The Effects and Current Development of Traditional Chinese Medicine Polysaccharides on Cardiovascular Diseases

Mingliang Yin, Yuqing Tong
Affiliated Hospital of Inner Mongolia Minzu University, Tongliao, Inner Mongolia Autonomous Region, China

Abstract: Cardiovascular diseases (CVD) pose a significant threat to human health. Polysaccharides are high molecular weight compounds composed of multiple monosaccharides linked by glycosidic bonds. Current research indicates that plant-derived polysaccharides exhibit a range of bioactive properties, such as antiviral, anti-inflammatory, antioxidant, lipid-lowering, anti-angiogenic effects, immune function activation, gut microbiota regulation, hypoglycemic, and anti-tumor activities, while demonstrating minimal toxic side effects. They play a crucial role in the prevention and treatment of cardiovascular diseases, with potential to improve conditions like myocardial fibrosis, myocardial infarction, atherosclerosis, and hypertension. This study reviews the effects and current developments of Traditional Chinese Medicine polysaccharides in the context of cardiovascular disease prevention and treatment, offering valuable insights for future research and application in this field.

Keywords: Traditional Chinese Medicine Polysaccharides; Cardiovascular Diseases; Mechanism of Action; Current Development Trends

1. Introduction

Cardiovascular diseases (CVD) pose a significant threat to human health. In China, the current number of individuals suffering from cardiovascular diseases is staggering, with 330 million affected by various conditions such as 13 million cases of stroke, 11.39 million cases of coronary heart disease, 8.9 million cases of heart failure, 5 million cases of pulmonary heart disease, 4.87 million cases of atrial fibrillation, 2.5 million cases of rheumatic heart disease, 2 million cases of congenital heart disease, and 45.3 million cases of peripheral arterial disease, as well as 245 million cases of hypertension [1]. Polysaccharides, naturally occurring high molecular weight polymers, are composed of ten or more monosaccharides linked by glycosidic bonds. They are widely present in animals, plants, and microorganisms [2]. Research has revealed that traditional Chinese medicine polysaccharides can ameliorate various cardiovascular diseases, including myocardial ischemia-reperfusion injury, myocardial infarction, atherosclerosis, and myocardial hypertrophy [3]. The identified protective mechanisms involve the activation or inhibition of multiple signaling pathways such as NF-κB, PI3K/Akt, endoplasmic reticulum stress, and Nrf2, thereby exerting protective effects against oxidative stress, inflammation, endoplasmic reticulum stress, cellular apoptosis, and regulation of energy metabolism imbalance in cardiovascular diseases [4]. This study provides an analytical study of the effects and current developments of traditional Chinese medicine polysaccharides in the context of cardiovascular diseases, aiming to offer valuable insights for the future prevention and treatment of cardiovascular diseases using traditional Chinese medicine polysaccharides.

