

Recent advances in Representational structures and pharmacological activities of *Polygonatum odoratum* polysaccharide

Cong Li *, Renyue Cai, Canpeng Luo, Jiahui Li, Zuoduo Wu, Jiuming Dong
College of Hunan Agricultural University, Changsha, China

*Corresponding Author: Cong Li

ABSTRACT

With the growing market of Chinese medicinal materials in China, *Polygonatum odoratum* is popular among the public as the leading medicinal materials in Hunan Province, and *Polygonatum odoratum* is recognized as the first batch of Chinese medicinal materials with the same origin as food and medicine by the National Health Organization. As one of the main active ingredients, its polysaccharide has anti-aging, anti-oxidation, immune regulation, hypoglycemia and other effects. In this paper, Extraction and purification methods, structure elucidation and characteristics, biological activity and mechanism, innovative application, biosynthesis mechanism research and development prospect of this herb were reviewed.

KEYWORDS

Polygonatum polysaccharides; Traditional Chinese medicine; Characterization studies; Separation and purification; Pharmacological activities.

1. INTRODUCTION

Jade bamboo, also called Weiwei and Lady's wilt, is the dried rhizome of *Polygonatum odoratum* (Mill.) Druce, family Liliaceae, which is also highly valued for its edible and medicinal properties [1]. Yuzu has been regarded as a medicinal herb in China since ancient times, and is mainly produced in Hunan, Anhui, Henan and Zhejiang. According to "Shennong's Classic of the Materia Medica", "Yuzu is known as a superior Chinese herbal medicine, and its functions include nourishing yin and moisturizing dryness, generating fluids and quenching thirst. At the same time, it has a certain moisturizing in anti-aging effect on human skin." In recent years, more than 150 compounds have been isolated from yucca respectively steroidal saponins, polysaccharides, flavonoids, alkaloids, volatile oils, etc. and modern pharmacological studies have shown that some of the compounds in yucca have the efficacy of hypoglycemia, anticancer, antiaging, immunomodulation, antibacterial, etc. [2]. Among them, polysaccharide is one of the main pharmacological active ingredients. At present, the research and application development of the polysaccharide composition of yucca has achieved certain results on yucca. In this paper, we review the polysaccharide extraction and purification methods, structural analysis and characterization, biological activities and mechanisms, innovative applications, biosynthesis mechanism studies, challenges and prospects for future research.

2. EXTRACTION OF POLYSACCHARIDES FROM POLYGONUM MULTIFLORUM

2.1. Traditional extraction methods

The polysaccharide content of *Yucca schidigera* is related to the growth years, rhizome age nodes, species, harvesting period and processing methods. In recent years, research on polysaccharide extraction has focused on improving the traditional hot water extraction method, supplemented by physical techniques such as microwave and ultrasonic waves to increase polysaccharide yield. These efforts aim to optimize the productivity of polysaccharides. However, it is worth noting that hot water extraction methods usually have some limitations such as lower leaching efficiency, higher extraction temperature, longer extraction time and less monosaccharide composition in the extracted polysaccharides [3]. For example, Xie Jianjun et al. determined the optimal extraction process conditions for the aqueous extraction of yucca polysaccharides through orthogonal experiments as temperature 90C, material-liquid ratio 1:30, extraction time 3h, alcohol precipitation concentration 90%, and this method can make the dried finished product polysaccharides with an average content of 86.02%; the other more commonly used is the aqueous ethanol precipitation method, such as Wang Qiang et al. utilized the aqueous ethanol precipitation method to extract the yucca polysaccharides, and the optimal extraction process conditions were obtained as follows The optimum extraction conditions were 1:15 ratio of material to liquid, 70C temperature, 1.0h time and 95% ethanol concentration, and the maximum extraction rate of polysaccharides in this method could reach 8.13%.

2.2. Exploration of innovative extraction methods

The extraction process of traditional Chinese medicine can be divided into three steps: 1. penetration and diffusion of the extraction solvent into the interior of the herb; dissolution of the active ingredients inside the herb into the solvent; diffusion of the internal active ingredients into the external surface layer of the herb and into the external solvent. Yucca polysaccharide is a kind of hydrophilic substance, common extraction methods of polysaccharide are enzyme extraction method, aqueous alcohol precipitation method, ultrasonic assisted extraction method, supercritical fluid extraction method.

