Annals of Pharmacology and Pharmaceutics

Research Article
Published: 06 Jan, 2020

Ectogenous Sodium Hyposulphite Enhanced Anti-Pyretic, Analgesic and Anti-Inflammatory Effects of *Radix saposhnikoviae*

Hua Jiang[1,2], Jing-Ming Yang[2] and Xiang-Cai Meng[1]*

[1]*Heilongjiang University of Chinese Medicine, China*

[2]*Jinzhou Medical University, China*

Abstract

Introduction: Unfavorable situations are key factors for elevation of herbal medicine quality. Plants produce a wide range of secondary metabolites to resist environmental stresses. As such, the aim of this study was to investigate whether $Na_2S_2O_4$ stress can enhance the antipyretic, analgesic and anti-inflammatory effects of *Radix saposhnikoviae* (RS).

Materials and Methods: The roots of RS was sprayed with 3 mmol/l $Na_2S_2O_4$ aqueous solution to wet and kept in a relative humidity of 90% for seven days and were named as $Na_2S_2O_4$-stress-RS groups. After this processing, the contents and pharmacokinetic parameters of chromones in rats were measured by HPLC. The antipyretic, analgesic and anti-inflammatory effects were evaluated by pyretic animal model, hot plate test and paw edema model, respectively.

Results: Under $Na_2S_2O_4$ stress, the content of chromone was significantly increased. And only cimifugin was found in plasma after RS and $Na_2S_2O_4$-stress-RS were administered to rats, with a 25.8% increase of $AUC_{0\text{-}24h}$ in the $Na_2S_2O_4$-stress-RS groups. Likewise, more potent antipyretic, analgesic, and anti-inflammatory activities were also found in the latter.

Conclusion: Exposure of *S. divaricata* fresh roots to $Na_2S_2O_4$ enhanced the quality and pharmacological actions of RS.

Keywords: ***Radix saposhnikoviae*; $Na_2S_2O_4$; Pharmacokinetics; Pharmacological actions**

OPEN ACCESS

Correspondence:
Xiang-Cai Meng, Heilongjiang University of Chinese Medicine, Harbin, China,
E-mail: jianghua4657@163.com

Received Date: *19 Nov 2019*
Accepted Date: *16 Dec 2019*
Published Date: *06 Jan 2020*

Citation:
Jiang H, Yang J-M, Meng X-C. Ectogenous Sodium Hyposulphite Enhanced Anti-Pyretic, Analgesic and Anti-Inflammatory Effects of Radix saposhnikoviae. Ann Pharmacol Pharm. 2020; 5(1): 1173.

Introduction

Radix saposhnikoviae (RS), the dry root of *S. divaricata* (Turcz) schischk, is widely used as a medicinal herb in Asian countries [1,2]. It contains chromones such as Prime-O-Glucosylcimifugin (PGCN), cimifugin, and 4'-O-β-D-glucosyl-5-O-Methylvisamminol (GML) [3-6] with the anti-pyretic, analgesic and anti-inflammatory effects [2,7,8]. Now, RS is almost obtained from the cultivated *S. divaricata* and its quality is reduced heavily. So, how to improve the quality of cultivated RS is the key and difficulty in the development of traditional Chinese medicine herbs.