2. Preventive and Therapeutic Effects of Traditional Chinese Medicine Polysaccharides on Myocardial Fibrosis

Myocardial fibrosis, a significant pathological process in cardiovascular diseases typically induced by inflammation and excessive expansion, leads to the activation of myofibroblasts and excessive accumulation of collagen I, III, and IV in the extracellular matrix [5-7]. Mitochondrial dysfunction and oxidative stress reactions promote the fibrotic process [8]. Mitochondria serve as the hub for organismal energy metabolism, and their malfunction leads to disruptions in myocardial cell energy metabolism, resulting in fibrosis and arrhythmias [9]. Research has demonstrated that ginseng polysaccharides can protect myocardial cells by regulating mitochondrial apoptosis [10]. Studies by Ma et al. [11] have revealed that red ginseng polysaccharides (RGP) can regulate and alleviate oxidative stress reactions in vivo in small coronary atherosclerotic heart disease (CHD) mice, improving myocardial fibrosis by modulating the SIRT1/PGC1α signaling pathway and regulating myocardial mitochondrial energy metabolism. Lycium barbarum polysaccharide (LBP), a major active component of Lycium barbarum, demonstrates significant therapeutic efficacy in treating hypertension, atherosclerosis, and other cardiovascular diseases [12]. Research by Ma et al. [13] has shown that Ningxia Lycium barbarum polysaccharides can effectively inhibit TGF-β1-stimulated activation of CFs, reduce the mRNA expression of fibrosis transcription factors such as Snail, Twist, and S100A4, consequently causing a down-regulation of myocardial fibrosis-related genes including Smad2, p-Smad2, Smad3, p-Smad3, and Smad4 protein expression levels. Studies indicate that astragalus polysaccharides (APS), one of the primary active components of the traditional Chinese medicine Astragalus, primarily composed of two polysaccharides, APSI and APSII [14]. APS enhances the survival rate of myocardial cells, inhibits myocardial cell apoptosis, and exerts a certain protective effect on myocardial cells subjected to hypoxia/reoxygenation injury [15]. Research by Zhu et al. [16] suggests that APS has a certain preventive and therapeutic effect on isoproterenol (ISO)-induced myocardial fibrosis, with its mechanism associated with the inhibition of the TGF-β1/Smads pathway. Studies have reported that Angelica sinensis polysaccharide, through the inhibition of the MAPK/NF-κB pathway, reduces the generation of high levels of inflammatory factors such as TNF-α, IL-1β, and IL-6 after myocardial infarction [17], thus alleviating the inflammatory response and delaying the myocardial fibrotic process. Sugarcane leaf polysaccharide promotes the expression of vascular endothelial growth factor (VEGF) in the myocardial tissue surrounding the infarcted area, exhibiting a certain protective effect on ischemic myocardium. In addition, studies on the pharmacological effects of sugarcane leaf polysaccharides demonstrate its anti-inflammatory, antioxidant, and free radical scavenging properties [18]. Research by Liu et al. [19] has revealed that sugarcane leaf polysaccharides can alleviate interstitial fibrosis in the border zone of the infarcted myocardium in rats after myocardial infarction, and its mechanism is associated with the inhibition of the expression of the pro-fibrotic genes TGF-β1 and NFκ-B mRNA, and down-regulation of pERK1/2/ERK1/2 protein expression levels. Chitosan is a natural polysaccharide that, as a biomaterial base, possesses sufficient mechanical stability to stimulate the natural collagen fiber structure, inducing pluripotent stem cells and mesenchymal stem cells to differentiate into myocardial cells, thereby being employed in cardiac tissue engineering for the repair of damaged cardiac tissue [20]. In conclusion, traditional Chinese medicine polysaccharides demonstrate potential protective effects on myocardial fibrosis through the modulation of multiple signaling pathways, the alleviation of inflammatory responses, and the inhibition of oxidative stress.

