

Research on the biological activity of rosemary extracts and its application in food

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Abstract. Rosemary extracts contains a variety of active components, which have physiological functions such as antioxidant, antibacterial, antiviral and anticancer. This article describes the biological activity of rosemary extracts and its research progress in the field of food processing such as oil storage, meat and aquatic products preservation and anti-corrosion, aiming to provide a theoretical reference for the application of rosemary extracts in food. It also pointed out the application prospects of rosemary extracts in the field of medicine, new feed additives, and functional food.

1 Background

Rosemary (*Rosmarinus officinalis* L.) belongs to the Lamiaceae plants. It is native to the Mediterranean region and is now cultivated all over the world. It was first recorded in "Supplements of Materia Medica" and has the effects of soothing the nerves, strengthening the stomach and relieving pain. Recent studies have shown that rosemary extracts has good biological activity, contains active components such as terpenoids, phenolic acids and flavonoids, and has anti-oxidation, antibacterial, anti-virus and cancer treatment effects. At present, rosemary extracts is mainly used in the fields of food, medicine, health care products and cosmetics. In the future, it has application prospects in new feed additives and compounding. Rosemary extracts has become a research hotspot at home and abroad.

2 Biological activity of rosemary extract

2.1 antioxidant activity

Rosemary extracts contains a variety of antioxidant components such as rosmarinic acid, sagenic acid and carnosol, which is a natural non-toxic new antioxidant. Rosmarinic acid and lipid peroxide block lipid peroxidation by competitive binding; can also promote the recovery of mitochondrial membrane potential by inhibiting the formation of reactive oxygen species in cells and reducing the activation of c-Jun N-terminal kinase and extracellular signal-regulated kinase^[1]. It was found that the antioxidant activity of rosmarinic acid was closely related to its structure. The O-diphenol hydroxyl in the structure could scavenge free radicals, so that rosmarinic acid entered the lipid bilayer and played an antioxidant role. Studies have

confirmed that^[2] carnosic acid of rosemary extracts can interact with each components, and when scavenging reactive oxygen, carnosic acid can produce secondary antioxidants. This process may enhance antioxidants active. In addition, the combination of ursolic acid and oleanolic acid in rosemary extracts also has an antioxidant effect to a certain extent.

2.2 antibacterial activity

A large number of studies have confirmed that rosemary extracts and its essential oil are often used as antibacterial agents because of their antibacterial activity. Among them, carnosic acid and rosmarinic acid are the most common active ingredients of phenolic acids. The main active ingredients of essential oils are 1,8-cineol, camphor and α -pinene. Rosemary extracts can effectively inhibit the reproduction of many microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Candida albicans* and *Saccharomyces cerevisiae*. The experiment of Ekambaram et al.^[3] showed that rosemary extracts had inhibitory effects on *Staphylococcus aureus* and methicillin-resistant *Staphylococcus aureus* (MRSA), and its minimum inhibitory concentration (MIC) were 0.8mg/mL and 10.0mg/mL. The antibacterial effect of rosmarinic acid may be related to its effect on the main virulence factors (MSCRAMM) of *Staphylococcus aureus* and MRSA surface proteins. In addition, Cai Xiaojun et al.^[4] used six monomers of rosemary to explore the inhibition mechanism on *Salmonella*. The results showed that the six monomers had strong antibacterial effect on *Salmonella*, especially the inhibitory effect of 1,8-cineol on *Salmonella* was the most significant, which played an antibacterial role mainly by damaging the cell structure of *Salmonella* and causing the extravasation of intracellular substances.

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2.3 antiviral activity

Rosmarinic acid has antiviral effect and can inhibit the growth of HIV, hepatitis B virus, enterovirus 71 and other viruses. Studies have found that rosmarinic acid could react with NO_2^- to obtain 6-nitro and 6,6-dinitro rosmarinic acid. These two compounds were used for HIV-1 integrase to inhibit the viral replication of lymphocyte MT-4 cells, and the nitrification products of rosemary also enhanced the antiviral activity of the inhibitor. Currently, hepatitis B virus can be treated with nucleoside analogues (NAs), but the development of new anti-HBV drugs is still urgent. Yuta et al.^[5] found that the interaction between ϵ -sequence in RNA of the pregenomic HBV and the viral polymerase (Pol) is a key process of HBV replication, and the special structure of rosmarinic acid can be specifically targeted by epsilon-Pol binding To inhibit the replication of HBV.

