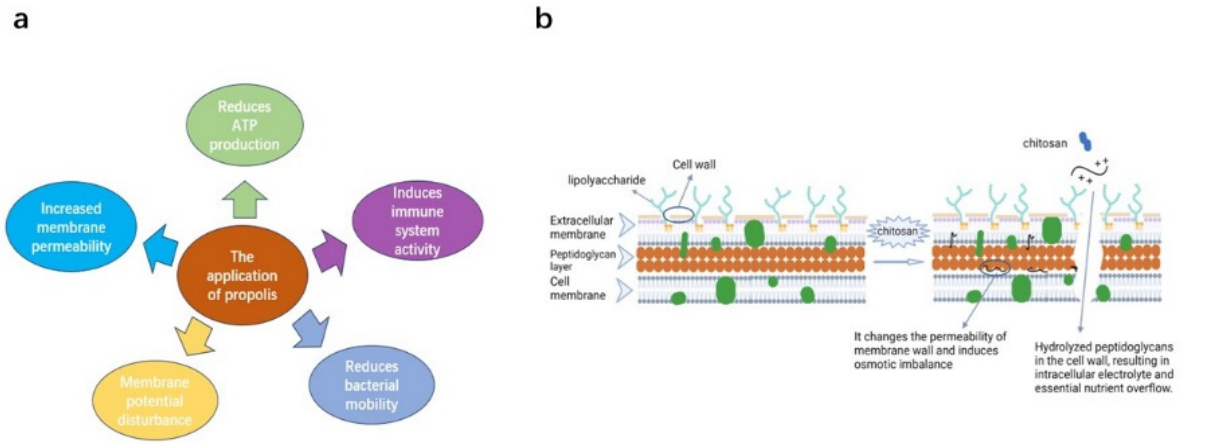

Figure 2. Bacteriostatic mechanism of propolis and chitosan. a) Bacteriostatic mechanism of propolis. b) Inhibitory mechanism of chitosan.

In recent years, there has been a growing body of research on the use of chitosan films and coatings combined with natural bioactive compounds. These compounds help to improve the stability of products during storage, inhibit microbial spoilage, and prevent lipid oxidation[19]. In addition, chitosan in the form of chitosan or different chitosan forms (e.g. carboxymethyl chitosan) are widely used as antioxidants, emulsifiers and skin protectants in cosmetics, etc [20]. Therefore, there will also be a new trend to develop this natural and novel antibacterial material to be used in synergy with natural preservatives.

4.3. Natural preservative of microbial origin

Preservatives of microbial origin, such as Lactobacillus and bacteriocins, also show strong antibacterial potential. Lactobacilli inhibit the growth of other microorganisms by producing metabolites such as organic acids and antimicrobial peptides, whereas bacteriocins are a class of protein-based antimicrobial substances produced by bacteria that act specifically on certain bacteria, performing their bacteriostatic action by disrupting their cell membranes or inhibiting key biological processes[21]. The mechanism of inhibition of antimicrobial peptides, a natural preservative of microbial origin, is shown in Figure 3.

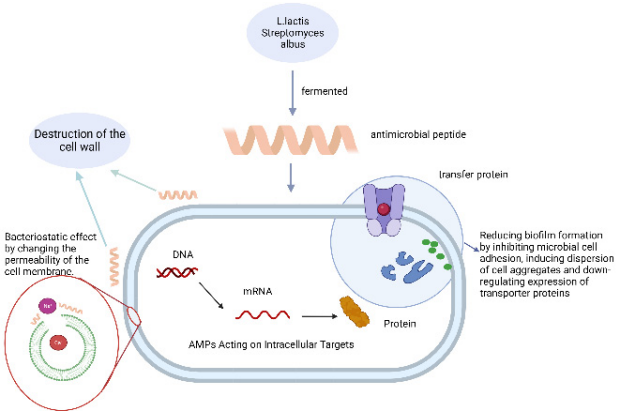

Figure 3. Mechanism of bacterial inhibition by antimicrobial peptides.

In shampoo and conditioning products such as shampoos, conditioners and scalp care products, which usually need to be kept in a humid environment for a long period of time and are susceptible to the growth of bacteria and moulds, Kevser Karaman reported that natamycin has a good inhibitory effect on yeast, which makes it a good natural preservative[22]. He Xingfen also reported the preparation of water-in-oil (W/O) cinnamaldehyde microemulsions loaded with ε-polylysine and their antimicrobial properties, which offer the possibility of anticorrosion of emulsions [21].Based on the antiseptic properties of these natural preservatives, they can have the potential to be applied in daily chemical products such as

face masks, moisturising waters, creams, toothpastes, mouthwashes and so on.