3. The Effects of Traditional Chinese Medicine Polysaccharides in Coronary Heart Disease

Coronary heart disease, with atherosclerosis of the coronary arteries as its pathological basis, remains the leading cause of cardiovascular mortality. Atherosclerosis is a complex inflammatory process mediated by lipids and cholesterol in the arterial vessel walls. Due to inadequate blood supply and reduced vascular compliance, the vessel walls gradually narrow, leading to cardiovascular diseases. Peng et al. [21] isolated homogeneous polysaccharides from kelp, known as laminarin-derived homogeneous polysaccharides (LJP12). LJP12 has been shown to dose-dependently inhibit the formation of atherosclerotic plaques and reduce blood lipid levels induced by a high-fat cholesterol diet (HFD). Long-term oral administration of LJP12 prevents the occurrence of atherosclerosis by inhibiting inflammation mediated by the NF-kB/MAPKs pathway. Wan et al. [10] established a coronary heart disease model in rats by feeding them a high-fat diet. They found that ginseng polysaccharides can significantly reduce mitochondrial calcium (Ca^{2+}) levels and increase succinate dehydrogenase (SDH) activity, thereby improving the body's antioxidant capacity. Ginseng polysaccharides also enhance antioxidant levels in coronary heart disease rats by improving levels of malondialdehyde (MDA), glutathione peroxidase (GSH-Px), and superoxide dismutase (SOD). Additionally, increasing concentrations of ginseng polysaccharides significantly reduce the expression levels of Fas, FASL, Bcl-2, and Bax genes in rats. Li et al. [22] demonstrated that dendrobium polysaccharides have significant scavenging effects on DPPH· and ·OH radicals, indicating good in vitro antioxidant capability. This offers a potential reference for the development of drugs against atherosclerosis and cardiovascular diseases. Astragalus polysaccharides can upregulate cholesterol α-hydroxylase and low-density lipoprotein receptor expression in the liver, leading to reduced total cholesterol and triglycerides in the liver. Studies have shown that after intervention with astragalus polysaccharides for three months in a mouse model of atherosclerosis, there was a 45.8% reduction in total cholesterol, a 30% reduction in triglycerides, and a 47.4% reduction in low-density lipoprotein-cholesterol complexes. Astragalus polysaccharides participate in regulating the progression of atherosclerotic lesions by promoting cholesterol metabolism and transport [23] Musa balbisiana polysaccharides effectively reduce excessive proliferation of vascular smooth muscle cells (VSMCs) by downregulating the expression of sterol regulatory element-binding proteins (SREBPs) and suppressing cholesterol overproduction. Musa balbisiana polysaccharides have a positive significance in regulating cholesterol metabolism disorders and controlling atherosclerosis [24]. Ophiopogon japonicus-derived fructooligosaccharides have been found to have anti-myocardial ischemia effects [25,26] Allium macrostemon (AMB) and allium chinensis (ACGD) crude polysaccharides have in vivo anti-atherosclerotic and lipid-lowering activities. These crude polysaccharides significantly reduce blood lipid levels, improve the morphology and arrangement of myocardial cells, and alleviate the development of myocardial fibrosis. They also show visual improvements in the affected areas of the aorta and aortic valve [27]. Traditional Chinese medicine polysaccharides have various mechanisms of action, including antioxidative, anti-inflammatory, anti-myocardial ischemia, lipid-lowering, and regulation of cholesterol metabolism disorders. These mechanisms play a preventive and adjuvant therapeutic role in coronary heart disease.

4. The Effects of Traditional Chinese Medicine Polysaccharides on Hypertension

Vascular remodeling stands as a significant contributor to hypertension, as the excessive proliferation of smooth muscle cells leads to a reduction in vessel lumen diameter and an increase in vessel wall thickness, constituting the fundamental pathogenic mechanism of hypertension [28]. Polysaccharides with antihypertensive properties have been widely sourced, including those extracted from aquatic plants (such as brown algae, kelp, seaweed, red algae, and sea sedge) and terrestrial plants (cactus fruit, Gastrodia, astragalus, and Lycium barbarum), microbial polysaccharides extracted from fungi (such as pleurotus nebrodensis, Cordyceps sinensis) and bacteria (such as Lactobacillus kefiranofaciens), as well as animal polysaccharides (oysters and squid skin). Ulva polysaccharides have been shown to reduce systolic and diastolic blood pressure by 19% and 39% respectively in Wistar male rats [39]. Studies by Gong et al. [30,31] have shown that polysaccharides from Dictyophora indusiata meet the oral administration requirements for antihypertensive drugs and significantly reduce blood pressure in SD rats, dogs, and spontaneously hypertensive rats (SHR). Polysaccharides from corn stigma (PCS), a water-soluble extract from corn silk with a content of 4%, reduce high-salt-induced hypertension by lowering vascular oxidative stress reactions, enhancing antioxidant capacity, and subsequently influencing vascular contractile function [32]. Polysaccharides from Dendrobium officinale significantly reduce blood pressure in SHR rats, with effects comparable to those of the Western medicine Amlodipine [33]. Plantain seed crude polysaccharides lower blood pressure in hypertensive patients by promoting the growth of intestinal bifidobacteria and bacteroides, thereby improving gut microbiota [34]. Salvia miltiorrhiza polysaccharides exhibit significant antihypertensive activity by modulating the expression of the COX-2 gene to reduce blood pressure [35]. Oyster polysaccharides also have a marked effect on reducing both systolic and diastolic blood pressure in hypertensive model rats through gastric administration [36], with antihypertensive efficacy comparable to Captopril [37]. Grifola frondosa polysaccharides possess good blood pressure-lowering effects and show some restorative action on damage caused by hypertension [38]. Cactus fruit polysaccharides (CPFP) predominantly exert a dose-dependent antihypertensive effect in SHR. While its antihypertensive effect is not as rapid as that of captopril, it features an overall mild and long-lasting effect without any apparent drug tolerance, with no significant impact on heart rate, thus ensuring a safe and reliable antihypertensive effect [39]. CPFP achieves the alleviation of hypertension by reducing the expression of proliferating cell nuclear antigen (Ki-67) and basic fibroblast growth factor (bFGF) to mitigate the abnormal proliferation of vascular smooth muscle cells [40]. Cordyceps sinensis polysaccharides significantly downregulate the protein expression of hepatic smooth muscle actin, TGF-β1, TBR-I, p-Smad2, p-Smad3, and TIMP2, indicating that Cordyceps sinensis polysaccharides mitigate hypertension by regulating the TGF-β/Smads signaling pathway [41]. Furthermore, brown algae sulfated polysaccharides, marine sulfated polysaccharides (AHD), and Gastrodia polysaccharides can reduce blood pressure levels by promoting nitric oxide (NO) generation and lowering the levels of ET and Ang-II in the body [42]. Due to the diverse etiology and intricate pathogenesis of hypertension and the difficulty of achieving significant therapeutic effects with single-target antihypertensive drugs, polysaccharides, owing to their abundant sources, diverse activities, and low toxicity, have played a positive role in hypertension prevention and treatment, holding potential for development as antihypertensive drugs.