Lin et al.^[6] found that rosmarinic acid could protect cells from the pathological changes induced by enterovirus 71 (EV71), and the inhibitory activity of rosmarinic acid was the strongest at the early stage of EV71 infection, which could be used as an antiviral drug for EV71 infection in the early stage of treatment. In addition, rosemary extracts can also inhibit the replication of influenza virus and has a therapeutic effect on virus-induced pneumonia injury.

2.4 antitumor activity

2.4.1 anti-breast cancer

At present, breast cancer is one of the most common female cancers, but drug resistance may occur in drug treatment. Therefore, it is urgent to develop effective anti-breast cancer drugs. Studies have found^[7-8] that carnosol not only effectively inhibited the growth of breast cancer T47D cells, but also significantly increased the ratio of estrogen receptor α and β subtypes, and prevented the proliferation of breast cancer cells MCF-7, so that it is blocked in S phase. This indicated that carnosol could inhibit the proliferation and migration of estrogen receptor-positive breast cancer cells. In addition, scientists have confirmed that rosmarinic acid could also inhibit the proliferation and differentiation of breast cancer cells. Ren Boxue et al.^[9] have shown that rosmarinic acid could inhibit the growth of breast cancer MDA-MB-231 cells in a time and dose-dependent manner. It could induce apoptosis of cancer cells and reduce the migration of cancer cells.

2.4.2 anti-hepatoma

Zhao Shasha et al.^[10] studied the effects of rosmarinic acid on the proliferation and apoptosis of human liver cancer Huh7 cells. The result showed that rosmarinic acid could effectively inhibit the proliferation of human liver cancer Huh7 cells by increasing the concentration and time in a dose-dependent manner, and promote the apoptosis of Huh7 cells by regulating Bcl-2, Bax and Cleaved caspase-3. Wen Cao et al.^[11] have shown that rosmarinic acid could inhibit the tumor growth of H22 tumor-bearing mice, and inhibit the expression of NF- κ B p65 in tumor

microenvironment by regulating the secretion of inflammatory cytokines, thus exerting the effect of inhibiting liver cancer. In addition, Qunfeng Wu et al.^[12] found that carnosic acid and vitamin D combined with sorafenib could effectively promote the occurrence of autophagy in liver cancer cells, which played anti-hepatocarcinoma effect by activating LC3 protein.

2.4.3 anti other cancers

Rosmarinic acid has a strong inhibitory effect on colon cancer. Karthikkumar et al.^[13] studied the inhibitory effect of rosmarinic acid on 1,2-dimethylhydrazine (DMH) -induced colon cancer in rats, and found that rosmarinic acid could reduce the production of abnormal crypt foci (ACF), as a biomarker of colon cancer, and inhibit the growth of tumors. In addition, Tang Shuangyi et al.^[14] found that rosmarinic acid also could block cell cycle G2 to inhibit the activity of prostate cancer cell PC3, and play an anti-tumor role by regulating signaling pathways and apoptosis and other related proteins. Chu Xu et al.^[15] showed that rosmarinic acid could inhibit the proliferation of prostate cancer cell DU-145 in a concentration-dependent manner and inhibit the migration of cancer cells. Its anti-cancer mechanism may be closely related to the regulation of MAPK pathway.

Furthermore, the carnosic acid in rosemary extracts could induce apoptosis of human renal cancer cells by regulating the increase of subdiploid DNA content, cleavage of PARP apoptotic factors and activation of apoptotic molecules such as caspase-3, thus exerting anti-cancer effect.

2.5 antidepressant effect

Depression is a serious psychological disorder, which has attracted wide attention with the increase of its incidence in China in recent years. Jin Xiang et al.^[16-17] found that rosmarinic acid can promote the growth of hippocampal astrocytes in neonatal rats, and release brain-derived neurotrophic factor (BDNF), which improved the depression-like behavior of rats. It was speculated that the antidepressant mechanism may be related to increasing the viability of astrocytes, promoting the secretion of BDNF and up-regulating the phosphorylation of extracellular regulated protein kinase. Ying Guo et al.^[18] showed that inflammation was an important pathological factor of depression, and rosemary extracts could inhibit the expression of IL-1 β , TNF- α and other factors in the hippocampus and Iba1, and change the sequence proportion of microorganisms in the body, indicating that the antidepressant mechanism of rosemary extracts was mediated by the anti-inflammatory effect on the hippocampus and the rebalance of intestinal microflora.