2.2.1. Enzyme extraction method

The process of enzyme extraction of polysaccharides from yucca is as follows: yucca tuber → drying → crushing → soaking → adjusting PH → adding hydrolase → extraction → centrifugal filtration → centrifugal drying → yucca polysaccharides

The principle of enzyme extraction of polysaccharide lies in the specific catalytic effect of enzyme. Enzymes can selectively degrade the cell wall and cell membrane to release the active ingredients, while the use of enzymes can also allow the degradation of large molecular weight polysaccharides into smaller molecular weight polysaccharide fragments, which is more conducive to the experimenter to isolate the yucca polysaccharides from the cells. liu et al. optimized the cellulase-assisted extraction of polysaccharides of yucca using response surface methodology with the following process conditions: extraction temperature of 58.21°C, extraction time of 3.18h, pH of 3.18h, and extraction time of 3.18h, and extraction time of 3.18h. 3.18h, pH 5.8 and cellulase dosage 6.0%. Under these conditions, the relative yield of polysaccharides extracted with higher than hot water was 15.76% [4].

2.2.2. Water extraction and alcohol precipitation method

Yucca polysaccharide aqueous alcohol precipitation process: yucca drying → crushing → weighing the sample → water constant temperature extraction → filtration → take the filtrate → ethanol

precipitation for 24 h → centrifugation to get the precipitate → low temperature lyophilization → crude polysaccharides standby

In the traditional polysaccharide extraction method, for polysaccharide hydrophilic substances, the method has simple experimental equipment, easy operation and high accuracy, but the extraction rate is relatively low. In order to shorten the extraction time and increase the extraction rate, the researchers improved the extraction method and introduced the dilute alkali extraction method. Compared with water extraction, glycopeptide-bonded glycoproteins are more easily decomposed and polysaccharides are degraded under alkaline conditions, which increases the solubility of polysaccharides [5].

2.3. The development of purification technology of polysaccharide of *Polygonum multiflorum*

At present, most of the researches mainly focus on the process of separation and removal of impurities, extraction and purification, and most of the existing reports use column separation, membrane separation, ion exchange chromatography [6], ultrasound-assisted extraction [7], to purify polysaccharides. The complexity of the process and the low yield of polysaccharides have caused certain difficulties in the structural identification of polysaccharides, and the pharmacological effects and active mechanisms have been less studied.

3. STRUCTURAL ANALYSIS AND CHARACTERIZATION OF YUCCA POLYSACCHARIDES

3.1. Application and limitations of traditional structural characterization methods

The structure of yucca polysaccharides is divided into four levels, and since most of the current studies on the structure of yucca polysaccharides focus on the primary structure, the structure of yucca polysaccharides is generally categorized into the primary structure and the advanced structure. Most of the traditional methods for analyzing yucca polysaccharides are limited to the primary structure, so the mechanism of blood glucose lowering of yucca polysaccharides has not been accurately analyzed, and the molecular structure of polysaccharides has not been completely clarified, and there is a lack of studies on the conformational relationship

between the molecules of yucca polysaccharides. The primary structure of yucca polysaccharide is mostly studied by gel column chromatography and anion-exchange chromatography to obtain polysaccharides for further purification and analysis. Peng et al. separated and purified the crude polysaccharides of yucca polysaccharides into four fractions by using anion-exchange chromatography and gel column chromatography and measured the molecular weights of three fractions of the polysaccharides. Instrumental methods for analyzing the advanced structure of yucca polysaccharides include nuclear magnetic resonance (NMR) and scanning electron microscopy (XRD), etc. However, due to the complexity and variability of the advanced structure of polysaccharides, there is little research on the advanced structure of yucca polysaccharides at present [13].

Table 1.fractions of *Polygonatum odoratum* polysaccharide and related information

subheading	molecular mass	Monosaccharide composition and molar ratio	Structural information	literatures
Neutral yucca polysaccharide	1.21 x 10 ⁶ Da	Mannose: glucose = 5:1	-	[8]
POAP80	-	mannose: glucose: galacturonic acid: galactose = 0.93: 2.65: 29.38: 3.47	β-Pyranose conformation	[9]
POA-70P	4.51 x 10 ⁴ Da	Mannose: glucose: galactose: arabinose: galacturonic acid = 36.67:1.63:8.73:5.36:0.99	Non-homogeneous reticulated or globular structure	[10]
POA-70S	3.89 x 10 ³ Da	Fructose: Fucose: Glucose: Mannose = 69.05:3.85:2.5:0.30	Smooth amorphous solid flake-like appearance	[10]
POAP60-1	-	Mannose: rhamnose: glucose: galactose: arabinose: galacturonide = 1.00:0.82:12.61:4.87:2.23:0.22	β-pyranose configuration, fibrous, branching and twisting into a dendritic form	[11]
NPOP60-1	-	Mannose: glucose: galactose = 1.00:12.07:9.55	β-pyranose configuration, distributed singly or in aggregates, folded into clusters	[11]
PORPs	-	Mannose: glucuronic acid: galacturonic acid: glucose: arabinose: fucose = 18.30:0.81:1.46:41.83:1.53:1.06	Dome-shaped granular, aggregated into smooth, dense, wrinkled sheets	[12]
PORP-1	4025Da	Mannose: glucuronic acid: glucose: arabinose: fucose = 19.28:0.41:39.76:1.54:1.08	Polysaccharides that do not have a triple-stranded helical structure, with a micrometer structure showing diameters in the range of 123-202 nm	[12]