5. The Effects of Traditional Chinese Medicine Polysaccharides on Cardiomyopathy

Myocardial hypertrophy is an adaptive response of the heart to various injurious stimuli, characterized by increased synthesis of myocardial cell proteins, enlargement of myocardial cell volume, and concurrent proliferation and fibrosis of cardiac interstitial cells [43]. Astragalus polysaccharides can improve isoproterenol-induced myocardial hypertrophy and myocardial cell apoptosis, potentially by protecting the heart through the modulation of protein expression related to cellular apoptosis, including bcl-2, bax, and caspase-3 [44]. Hedysarum polybotys polysaccharides have an ameliorating effect on isoproterenol-induced myocardial hypertrophy in mice, which is associated with the enhancement of PI3K/Akt signaling pathway activity [45]. Poria cocos polysaccharides can inhibit the occurrence and development of myocardial hypertrophy in rats, improve the hemodynamics of myocardial hypertrophy rats, enhance myocardial contractile function, improve myocardial diastolic function, and increase cardiac output in myocardial hypertrophy rats [46]. Ginseng polysaccharides have the ability to effectively inhibit myocardial hypertrophy in AAC rats and improve their energy metabolism, thereby enhancing mitochondrial vitality [47]. Astragalus polysaccharides improve pressure overload-induced myocardial hypertrophy in mice by modulating the ROS/Akt signaling pathway [48].

6. Conclusion

In recent years, extensive attention has been given to the research regarding the protective effects of traditional Chinese medicine polysaccharides in cardiovascular health. Currently, some of these polysaccharides have been developed into medications for the treatment of cardiovascular diseases. Clinical practice has demonstrated the favorable efficacy of these medications in lowering blood pressure, improving myocardial ischemia, and exhibiting minimal side effects. As research into traditional Chinese medicine polysaccharides deepens, their protective effects on the cardiovascular system continue to be revealed, offering the promise of better strategies for the prevention and treatment of cardiovascular diseases in the future.

While traditional Chinese medicine

polysaccharides have made significant strides in the prevention and treatment of cardiovascular diseases, they still face numerous challenges. Firstly, the diverse and complex composition of traditional Chinese medicine polysaccharides necessitates further in-depth research into their exact mechanisms of action. Secondly, there is an urgent need to address how to enhance the bioavailability and stability of these polysaccharides. Finally, the future direction of research also involves optimizing the application of traditional Chinese medicine polysaccharides in clinical practice to achieve personalized therapy.