3 Application in the food industry

3.1 application in storage of oil

The rancidity of oil easily occurs in the process of food

processing and storage, and the sensory quality and nutritional value are significantly reduced. In addition, the oxidative rancidity of oil not only produces a large number of free radicals, but also produces products such as malondialdehyde (MDA), 4-hydroxynonenal (HME) and

acrylaldehyde, which will seriously endanger human health. At present, antioxidants are mainly added to prevent or delay the oxidative rancidity of oil. Rosemary extracts is widely used because of its good safety, heat resistance and antioxidant activity.

Table 1 Application of rosemary extracts in inhibiting oil oxidation

product variety	addition of substances	dosage addition	applying effect	references
perilla seeds oil	rosemary extracts	0.08 % (W/W)	Rosemary extracts could effectively enhance the antioxidant activity of perilla seeds oil and prolong the rancidity time of perilla seeds oil	[19]
soybean oil	rosemary extracts	400mg/kg	Rosemary extracts could effectively reduce the loss of polyunsaturated fatty acids in soybean oil during storage, and enhance the scavenging ability of DPPH and ABTS free radicals	[20]
oil-tea camellia seed oil	rosemary extracts	400mg/kg	Rosemary extracts could significantly delay the formation of lipid oxidation products, had good antioxidant properties, and significantly improved the storage stability of oil-tea camellia seed oil	[21]
large yellow croaker roe oil	rosemary extracts	0.04% (W/W)	When rosemary extracts was added to the oil sample, the peroxide value was lower than that of the blank group	[22]
turtle oil	lipid-soluble rosemary extracts	0.04% (W/W)	Rosemary extracts could effectively inhibit the increase of acid value and POV value, slow down the oxidation rate of oil and improve the storage stability of turtle oil	[23]
walnut oil	rosemary extracts	0.02%~0.06% (W/W)	The stability of walnut oil increased with the addition of rosemary extracts, which delayed the formation of trans fatty acids and other products	[24]
flaxseed oil	rosemary extracts	200mg/kg	Added rosemary extracts could effectively inhibit the increase of POV value and anisidine value of flaxseed oil, and had good antioxidant effect, which was better than BHT and alpha-tocopherol	[25]

It can be seen from Table 1 that the addition of an appropriate amount of rosemary extracts can significantly inhibit the lipid oxidation of edible vegetable oils such as perilla seeds oil, soybean oil, walnut oil, oil-tea camellia seed oil, and animal oil products such as turtle oil and fish roe oil in food processing, storage and transportation. Besides, it can delay the formation of oxidation products, and effectively extend the shelf life of products.

In addition, rosemary extracts can significantly improve the sensory quality of fried foods. Pengjuan Li et al.^[26] studied the effects of rosemary antioxidant on the quality of soybean oil-fried potato chips. The results showed that the addition of rosemary antioxidant in soybean oil could effectively enhance the antioxidant activity, and the effect was stronger than that of TBHQ, which had a significant effect on stabilizing the change of oil color. It was expected to replace synthetic antioxidants and be widely used in the frying food industry.

3.2 application in fresh meat products

A large number of studies have proved that the reasonable addition of rosemary extracts or essential oil can effectively inhibit the formation of oxidation products such as TBARS in the processing and storage of meat products, and ensure the sensory quality of products, with good antioxidant effect. Jianglei et al.^[27] determined the effect of adding rosemary extracts to salami, and the results showed that rosemary extracts with appropriate mass fractions could significantly inhibit the increase of TBARS content, effectively prevent the oxidation process of oil and protein in salami, and had good antioxidant activity. Rosemary extracts can also inhibit the proliferation of microorganisms such as spoilage bacteria and pathogenic bacteria in meat products during storage. Radic Z et al.^[28] found that rosemary essential oil

had good preservation effect on fresh chicken by soaking treatment, which could effectively inhibit the reproduction of spoilage bacteria, significantly reduce the TBARS, and maintain the sensory quality of chicken.