5. Conclusions and outlook

This review provides a comprehensive review of the extraction, preparation, stabilization and application of natural preservatives, highlighting their potential to improve the quality and safety of cosmetic products. It is shown that natural preservatives are effective in reducing microbial growth and certain chemical reactions, but their efficacy and broad-spectrum activity can be significantly enhanced by synergistic combinations with other preservatives[23]. Despite the efficacy of single plant preservatives, their limited bacteriostatic effect and narrow spectrum of activity can be overcome by formulating mixtures of different plant extracts to produce preservative systems with enhanced broad-spectrum antimicrobial properties[8].

Consumer demand highlights the need for refined natural preservative systems. Future research should aim to optimize the combinations of natural preservatives by exploiting their unique advantages to address the current limitations and expand their applications in cosmetics[8]. In addition, the exploration of novel natural preservatives will enrich the options for developing more effective preservative systems.

In conclusion, the strategic formulation and application of natural preservatives holds great promise for the cosmetic industry, providing avenues for the production of safer and more sustainable products. However, while this paper introduces extraction and preparation methods by reviewing previous literature, this review recognizes that there are shortcomings in summarizing and reviewing the aspects of a comprehensive strategy to improve the yield, purity, and cost-effectiveness of natural preservative production. Addressing these aspects remains an important direction for the future in order to improve the viability and scalability of natural preservatives in industrial applications.

Acknowledgements

The Central Government Guides Local Science and Technology Development Special Fund Project (No. YDZX2022181, YDZX2021051), Spring Industry Leader Talent Support Plan (grant number 1362022058, 2092021033); Yantai Development Zone Science and Technology Leading Talents Project (grant number 2020CXRC4, Lin Zhao, and Orlando Borrás - Hidalgo); Key innovation Project of Qilu University of Technology (Shandong Academy of Sciences) (2022JBZ01-06), Technological Small and Medium sized Enterprise Innovation Ability Enhancement Project (2022TSGC1076, 2023TSGC0167, 2023TSGC0169, 2021TSGC1296), the XPCC Financial Science and Technology Project in 2022 (No. 2022AB002), Key R&D Plan Projects in Shandong Province (2023CXPT037, 2022SFGC0301), Jinan Science and Technology Development Plan (202131004).

References

1. N. Halla et al., “Cosmetics Preservation: A Review on Present Strategies,” Molecules, vol. 23, no. 7, p. 1571, Jun. 2018, doi: 10.3390/molecules23071571.
2. M. E. Park and J. H. Zippin, “Allergic Contact Dermatitis to Cosmetics,” Dermatologic Clinics, vol. 32, no. 1, pp. 1–11, Jan. 2014, doi: 10.1016/j.det.2013.09.006.
3. K. Rybczyńska-Tkaczyk, A. Grenda, A. Jakubczyk, K. Kiersnowska, and M. Bik-Małodzińska, “Natural Compounds with Antimicrobial Properties in Cosmetics,” Pathogens, vol. 12, no. 2, p. 320, Feb. 2023, doi: 10.3390/pathogens12020320.
4. M. Pisoschi, A. Pop, C. Georgescu, V. Turcuş, N. K. Olah, and E. Mathe, “An overview of natural antimicrobials role in food,” European Journal of Medicinal Chemistry, vol. 143, pp. 922–935, Jan. 2018, doi: 10.1016/j.ejmech.2017.11.095.
5. Z. A. A. Aziz et al., “Essential Oils: Extraction Techniques, Pharmaceutical And Therapeutic Potential - A Review,” Current Drug Metabolism, vol. 19, no. 13, pp. 1100–1110.
6. J. Cui et al., “Extraction, purification, structural character and biological properties of propolis flavonoids: A review,” Fitoterapia, vol. 157, p. 105106, Mar. 2022, doi: 10.1016/j.fitote.2021.105106.
7. N. Islam, M. Hoque, and S. F. Taharat, “Recent advances in extraction of chitin and chitosan,” World J Microbiol Biotechnol, vol. 39, no. 1, p. 28, Nov. 2022, doi: 10.1007/s11274-022-03468-1.
8. D. Bukvicki et al., “Essential Oils and Their Combination with Lactic Acid Bacteria and Bacteriocins to Improve the Safety and Shelf Life of Foods: A Review,” Foods, vol. 12, no. 17, Sep. 2023, doi: 10.3390/foods12173288.
9. “Antioxidative Activity of Thyme (Thymus vulgaris) and Oregano (Origanum vulgare) Essential Oils and Their Effect on Oxidative Stability of Minced Pork Packaged Under Vacuum and Modified Atmosphere - Boskovic - 2019 - Journal of Food Science - Wiley Online Library.” Accessed: Mar. 22, 2024. [Online]. Available: https://ift.onlinelibrary.wiley.com/doi/10.1111/1750-3841.14788
10. S. Cen et al., “Effects of chitosan-sodium alginate-nisin preservatives on the quality and spoilage microbiota of Penaeus vannamei shrimp during cold storage,” International Journal of Food Microbiology, vol. 349, p. 109227, Jul. 2021, doi: 10.1016/j.ijfoodmicro.2021.109227.
11. A.-P. Li, Y.-H. He, S.-Y. Zhang, and Y.-P. Shi, “Antibacterial activity and action mechanism of flavonoids against phytopathogenic bacteria,” Pesticide Biochemistry and Physiology, vol. 188, p. 105221, Nov. 2022, doi: 10.1016/j.pestbp.2022.105221.