3.2. Innovative structural analysis and exploration of yucca polysaccharides

Compared with the traditional method, which focuses on the physical separation of polysaccharides by chromatography and other methods, and then purified and analyzed, the new method of structural analysis of yucca polysaccharides has been innovated in two directions. The first direction is to integrate biological methods into the structure detection technology, such as specific nucleoside bond zymography and immunological methods; the second direction is to combine multiple processing methods to complement each other's strengths and weaknesses. Zhao Yuanyuan et al. separated polysaccharides by column chromatography, and then determined the polysaccharides with methylation analysis and two-dimensional nuclear magnetism, and proved that the polysaccharides possessed good antioxidant activity by analyzing nine residues of the target polysaccharides. antioxidant activity. The structural study of yucca polysaccharide plays an important role in product development.

3.3. Characteristics of Yucca polysaccharides and their association with pharmacological activities

Polysaccharide is a kind of sugar chain bonded by glycosidic bonds, and its structure includes molecular weight, monosaccharide composition, and spatial three-dimensional structure. Yucca polysaccharide is a white water-soluble polysaccharide solid powder with a molecular weight of approximately 2734 [14]. Zong Xinyan et al. concluded by infrared spectroscopy that most of the yucca polysaccharides were neutral sugars, mainly fructose, and existed in the β -configuration. The rest were glucose, fucose and mannose, and the polysaccharide mass fraction ratios were in the order of 69.05:3.85:2.65:0.30. Jing et al [15] used high performance liquid chromatography (HPLC) to determine the content of polysaccharides in yucca. The results showed that the analytical method could meet the requirements of fingerprint analysis. The results of principal component analysis (PCA) showed that mannose (58.13% ~ 78.18%) and glucuronic acid (2.36% ~ 11.72%) could be used as herbaceous markers for the quality control of yucca, as shown in Fig. 1. Qin et al. analyzed a new sugar ligand obtained by extracting from yucca rhizomes using spectroscopic techniques and chemical methods. This sugar ligand was characterized as 22-OH-25(R,S)furan-5-ethyl-12-on-3 β ,22,26-triol 26-O- β -D-glucopyranoside.

3.3.1. Hypoglycemic effect

In recent years, the number of people suffering from diabetes mellitus in China has gradually increased, and it is impossible to cure it at the clinical level, which poses a greater threat to human health. As a kind of medicinal and food substance, the polysaccharide composition of yucca can effectively reduce blood glucose. Mice in the yucca polysaccharide-treated group showed lower levels of water intake, food intake and urine output than those in the control group [16]. In addition, the application of polysaccharides reduced the rate of apoptosis in diabetic mice induced by STZ, and decreased the serum levels of Caspase-3 and NO, as well as the expression level of iNOS mRNA. The results suggest that polysaccharides have a protective effect on ALX-induced diabetic mice and that this protective effect may be related to their antioxidant activity. It also reduced the blood glucose level in STZ-induced diabetic rats and showed some protective effects. The mechanism of this protective effect may involve inhibition of pancreatic islet cell apoptosis, reduction of caspase-3 levels, and inhibition of iNOS mRNA activity [17][18]. Yucca polysaccharides may exhibit strong hypoglycemic effects by reducing oxidative stress in mice, inhibiting glucosidase activity, lowering blood Glc, ameliorating Glc intolerance, ameliorating insulin resistance, and lowering blood lipids [19].

3.3.2. Anti-cancer effects

Yucca polysaccharide can achieve anticancer effects by inhibiting cancer cell division and proliferation and inducing apoptosis. It is used for the treatment of apoptosis induced through death receptor and mitochondrial pathways, and can promote the apoptotic program of cancer necrosis factor alpha (TNF- α)-induced L929 cells [20]. Ning et al. reported that yucca polysaccharides enhanced the apoptosis of MDA-MB-231 cells, up-regulated the expression of bax, and inhibited the expression of bcl-2 in a concentration-dependent manner, which effectively inhibited the proliferation and induced the apoptosis of breast cancer cells [21]. proliferation and induced apoptosis [21]. Liu et al. showed that yucca polysaccharides induced apoptosis in L929 cells through death receptor and mitochondrial pathways and amplified tnfa-induced apoptosis in L929 cells [22]. Most of the related literature reports inhibit the value-added of cancer cells by highly stimulating chemical methods, while yucca, as a traditional Chinese herb in China, has an equivalent anticancer effect and produces weak adverse effects on the human body, so it can be used as a potential drug for anticancer.