Furthermore, rosemary extracts can also cooperate with new processing technologies to enhance the good preservation effect^[29-30]. Huang et al. showed that the nanoemulsion-based edible coating of rosemary extracts and ϵ -poly-L-lysine complex mixtures could significantly inhibit the total viable count (TVC) and the number of microorganisms such as molds in ready-to-eat roast chicken, reduce the lipid oxidation and maintain the stability of pH, so the shelf life of the product was effectively prolonged.

3.3 application in fresh-keeping aquatic products

Aquatic products have high water content and are rich in nutrients such as protein and unsaturated fatty acids. However, they are easy to cause corruption and deterioration, reduce sensory quality, and even cause food-

borne diseases in the process of processing, storage and transportation. Therefore, natural rosemary extracts with good antibacterial effect have been widely used in the preservation of aquatic products. A large number of studies have shown that the synergistic treatment of rosemary extracts or essential oil with storage technologies such as ice storage and active packaging could effectively inhibit the peroxide value, TBARS value, TVBN and other physicochemical indexes of sardines, rainbow trout, red shrimp and other aquatic products during storage. Moreover, significantly delay the spoilage and the proliferation of microorganisms, maintain the sensory quality of the product, thus effectively prolong the shelf life of aquatic products^[31-35]. In addition, rosemary extracts can also be used to prepare composite membrane of food, which has good preservation effect in the application of aquatic products^[36-37]. Dong Ruyue et al. found that the gelatin-chitosan-rosemary extracts composite coating film could effectively inhibit protein oxidation and maintain the sensory quality of shrimp.

Table 2 Application of rosemary extracts in fresh-keeping aquatic products

product variety	application method	applying effect	references
fresh pacific white shrimp	placed the shrimp around a small petri dish containing rosemary extracts at a dosage of 0.75 mg/cm ² , placed the sample in a plastic bag and refrigerated at 4°C for 12 days	The active packaging of rosemary extracts could inhibit the increase of POV and TBARS value of the samples during the cold storage process, slow down the changes in the activity of Ca ²⁺ -ATPase and sulfhydryl groups, and prolong the shelf life of shrimps	[31]
large yellow croaker	large yellow croaker was soaked in 0.2% rosemary extracts solution for 1 hour, then drained, packed in a cooking bag and refrigerated at 4°C for 20 days	Rosemary extracts could effectively inhibit the growth of microorganisms, reduce the increase of TBARS, TVBN and K value, slow down the oxidation of protein, and extend the shelf life of products	[32]
sardine	sardine fillets were soaked in 10 g/L rosemary extracts solution for 4 minutes, then vacuum packaged and stored at 3°C for 20 days	Rosemary extracts could significantly reduce the increase of TVBN, TBARS, free fatty acid (FFA) and other physicochemical indexes, inhibit the proliferation of microorganisms, and effectively extend the shelf life	[33]
rainbow trout	rainbow trout fillets were soaked in 4% rosemary essential oil nanoemulsion solution for 3 minutes, packaged them in stretch film and stored them at 2°C for 20 days	The soaking treatment of rosemary essential oil nanoemulsion solution could effectively reduce the increase of physicochemical indexes such as TVB-N, TBARS and FFA, inhibit the growth of bacteria, and improve the sensory quality of the product	[34]
red shrimp	red shrimps were soaked in 0.2% (W/W) rosemary extracts solution at 0°C for 10s-15s and stored them at -20 °C for 24 weeks	The soaking treatment of rosemary extracts solution could effectively reduce the increase of TVB-N, POV value and FFA, and maintain the sensory quality of the product	[35]

4 Conclusion

In summary, rosemary extracts has been widely range of applications in various fields such as food processing and pharmaceutical industry. Because of its antioxidant physiological function, it is an effective free radical scavenger, which can prevent the spoilage of foods, and improve the nutritional value of food. Moreover, it has the application prospect of antibacterial and antiviral effects, prevention and treatment of cancer and depression, etc., and is widely favored in the medical field. In recent years, rosemary extracts has been used as an additive in livestock and poultry production. It can not only improve the oxidative damage, resist the invasion of pathogenic bacteria and enhance the immunity of the body, but also effectively improve the growth performance of livestock and poultry and improve the nutritional value of meat. In addition, rosemary extracts has the effects of preventing aging and improving memory, which can be used as a good anti-aging and brain-strengthening functional factor for the development of functional foods. With the continuously further study of rosemary extracts, it is believed that rosemary extracts will have a broader application prospect in the future and have more positive effects on people's lives

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