In conclusion, traditional Chinese medicine polysaccharides, as a class of natural drug components with broad prospects for application, merit in-depth research and development for their role in the prevention and treatment of cardiovascular diseases. With the continuous advancement of science and technology, as well as the accumulation of clinical applications, it is believed that traditional Chinese medicine polysaccharides will bring about new breakthroughs and hope for the treatment and prevention of cardiovascular diseases.

References

[1] National Center for Cardiovascular Diseases. Annual Report on Cardiovascular Health and Diseases in China (2022). Beijing: Peking Union Medical College Press, 2023.
[2] Yu Y, Shen M, Song Q, et al. Biological activities and pharmaceutical applications of polysaccharide from natural resources: A review. Carbohydr Polym.2018, 183: 91.
[3] Xie M, Tao W, Wu F, et al. Anti-hypertensive and cardioprotective activities of traditional Chinese medicinederived polysaccharides: A review. Int J Biol Macromol, 2021, 185:917-934.
[4] Guo J W, Fu Z F, Zhan J G, et al. Research progress on mechanism of traditional Chinese medicine polysaccharides in prevention and treatment of cardiovascular diseases. Drugs & Clinic. 2023, 38(07):1779-1785.
[5] Lafuse W P, Wozniak D J, Rajaram M V S. Role of cardiac macrophages on cardiac inflammation, fibrosis and tissue repair. Cells, 2020, 10(1):51.
[6] Liu M R, López de Juan Abad B, Cheng K. Cardiac fibrosis: Myofibroblast-mediated pathological regulation and drug delivery strategies. Adv Drug Deliv Rev, 2021, 173:504-519.
[7] Yuan Q, Tan R J, Liu Y H. Myofibroblast in kidney fibrosis: Origin, activation, and regulation. Adv Exp Med Biol, 2019, 1165:253-283.
[8] Li X Y, Zhang W, Cao Q T, et al. Mitochondrial dysfunction in fibrotic diseases. Cell Death Discov, 2020, 6:80.
[9] Zheng Z, Xian Y, Jin Z, et al. Rhaponticum carthamoides improved energy metabolism and oxidative stress through the SIRT6/Nrf2 pathway to ameliorate myocardial injury. Phytomedicine, 2022, 105:154197.
[10]Wan H F, Ying J N, Guan Y, et al. Protective effect of ginseng polysaccharide on mitochondria in rats with coronary heart disease. Modern Food Science and Technology. 2020, 36(11):24-28+60.
[11]Ma X G, Zhao S C, Li S X. Effects of red ginseng polysaccharide on myocardial fibrosis and mitochondrial energy metabolism in mice with coronary heart disease. Chinese Journal of Evidence-Bases Cardiovascular Medicine. 2023, 15(06):740-744+74.
[12]Zhou B, Xia H, Yang L, Wang S, Sun G. The Effect of Lycium Barbarum Polysaccharide on the Glucose and Lipid Metabolism: A Systematic Review and Meta-Analysis. J Am Nutr Assoc. 2022 Aug; 41(6):618-626.
[13]Ma Z H, Niu P L, Xu X B, et al. Inhibitory Mechanism of Lycium barbarum Polysaccharide against Cardiac Fibroblast Activation Induced by TGF-β1. Food Science. 2022, 43(19):144-150.
[14]Shao B M, Xu W, Dai H, et al. A study on the immune receptors for polysaccharides from the roots of a stragalus membranaceus. Biochem Biophys Res Commun, 2004, 320 (4) :1103-1111.
[15]Min Q, Bai Y T, Yu W, et al. Protective effects of Astragalus Polysaccharide on cultured myocardial cells subjected to anoxia/reoxygenation injury in neonatal rats. Chinese Pharmacological Bulletin. 2010, 26 (12):1661-1664.