High-quality of *S. divaricata* is mainly distributed in semiarid region which was considered as inappropriate environment or stress. Medicinal plants could not move but mainly depend on the secondary metabolism to adapt to the stress such as high- temperature, strong light and drought [9]. It was showed that environmental stress could lead to excessive production of Reactive Oxygen Species (ROS) in medicinal herbs, with superoxide anion ($O_2^{\cdot-}$) could be increased by 3 times, hydrogen peroxide (H_2O_2) by 20 times [10]. Excessive ROS will damage the medicine plants. Previous studies have shown that ROS was eliminated by antioxidant enzyme and secondary metabolites [11]. Further, the secondary metabolites of medicinal herbs increased concomitantly, which indicated that ROS maybe one of the essential factors for the quality formation of medicinal herbs [12]. Sodium hydrosulfite ($Na_2S_2O_4$), can produce superoxide radical ($\cdot O_2$) in water solution without any toxic substance left [13], is widely used in antichlor, food decolorizer and cosmetics antioxidant. Since the medicinal plants can produce a large amount of ROS under stress, and $Na_2S_2O_4$ maybe have the effect of simulating environmental stress [14]. Fresh root of medicinal herb as a living organism with a complete metabolic unit can directly respond to the environmental stress to avoid the oxygenic photosynthesis. So, fresh root of RS under $Na_2S_2O_4$ stress may continue the physiological process that under inappropriate environment. Therefore, in the processing of RS, the

root of RS was placed in $Na_2S_2O_4$ stress which was named as $Na_2S_2O_4$-stress-RS groups to find out whether $Na_2S_2O_4$ stress has the effect to enhance the secondary metabolites of RS, including chromone which was considered as medicinal active substance of RS.

RS contains a variety of chromones, their contents and activities are various [15], and furthermore the polysaccharide in RS can also affect the bioavailability of chromone [16]. So, it is imprecise to evaluate the quality of RS dependent on the contents of one or more chromones. So, in this study the quality of RS and $Na_2S_2O_4$-stress-RS were evaluated by pharmacokinetics and pharmacological methods.

Materials and Methods

Materials and reagents

HPLC grade methanols were purchased from Tianjin Guangfu Fine Chemical Research Institute (Tianjin, China). Ultra-pure water was prepared from distilled water and used in the experiment. Cimifugin, PGCN and GML were purchased from China food and drug testing institute (Beijing, China) and their purity was higher than 98% by HPLC analysis. 2,4-Dinitrophenol (DNP) was obtained from Chengdu Xiya Chemical Co., Ltd. (Chengdu, China).

Roots collection and treatment

Fresh roots of two years old cultivated *S. divaricata* were collected from Heilongjiang university of Chinese medicine, China. The root of each plant was equally divided into two parts. One part was sprayed with 3 mmol/l $Na_2S_2O_4$ aqueous solution to wet and kept in a relative humidity of 90% for seven days, and finally dried at 55°C ($Na_2S_2O_4$-stress-RS), and the other part was dried at 55°C (RS) directly.

Animals

Animal care and treatment were carried out following the Chinese National Research Council guidelines and were approved by the Subcommittee on Research Animal Care and Laboratory Animal Resources of the Heilongjiang University of Chinese Medicine in China. 160 male Wistar rats (age: 6 weeks, body weight: 200 g ± 20 g) and 70 male Kunming mice (age: 6 weeks, body weight: 20 g ± 2 g) and were purchased from Dalian Medical University. The animals were maintained in cages in a well-ventilated room at temperature of 23°C ± 2°C, humidity of 60% ± 5%, under a 12/12 h light/dark cycle, and were provided free access to standard pellet chow and water.

Determination of chromone contents

The mixture of 0.25 g fine powder of RS or $Na_2S_2O_4$-stress-RS and 10 ml methanol underwent reflex extraction for 2 h. The supernatants were used to determinate the contents of cimifugin, PGCN and GML by High Performance Liquid Chromatography (HPLC). The HPLC analysis method was performed as Yang et al. [15].

Preparation of RS aqueous extract

In each group, 100 g of the dried root power (d<1 mm) was extracted with 1000 ml water at 100°C with reflux for 2 h and the extract was filtered through muslin cloth. Then the residual was extracted with another 1000 ml water again. The two supernatants were mixed and concentrated with vacuum rotary evaporator. Finally, distilled water was added to make aqueous extract at 2 g/ml.