3.3.3. Anti-aging effect

Skin aging is one of the hot topics for people nowadays, and excessive accumulation of ROS after exercise can lead to lipid peroxidation of polyunsaturated fatty acids in biofilm and blood [23] and

interfere with cellular functions. Lipid peroxidation can lead to loss of membrane fluidity and increase in permeability, resulting in the loss of cytoplasmic proteins[24], Yang et al. showed that yucca polysaccharides have the ability to inhibit the production of ROS and thus have a regulatory effect on lipid oxidation[25]. And yucca polysaccharide can enhance the scavenging ability of free radicals and inhibit lipid peroxidation[26]. Luo Rui et al. used a two-phase aqueous system to extract total flavonoids from yucca to formulate sunscreen with yucca polysaccharides as the main ingredient, and its absorbance was measured as 1.037, which was a moderate sunscreen effect. Yuan et al. configured yucca polysaccharides as a moisturizing cream with a moisture retention rate of more than 80%, which was a good moisturizer, and explored the safety of its safety, and found that yucca polysaccharides extracted from the sunscreen were non-toxic, harmless, and highly safe [27].

3.3.4. Other pharmacological effects

According to research, yucca polysaccharides also have certain pharmacological effects in regulating blood lipid levels, which is achieved through the regulation of cytokines to reduce blood lipids [28].

Yucca polysaccharide has some antibacterial effect, Wang et al. extracted polysaccharides from the rhizome of yucca and carried out antibacterial research on cucumber anthracnose pathogens. The results showed that the bacterial inhibition rate was 100%. This research result provides some help for plant source pesticide and bacteriostatic research [29].

Yucca polysaccharide has the ability to regulate glucose metabolism, energy metabolism, amino acid metabolism and lipid metabolism. In hyperthyroidism, it can play an intervening role in adjusting the overall metabolic level to normal. In addition, the changes in metabolic pathways of yucca polysaccharides provide a reference for the diagnosis and treatment of renal yin deficiency syndrome [30].

In high-fat diet-induced obesity experiments in rats, yucca polysaccharides were able to increase the expression of genes related to adipocyte differentiation and lipolysis and decrease the expression of genes related to lipid synthesis. This led to alterations in PPAR γ and FABP4 protein expression, which in turn improved the community structure of the intestinal flora [31]. In addition, yucca polysaccharides have significant inhibitory effects on bacteria such as *Staphylococcus aureus*, *Pseudomonas aeruginosa*, *Bacillus subtilis* and *Escherichia coli* [32].

4. BIOACTIVITIES AND MECHANISMS OF YUCCA POLYSACCHARIDES

4.1. Research on antioxidant activity and its mechanism

Due to the complexity of the structure of yucca polysaccharides themselves, different sources of yucca polysaccharides show different degrees of antioxidant activity, but it is recognized that the antioxidant activity of yucca polysaccharides originates from their scavenging ability of free radicals. Yang et al. showed that polysaccharides in yucca could strengthen the antioxidant defense system and reduce lipid peroxidation in mice through four groups of controlled experiments in mice[33]. Chen et al. showed that yucca soluble polysaccharides had significant inhibitory effects on 1,1-diphenyl-2-picrylhydrazyl (DPPH) radical scavenging, hydroxyl radical scavenging, and on polyunsaturated fatty acid (PUFA) peroxidation [34]. Chen et al. used orthogonal tests to optimize the extraction of alkaline soluble polysaccharides, and demonstrated that polysaccharides from *Yucca schidigera* possessed the ability of scavenging DPPH free radicals, scavenging hydroxyl radicals, scavenging hydroxyl radical scavenging capacity, PUFA protection capacity and other antioxidant activities. Zhao Yuanyuan et al. applied column chromatography four times to yucca crude polysaccharides to obtain PCP-F1, which was then subjected to methylation analysis and two-dimensional nuclear magnetic resonance (NMR), which demonstrated that its primary structure had a total of nine residues, and that this structure possessed a higher free radical scavenging capacity. Even though the antioxidant activity of yucca polysaccharides from different sources may vary due

to their structures, it can be summarized that the antioxidant activity of yucca polysaccharides with high carboxyl group content or with phenolic acid structure will be higher.

4.2. Research on anti-tumor activity and related mechanisms

Under the action of tumorigenic factors, cell proliferation in local tissues can pose a threat to the health of the organism and human life. However, yucca polysaccharides can effectively inhibit the proliferation of cancer cells, enhance the body's immune function, and synergize with chemotherapeutic drugs to improve the pharmacological therapeutic effect [35]. It can inhibit the proliferation of breast cancer cells MDA-MB-231 and reduce the expression of β -cell lymphoma-2 gene, thus effectively inhibiting the proliferation and promoting apoptosis of breast cancer cells [36]. In one study, yucca polysaccharides also promoted apoptosis in A549 cells, inhibited cell proliferation, reduced tumor size and weight, and regulated the expression of Wnt/ β -linker protein and cyclinD1, thereby inhibiting cell proliferation and inducing apoptosis in cancer cells [21].