[16]Zhu X Y, Wang H X, Li J S, et al. Protective effect of astragalus polysaccharide on the myocardial fibrosis in rats. Journal of Shenyang Pharmaceutical University. 2017, 34(08):686-693.
[17]Pu S S, Niu X W, Zhang Z. Application of impedance-based real time cellular analyzer to explore the effect of angelica sinensis poly-saccharides on ischemic injury after acute myocardial infarction. Journal of Cardiovascular and Pulmonary Diseases. 2020, 39(3):338-342.
[18]Wei J H, Lan C, Tian L. Analysis and evaluation of medicinal value and comprehensive utilization of sugarcane leaves. Popular Science and Technology. 2016, 18(6):84-86.
[19]Liu D, Lin K, Hou X T, et al. Effects of sugarcane leaf polysaccharide on myocardial fibrosis after myocardial infarction in rats. Journal of Guangxi Medical University. 2021, 38(11):2058-2063.
[20]Patel B, Manne R, Patel DB, Gorityala S, Palaniappan A, Kurakula M. Chitosan as Functional Biomaterial for Designing Delivery Systems in Cardiac Therapies. Gels. 2021 Dec 9; 7(4):253.
[21]Peng F H, Zha X Q, Cui S H, et al. Purification, structure features and anti-atherosclerosis activity of a Laminaria japonica polysaccharide. Int J Biol Macromol, 2015, 81:926-935.
[22]Li X L, Bai Q F, Sun T J, et al. Structural Characterization and Antioxidant Activity of Dendrobium officinale Polysaccharides. Science and Technology of Food Industry:1-12 [2024-03-31].
[23]Cheng Y, Tang K, Wu S, Liu L, Qiang C, Lin X, et al. Astragalus polysaccharides lowers plasma cholesterol through mechanisms distinct from statins. PloS one. 2011, 6:e27437.
[24]Pan X T, Liang Y, Zeng D C, et al. Effects of Musa balbisiana polysaccharide on the proliferation of vascular smooth muscle cells in SHR rats and their relationship with sterol regulating elements binding protein expression. Chinese Journal of Traditional Chinese Medicine and Pharmacy. 2019, 34(07):3026-3030.
[25]Wang S, Feng Y, Xu D S, et al. Research on the effect of Ophiopogon japonicus polysaccharides on leptin expression in endothelial cells based on antibody chip. 2008 Annual Academic Conference of the Chinese Pharmaceutical Association and the 8th Chinese Pharmacists Week Thesis Collection:9.2008,1664-1672.
[26]Wang S, Zhang Z, Lin X, et al. A Polysaccharides, MDG-1, induces S1P1 and b FGF expression and augments survival and in the ischemic heart. Glycobiology,2010,20(4):473-484.
[27]Qin Z, Huang M, Zhang X, et al. Structural and in vivo-in vitro myocardial injury protection features of two novel polysaccharides from Allium macrostemon Bunge and Allium Chinese G. Don. Int J Biol Macromol. 2024 Mar 2;264(Pt 1):130537.
[28]Zou F, Li Y, Zhang S, et al. DP1(prostaglandin D2 receptor 1) activation protects against vascular remodeling and vascular smooth muscle cell transition to myofibro-blasts in angiotensin II-induced hypertension in mice. Hypertension, 2022, 79:1203-1215.
[29]Tair Z, Bensalah F, Boukortt F. Effect of green al ga Ulva lactuca polysaccharides supplementation on blood pressure and on atherogenic risk factors, in rats fed a high fat diet. An nales De Cardiologie Et d'Angeiologie, 2018, 67(3):133−140.
[30]Gong S J, Su X J, Ruan J, et al. Effect of polysaecharides from Lysimachia fortunei maxim on blood pressure in SD animals. Lishizhen Medicine and Materia Medica Research, 2009, 20(3):579−580.
[31]Gong S J. Study on the purificatoin and antihypertension of polysaccharides from Lysimachia fortunei maxim. Guilin: Guangxi Normal University, 2006.
[32]Liang Y F, You Q X, Gu Q Y, et al. Antioxidative stress of corn silk polysaccharides on high-salt-induced hypertensive rats. Chinese Journal of Gerontology. 2022, 42(12):3037-3040.
[33]Zhao W H, Ma J Z, Nie X J, et al. Research on the hypotensive effect of Rehmannia glutinosa alcohol extract on spontaneous hypertensive rats. Zhejiang Journal of Traditional Chinese Medicine. 2018, 53(08):564-566.
[34]Li H, Xie H B, Qi R, et al. Clinical study on the effect of Plantain seed crude polysaccharide capsules on blood pressure

in elderly hypertensive patients affected by intestinal bacteria. Clinical Research of Traditional Chinese Medicine. 2019, 11(11):15-19.