Assessment of antipyretic effect

The antipyretic effect was performed according to the reported method with some modifications [16]. Total 70 rats with temperature fluctuation range ≤ 0.3°C were assigned randomly into RS groups, model group and $Na_2S_2O_4$-RS groups with 10 rats in each group. Rats

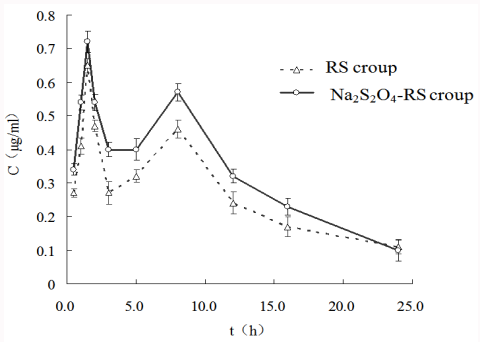

Figure 1: Concentration-time curve of cimifugin in rat plasma of RS and $Na_2S_2O_4$-tress-RS.

pyexia was produced by 15 mg/kg 2,4-dinitrophenol subcutaneous injection. In the $Na_2S_2O_4$-stress-RS group and the RS group, 2.0, 1.0, or 0.5 g/kg RS aqueous extracts were administrated to rats at 1 h after injection. In model group, rats were administered with 2 ml saline. The rectal temperature of each rat was measured using a digital thermometer before and 1, 2, 3 and 5 h after drug administration.

Assessment of anti-inflammatory effect

The anti-inflammatory effect was performed according to the reported method with some modifications [17]. Total 70 rats were assigned randomly into RS groups, model group and $Na_2S_2O_4$-stress-RS groups with 10 rats in each group. In the $Na_2S_2O_4$-stress-RS group and the RS group, 2.0, 1.0, or 0.5 g/kg RS aqueous extracts were administrated to rats. In model group, rats were administered with 0.4 ml saline. Rats paw edema model were established by injection with 0.1 ml of 1% carrageenan solution 30 min after drug administration. And then the edema was measured with volume meter before and 1, 2, 3, 4, and 6 h after edema model injection.

Assessment of analgesia effect

The analgesia effect was performed according to the reported method with some modifications [17]. Mice hot plate test set at 55°C ± 0.5°C was performed to examine the analgesic effect of the drugs. Kunming female mice having latency time 5~30 s was selected in this test. Total 70 mice were randomly assigned into RS groups, model group and $Na_2S_2O_4$-stress-RS groups with ten mice in each group. In the $Na_2S_2O_4$-RS group and the RS group, 2.0, 1.0 or 0.5 g/kg RS aqueous extracts were administrated to mice. In model group, mice were administered with 2 ml saline. The latency times were recorded before and 0.25, 0.5, 1, 1.5 and 2 h after drug administration.

Pharmacokinetic evaluation of chromones

After 24 h starvation, 20 male rats were selected and randomly separated into two groups, with ten rats in each group. In the $Na_2S_2O_4$-stress-RS group and the RS group, 2.5 g/kg RS and $Na_2S_2O_4$-stress-RS extracts were administrated to rats. Blood was obtained from the rat orbit veins at 0.5, 1, 1.5, 2, 3, 5, 8, 12, 16 and 24 h, respectively. The blood samples were treated in the same ways as follows. The sample was centrifugated at 3000 rpm for 10 min. 0.1 ml supernatant was transferred and mixed with 20 μl of 70% perchloric acid. The mixture was vibrated and blended, and then was centrifugated at 3000 rpm for 10 min again. Finally, the supernatant was subjected to 0.45 μm microporous filter for HPLC analysis using a Waters 2695 HPLC with Kromasil C_{18} (4.6 mm × 200 mm, 5 μm). The mobile phases consisted of (A) methyl alcohol and (B) water. The elution condition

Table 1: The chromone contents in RS and $Na_2S_2O_4$-tress-RS (x± s, n=10).