4.3. Exploration of anti-inflammatory and immunomodulatory activities

The study by Han et al. explored the protective effects of yucca polysaccharides in acute kidney injury (AKI) induced by gentamicin injection in rats. In the study, rats were given different doses of yucca polysaccharides (0.25, 0.5 and 1 g/kg) by gavage for 7 consecutive days. The results showed that yucca polysaccharides significantly reduced renal coefficient, serum creatinine (CRE) and urea levels in rats. In addition, the expression of NGAL and KIM-1 mRNA in renal tissues was reduced. It was also found that yucca polysaccharides inhibited the p38 MAPK/ATF2 signaling pathway as well as the production of inflammatory factors TNF- α , IL-1 β and IL-6 [37]. In addition, a recent study by Liu et al. found that intraperitoneal injection significantly attenuated lung pathological changes in lps-induced acute lung injury (ALI) rats, decreased lps-induced MPO (myeloperoxidase) activity in lung tissues, and increased MDA (malondialdehyde) levels in lung tissues. In addition, yucca polysaccharides decreased the LPS-induced increase in neutrophil ratio and the levels of inflammatory factors in bronchoalveolar lavage fluid (BALF). In addition, polysaccharides reduced LPS-induced inflammatory factor expression in lung tissue [38].

5. INNOVATIVE APPLICATIONS OF YUCCA POLYSACCHARIDES

5.1. Development of drug delivery system

Yucca polysaccharide has a very high value of bioactive utilization. According to the research results of Xingchen Fang et al, direct oral administration of plant polysaccharides will face the problems of polysaccharide degradation by gastric acid and digestive enzymes and the difficulty of large polysaccharides to cross the blood-brain barrier, so they proposed to apply nanotechnology to the delivery process of plant polysaccharides. Yucca polysaccharides are plant polysaccharides, and the integration of nanotechnology into the delivery system of Yucca polysaccharides can not only bring out the biological activities of Yucca polysaccharides, but also act as a carrier for drug delivery with the role of slow and controlled release or targeting, which can better improve the activity of the drug. The application of interactions between yucca polysaccharides and other drugs.

5.2. Application of the interactions between polysaccharides of Polygonum multiflorum and other drugs.

Yucca polysaccharide can also interact with other drugs while exerting its own biological activity. Yucca polysaccharide has the ability to assist the efficacy of anti-tumor drugs, which can improve the efficacy of anti-tumor drugs. In addition, Yucca polysaccharides can also combine with iron to form a combined supplement called Yucca polysaccharide iron (POPFe). Compared with traditional

iron supplements, Yucca polysaccharides iron has no or very little irritation to the gastrointestinal tract, and after the release of iron, the ligand polysaccharides have multi-faceted biological activity, which is beneficial to the body, can be absorbed and utilized, and will not produce adverse reactions.

6. RESEARCH ON THE BIOSYNTHETIC MECHANISM OF YUCCA POLYSACCHARIDES

6.1. Identification and study of biosynthetic pathway

It is now known that rhamnose, galactose, arabinose, mannose, glucose and fructose are present in the composition of yucca polysaccharides. Some studies have shown that the synthesis process of plant polysaccharides all involve the participation of β -fructofuranosidase (sacA), hexokinase (HK), fructose kinase (scrK), and phosphoglucomutase (PGM). Subsequent binding of activated ndp sugar precursors to polysaccharide residues promotes the formation of plant polysaccharides through a series of glycosyltransferase (GT) reactions. Most of the current studies on plant polysaccharide biosynthesis pathways start at the gene level, and therefore genome and transcriptome related approaches are often inseparable from it.

6.2. Application of genomics and transcriptomics in biosynthesis research

Table 2.Number of unigenes coding for some key enzymes of polysaccharide synthesis in *Polygonatum odoratum*

enzyme name	EC number	Number of single genes
β -Fructofuranosidase (sacA)	3.2.1.26	19
Hexokinase (HK)	2.7.1.1	9
Fructose kinase (scrK)	2.7.1.4	6
Mannose-1-phosphate guanylyltransferase (GMPP)	2.7.7.13	7
Glucose-6-phosphate isomerase (GPI)	5.3.1.9	7
Phosphoglucomutase (PGM)	5.4.2.2	5
UTP-glucose-1-phosphate uridyltransferase (UGP2)	2.7.7.9	11
udp - glucose-4-exonuclease (GALE)	5.1.3.2	4
udp - glucose-4-exonuclease (UGE)	5.1.3.6	6
udp - glucose 6-dehydrogenase (UGDH)	1.1.1.22	1
UDP-apiose/xylose synthase (AXS)	--	1
udp - arabinose-4-exonuclease (UXE)	5.1.3.5	3
Note: The data in this table were taken from the genes of key enzymes for polysaccharide synthesis identified by Dandan Li [35] et al.		