12. H. Xiang, J. Zuo, F. Guo, and D. Dong, “The water extract of Aspergillus violaceus prevents the germination of conidia from Aspergillus flavus and Aspergillus parasiticus: a comprehensive review,” Chin Med, vol. 15, p. 88, Aug. 2020, doi: 10.1186/s13020-020-00370-6.
13. D. Boateng, “Ginkgols and bilobols in Ginkgo biloba L. A review of their extraction and bioactivities,” Phytother Res, May 2023, doi: 10.1002/ptr.7877.
14. S. F. Nabavi, A. Di Lorenzo, M. Izadi, E. Sobarzo-Sánchez, M. Daglia, and S. M. Nabavi, “Antibacterial Effects of Cinnamon: From Farm to Food, Cosmetic and Pharmaceutical Industries,” Nutrients, vol. 7, no. 9, pp. 7729–7748, Sep. 2015, doi: 10.3390/nu7095359.
15. N. Leyva-López, E. P. Gutiérrez-Grijalva, G. Vazquez-Olivo, and J. B. Heredia, “Essential Oils of Oregano: Biological Activity beyond Their Antimicrobial Properties,” Molecules, vol. 22, no. 6, p. 989, Jun. 2017, doi: 10.3390/molecules22060989.
16. L. Dadashi and R. Dehghanzadeh, “Investigating incidence of bacterial and fungal contamination in shared cosmetic kits available in the women beauty salons,” Health Promot Perspect, vol. 6, no. 3, pp. 159–163, Aug. 2016, doi: 10.15171/hpp.2016.25.
17. B. M. Somai and V. Belewa, “Aqueous Extracts of Tulbaghia violacea Inhibit Germination of Aspergillus flavus and Aspergillus parasiticus Conidia,” Journal of Food Protection, vol. 74, no. 6, pp. 1007–1011, Jun. 2011, doi: 10.4315/0362-028X.JFP-10-434.
18. Przybyłek and T. M. Karpiński, “Antibacterial Properties of Propolis,” Molecules, vol. 24, no. 11, p. 2047, May 2019, doi: 10.3390/molecules24112047.
19. M. Mondéjar-López, A. J. López-Jiménez, J. C. G. Martínez, O. Ahrazem, L. Gómez-Gómez, and E. Niza, “Thymoquinone-Loaded Chitosan Nanoparticles as Natural Preservative Agent in Cosmetic Products,” International Journal of Molecular Sciences, vol. 23, no. 2, Jan. 2022, doi: 10.3390/ijms23020898.
20. Jimtaisong and N. Saewan, “Utilization of carboxymethyl chitosan in cosmetics,” International Journal of Cosmetic Science, vol. 36, no. 1, pp. 12–21, 2014, doi: 10.1111/ics.12102.
21. T. Li et al., “Activity and Mechanism of Action of Antifungal Peptides from Microorganisms: A Review,” Molecules, vol. 26, no. 11, p. 3438, Jun. 2021, doi: 10.3390/molecules26113438.
22. “Potential of natamycin to control growth of Zygosaccharomyces spp. in apple juice during storage,” International Journal of Food Microbiology, vol. 332, p. 108771, Nov. 2020, doi: 10.1016/j.ijfoodmicro.2020.108771.
23. V. Patrone, R. Campana, E. Vittoria, and W. Baffone, “In vitro synergistic activities of essential oils and surfactants in combination with cosmetic preservatives against Pseudomonas aeruginosa and Staphylococcus aureus,” Curr Microbiol, vol. 60, no. 4, pp. 237–241, Apr. 2010, doi: 10.1007/s00284-009-9531-7.