[35]Li X H, Jiang C, Song F Y, et al. Effects of Salvia miltiorrhiza polysaccharides on blood pressure and COX-2 gene's expression in SHR hypertensive rats. Beijing Journal of Traditional Chinese Medicine. 2017, 36(08):706-709.

[36]Shi X, Guo G L, Ma H H, et al. Evaluation of antihypertensive effect of a water-soluble polysaccharide from Crassostrea gigas. Hebei Fisheries. 2015(02):1-2+52.

[37]Wang T, Ding J, Li H, et al. Antihypertensive activity of polysaccharide from Crassostrea gigas. International Journal of Biological Macromolecules,2016(83):195−197.

[38]Zhang L X, Yang J, Ni Y B, et al. Effects of Grifola frondosa Polysaccharide on blood pressure and ultrastructure of heart and kidney in spontaneous hypertensive rats. Chinese Journal of Gerontology. 2013, 33(19):4764-4766.

[39]Liu H G, Liang Q Y, Huang H X, et al. Pharmacodynamic Study on Cactus Fruit Polysaccharide Extract. Chinese Journal of Experimental Traditional Medical Formulae. 2011, 17(19):170-173.

[40]Liang Q Y, Huang H X, Cao J T, et al. Protective effect of Cactus fruit polysaccharides extract on endothelial function of spontaneously hypertensive rats. Journal of Chinese Medicinal Materials. 2011, 34(7):1104−1107.

[41]Peng J, Li X, Feng Q, et al. Anti-fibrotic effect of Cordy ceps sinensis polysaccharide: Inhibiting HSC activation, TGF-β1/ Smad signalling, MMPs and TIMPs. Experimental Biology & Medicine,2013,238(6):668−677.

[42]Miao H C, Shen Y S. Antihypertensive Effect of Polysaccharides substracted from Gastrodia elata Blume. Chinese Journal of Hypertension. 2006, 14(7):531−534.

[43]Oldfield CJ, Duhamel TA, Dhalla NS. Mechanisms for the transition from physiological to pathological cardiac hypertrophy. Can J Physiol Pharmacol, 2020, 98(2):74-84.

[44]Hu J, Wang H X, Tang F T, et al. Effects of Astragalus polysaccharides on myocardial hypertrophy and myocardial cell apoptosis induced by isoproterenol in rats. Pharmacology and Clinics of Chinese Materia Medica. 2016, 32(02):107-110.

[45]Chen Q Y, Sun Y, Gao C H, et al. Effects of Hedysarum polybotys polysaccharide on isoproterenol-induced mouse myocardial hypertrophy via PI3K/Akt signaling pathway. Chinese Traditional Patent Medicine. 2023, 45(11):3598-3603.

[46]Li X, Jiang C X, Hu Y D, et al. Effects of Poria cocos mushroom polysaccharides on cardiac function of rats with isoproterenolinduced cardiac hypertrophy. Chinese Journal of Injury Repair and Wound Healing (Electronic Edition). 2014, 9(04):367-371.

[47]Zhang D L, Wang H X, Liang L J, et al. Effect of ginseng polysaccharides on hypertrophy of abdominal aorta stenosis rats and myocardial energy metabolism. Chinese Journal of Modern Applied Pharmacy. 2013, 30(06):571-575.

[48]Chen G Q, He J L, Bai F W, et al. Mechanism discussion on the improvement of Astragalus polysaccharides on myocardial hypertrophy in abdominal aorta stenosis mice based on the ROS/Akt signaling pathway: Lishizhen Medicine and Materia Medica Research, 2022, 33(5):1083-1086.