At present, the genome of yucca is still little studied, and there is a lack of genomic data that can be used as a reference, so direct sequencing of the genome faces greater difficulties. However, since gene expression can be precisely quantified, we can first sequence the transcriptome, and then identify the functional genes of polysaccharides by backpropagation. Li et al. sequenced the transcriptome of rhizomes from different years of growth of the bamboo, and identified a total of 62,660 genes. A total of 62,635 functional genes were identified, including 89 functional genes encoding key enzymes for polysaccharide synthesis. Subsequently it screened more than 10,000 functional genes for annotation

and identified 588 functional genes corresponding to the polysaccharide biosynthesis pathway, including amino and nucleotide sugar metabolism, fructose and mannose metabolism, glycolysis, and interconversion of pentose and glucuronic acid [39]. When Wu et al. used a transcriptome approach to identify key genes for polysaccharide synthesis of the jade bamboo, they found that a jade bamboo polysaccharide synthesis gene whose expression protein was located in the chloroplasts pathway gene, *PcgalE1*, whose expression differences were most significant in two different sources of yucca material [40]. The results suggest that differences in the degree of expression of this gene lead to differences in the biosynthesis of polysaccharides from different sources of yucca, which in turn leads to differences in the content of polysaccharides in yucca. These results are important for the elucidation of the biosynthetic pathway of polysaccharides in *Yucca schidigera* and for further studies on the accumulation of related secondary metabolism.

7. DEVELOPMENT PROSPECT AND OUTLOOK

As a traditional type of Chinese herbal medicine in China, yucca is widely used in human health care and clinical treatment. On the one hand, as a popular medicinal material in the Chinese herbal medicine market, it has a broad market and wide demand, but its extraction technology is costly and complicated, and the research on polysaccharide extraction needs to be further explored. On the other hand, its polysaccharide components are loved by people for their hypoglycemic, anticancer and anti-aging effects, and there is no groundbreaking innovation in the uneven research on its pharmacological effects, and the means of research are also similar, and the research can be explored by analyzing its high-level structure and combining with its pharmacological activities. The physicochemical properties of yucca polysaccharide cannot be studied without its structural analysis, at present, there is still a lot of room for exploration in the analysis of the senior structure of yucca polysaccharide, and there is also a direction to continue to go deeper in the primary structure, due to the complexity of the composition of yucca polysaccharide, and there are differences in the composition of yucca polysaccharides of different origins, so it is possible to analyze the modality to achieve the relevant activities. At the same time, subsequent studies can be conducted to modify the polysaccharides by phosphorylation, acetylation and other modifications to achieve the target physiological active effects. In addition, the biosynthetic pathway of polysaccharides from *M. japonicum* can be analyzed at the genetic level to complete the genome map of polysaccharides from *M. japonicum* and explore the related secondary metabolic processes. As a medicinal and food substance, the development prospect of yucca is broad, and it can be further developed into health care products, beverages, and diets. This paper is expected to be of great help to the researchers in following up the study of polysaccharides from *Polygonum multiflorum*, which is one of the vacant areas in the research field nowadays.

REFERENCES

- [1] Zhou, X. L., Zhang, Y. P., Zhao, H. D., Liang, J. S., Zhang, Y., & Shi, Y. Y. (2015). Antioxidant homoisoflavonoids from *Polygonatum odoratum*. *Food Chemistry*, 186, 63–68.
- [2] Jiang, Q., Lv, Y., Dai, W., Miao, X., Zhong, D., 2013. Extraction and bioactivity of *Polygonatum* polysaccharides. *Int. J. Biol. Macromol.* 54, 131–135.
- [3] S. Huang, J. Li, Z. Wang, H. Pan, J. Che, and Z. Ning, “Optimization of alkaline extraction of polysaccharides from *Ganoderma lucidum* and their effect on immune function in mice,” *Molecules*, vol. 15, no. 5, pp. 3694–3708, 2010.
- [4] Liu X,Zhang M S,Guo K,et al.Cellulase-assisted extraction, characterization, and bioactivity of polysaccharides from *Polygonatum odoratum* [J].*International Journal of Biological Macromolecules*,2015,75(2):258-265.
- [5] K. Mohan, T. Muralisankar, V. Uthayakumar, R. Chandirasekar, N. Revathi, A. Ramu Ganesan, P. Seedeve, et al., Trends in the extraction, purification, characterisation and biological activities of polysaccharides from tropical and subtropical fruits - a comprehensive review, *Carbohydr. Polym.* 238 (2020), 116185.
- [6] Yelithao K, Surayot U, Lee JH, You S. RAW264.7 Cell Activating Glucomannans Extracted from Rhizome of *Polygonatum sibiricum*. *Prev Nutr Food Sci.* 2016 Sep;21(3):245-254.

- [7] Deng Y F, He K, Ye H L, et al. Saponin rich fractions from *Polygonatum odoratum* (Mill.) Druce with more potential hypoglycemic effects [J]. *Journal of Ethnopharmacology*, 2012, 55(1): 228-233.
- [8] Wang Q et al, Sulfation of polysaccharides from jade bamboo and their inhibitory activity against HepG-2 cells in vitro. *Journal of Guangdong Pharmaceutical University*, 2015. 31(05): p. 585-588.
- [9] Li Zhong et al, Isolation and purification of acidic polysaccharides and analysis of monosaccharide composition in Yuzhu. *Chinese Journal of Experimental Formulas*, 2013. 19(09): pp. 69-72.
- [10] Zong Xinyan et al, Isolation and purification of polysaccharides, physicochemical properties and antioxidant function of *Polygonum multiflorum*. *Journal of Nanchang University (Science Edition)*, 2019. 43(01): pp. 70-75.
- [11] Liu M, Extraction kinetic modeling and primary structure identification of water-soluble polysaccharides from *Yucca schidigera*, 2016, Guangdong Pharmaceutical University.
- [12] Huo Da, Isolation and purification, structural characterization, sulfation modification and activity study of water-soluble polysaccharides from jade bamboo, 2020, South China University of Technology.
- [13] Peng, Y. J., Extraction, isolation and purification, structural characterization and application of polysaccharides from Yuzu in cigarettes, 2012, Zhejiang University of Technology. Page 91.
- [14] Nie S P, Cui Steve W, Phillips Aled O, et al. Elucidation of the structure of a bioactive hydrophilic polysaccharide [J]. *Carbohydrate Polymers*, 2011(3): 894-899.
- [15] Jing, Y., et al., HPLC fingerprint analysis of polysaccharides from different accessions of *Polygonatum odoratum*. *Nat Prod Res*, 2023. 37(21): p. 3727-3731.
- [16] Xu, M.H.; Li, W.P.; Gong, H.L. Effects of *Polygona*-polysaccharose on blood glucose and lipid level of diabetic mice induced by alloxan. *Anhui Med. Pharm. J.* 2013, 13, 263–265.
- [17] Gong, H.L.; Li, W.P.; Yin, Y.Y. Hypoglycemic activity and mechanism of *Polygona*-polysaccharose on diabetic rat model. *China J. Chin. Mater Med.* 2009, 34, 1149–1154.
- [18] Gong, H.L. Study on the protective effect of polysaccharide on experimental diabetic animals and its mechanism. *Anhui Med. Univ.* 2009.
- [19] Huiyan Jiang, Yao Xu, Congyong Sun, et al. Physicochemical properties and antidiabetic effects of a polysaccharide obtained from *Polygonatum odoratum* [J]. *International Journal of Food Science & Technology*, 2018, 53(12): 2810-2822.
- [20] Luan W, Qian Y, Ni X, et al. *Polygonatum odoratum* lectin promotes BECN1 expression and induces autophagy in malignant melanoma by regulation of miR1290 [J]. *Oncotargets and Therapy*, 2017, 10(1): 4569-4577.
- [21] Ning D., Jin, M., Xv, T., Sun, J., & Li, M. (2018). Homoisoflavanone-1 isolated from *Polygonatum odoratum* arrests the cell cycle and induces apoptosis in A549 cells. *Oncology Letters*, 16(3), 3545–3554.
- [22] Liu B, Cheng Y, Zhang B, Bian HJ, Bao JK (2009) *Polygonatum cyrtonea* lectin induces apoptosis and autophagy in human melanoma A375 cells through a mitochondria-mediated ROS-p38-p53 pathway. *Cancer Lett* 275: 54–60.
- [23] Hsieh CC, Lee MY, Chen CC, Hsu JJ, Lu HK, Wang C. Hibiscus protocatechuic acid supplementation reduces oxidative stress induced by exhaustive exercise in rat muscle. *J Exerc Sci Fit* 2006; 4: 59-64.
- [24] Niu AJ, Wu JM, Yu DH, Wang R. Protective effect of *Lycium barbarum* polysaccharides on oxidative damage in skeletal muscle of exhaustive exercise rats. *Int J Biol Macromol* 2008; 42: 4474-4479.
- [25] Yang Hongjie, Zhang Xianhao, . Polysaccharides from *Polygonatum odoratum* strengthen antioxidant defense system and attenuate lipid peroxidation against exhaustive exercise-induced oxidative stress in mice [J]. *Tropical Journal of Pharmaceutical Research*, 2017, 16(4): 795-795.
- [26] Zhu, Q., et al., [Protective effects of *Polygonatum odoratum* polysaccharides on alcohol-induced injury of HepG2 cells and its mechanisms]. *Zhongguo Ying Yong Sheng Li Xue Za Zhi*, 2022. 38(3): p. 227-232.
- [27] Yuan, X. Jia, Tang, L. Lin & Zhang, H. Ping, Dual aqueous phase extraction of yucca polysaccharides for the preparation of moisturizing skin care products. *Guangzhou Chemical Industry*, 2018. 46(13): pp. 61-63.
- [28] Yang, L., et al., A Review of the Ethnopharmacology, Phytochemistry, Pharmacology, Application, Quality Control, Processing, Toxicology, and Pharmacokinetics of the Dried Rhizome of *Atractylodes macrocephala*. *Front Pharmacol*, 2021. 12: p. 727154.
- [29] Wang, D. M., Zhang, J. F. & Li, D. W., Study on the fat-soluble components and their antibacterial activities of the rhizomes of *Yucca schidigera* from the Qinling area. *Wuhan Botanical Research*, 2010. 28(05): p. 644-647.
- [30] Zhou, Y., Xiao, R., Hu, Y., Xiong, S., Xie, M., Xia, B., et al. (2017). Metabolomic study of *Polygonatum odoratum* polysaccharide on hyperthyroidism yin-deficiency rats based on GC-MS metabolomics. *Chinese Pharmacy Journal*, 52(14), 1263–1268.
- [31] Wang, Y., Fei, Y., Liu, I., Xiao, Y., Pang, Y., Kang, J., & Wang, Z. (2018). Polysaccharides from *Polygonatum odoratum* modulate gut microbiota and mitigate experimentally induced obesity in rats. *International Journal of Molecular Sciences*, 19(11).

- [32] Chen, Y., Yin, L., Zhang, X., Wang, Y., Chen, Q., Jin, C., ... Wang, J. (2014). Optimization of alkaline extraction and bioactivities of polysaccharides from rhizome of *Polygonatum odoratum*. *Biomed Research International*, 1–8, 2014.
- [33] YANG H J, ZHANG X H. Polysaccharides from *Polygonatum odoratum* strengthen antioxidant defense system and attenuate lipid peroxidation against exhaustive exercise-induced oxidative stress in mice [J]. *Trop J Pharm Res*, 2017, 16(4): 795-801
- [34] Chen Yong, Yin Luoyi, Zhang Xuejiao, et al. Optimization of alkaline extraction and bioactivities of polysaccharides from rhizome of *Polygonatum odoratum*. [J]. *BioMed research international*, 2014, 2014:504896.
- [35] Zhao, J., Ou, S., & Zhao, X. (2016). A study on the extraction of polysaccharide of *Polygonatum odoratum* using ultrasonic and its application in noodles. *Food Research and Development*, 20(37), 41–44.
- [36] Tai, Y., Sun, Y., Zou, X., Pan, Q., Lan, Y., Huo, Q., Liu, H. (2016). Effect of *Polygonatum odoratum* extract on human breast cancer MDA-MB-231 cell proliferation and apoptosis. *Experimental and Therapeutic Medicine*, 12(4), 2681–2687.
- [37] C. Han, T. Sun, Y. Liu, G. Fan, W. Zhang, C. Liu, Protective effect of *Polygonatum sibiricum* polysaccharides on gentamicin-induced acute kidney injury in rats via inhibiting p38 MAPK/ATF2 pathway, *Int. J. Biol. Macromol.* 151 (2020) 595–601.
- [38] T.Y. Liu, L.L. Zhao, S.B. Chen, B.C. Hou, J. Huang, X. Hong, L. Qing, Y. Fang, Z. Tao, *Polygonatum sibiricum* polysaccharides prevent LPS-induced acute lung injury by inhibiting inflammation via the TLR4/Myd88/NF-kappaB pathway, *Exp. Ther. Med.* 20 (4) (2020) 3733–3739.
- [40] Li, D., et al., De novo assembly and analysis of *Polygonatum cyrtoneuma* Hua and identification of genes involved in polysaccharide and saponin biosynthesis. *BMC Genomics*, 2022. 23(1): p. 195.
- [41] Wu, J., et al., Comparative Transcriptome Profiling Reveals Two WRKY Transcription Factors Positively Regulating Polysaccharide Biosynthesis in *Polygonatum cyrtoneuma*. *International journal of molecular sciences*, 2023. 24(16).