Groups	Contents(mg/g)			
	PGCN	cimifugin	GML	Total chromone
RS	7.03 ± 0.99	0.17 ± 0.02	4.98 ± 0.52	12.18
$Na_2S_2O_4$-stress-RS	8.35 ± 0.84	0.31 ± 0.02	6.47 ± 0.43*	15.13

Table 2: Effect of RS and $Na_2S_2O_4$-stress-RS on 2,4-dinitrophenol-induced pyrexia (x±s, n=10).

Groups	Rectal temperature fluctuation				
	0h	1h	2h	3h	5h
Model group	0.02 ± 0.01	2.31 ± 0.25	2.85 ± 0.26	2.64 ± 0.18	2.35 ± 0.22
1g/Kg RS	0.04 ± 0.03	1.96 ± 0.29	2.49 ± 0.24	2.17 ± 0.19	1.95 ± 0.22
2g/Kg RS	0.01 ± 0.05	1.75 ± 0.21	2.06 ± 0.15	1.88 ± 0.25	1.21 ± 0.19
4g/Kg RS	0.03 ± 0.02	1.77 ± 0.17	1.91 ± 0.21	1.57 ± 0.21	1.24 ± 0.24
1g/Kg $Na_2S_2O_4$-stress-RS	0.03 ± 0.02	1.39 ± 0.25**	2.12 ± 0.29**	1.83 ± 0.14**	1.50 ± 0.25**
2g/Kg $Na_2S_2O_4$-stress-RS	0.03 ± 0.03	1.43 ± 0.11*	1.71 ± 0.22*	1.57 ± 0.13*	1.09 ± 0.20
4g/Kg $Na_2S_2O_4$-stress-RS	0.05 ± 0.02	1.33 ± 0.18*	1.67 ± 0.21*	1.36 ± 0.26*	0.92 ± 0.21*

Table 3: Anti-inflammatory effects of the $Na_2S_2O_4$-stress-RS and RS(x± s, n=10).

Groups	Paw thickness after inflammation (mm)					
	0h	1h	2h	3h	4h	6h
Model group	2.25 ± 0.19	3.16 ± 0.22	3.99 ± 0.32	4.52 ± 0.27	4.82 ± 0.35	4.86 ± 0.33
1 g/Kg RS	2.13 ± 0.24	2.75 ± 0.18	3.47 ± 0.24	3.79 ± 0.31	4.03 ± 0.25	3.75 ± 0.36
2 g/Kg RS	2.26 ± 0.31	2.53 ± 0.25	2.85 ± 0.22	3.53 ± 0.33	3.37 ± 0.24	3.05 ± 0.21
4 g/Kg RS	2.21 ± 0.31	2.32 ± 0.28	2.64 ± 0.25	3.26 ± 0.31	2.86 ± 0.28	3.12 ± 0.21
1 g/Kg $Na_2S_2O_4$-stress-RS	2.22 ± 0.34	2.20 ± 0.14**	2.82 ± 0.30**	3.44 ± 0.32*	3.86 ± 0.22	3.61 ± 0.17
2 g/Kg $Na_2S_2O_4$-stress-RS	2.28 ± 0.34	2.35 ± 0.11*	2.56 ± 0.20*	3.00 ± 0.21*	3.12 ± 0.29	2.82 ± 0.24
4 g/Kg $Na_2S_2O_4$-stress-RS	2.24 ± 0.17	2.28 ± 0.23	2.33 ± 0.18*	2.85 ± 0.23*	2.71 ± 0.23	2.74 ± 0.23

was optimized as follows: 40% to 45% A (0~5 min), 45% to 60% A (5~10 min), 60% to 80% A (10~15 min), 80% to 95% A (15~20 min), 95% to 40% A (20~30 min). The flow rate was 1 ml/min. The column and autosampler temperature were maintained at 40°C and 10°C, respectively. The detection wave length was set at 254 nm. The injection volume was 20 µl.

Statistical analysis

The concentration of chronome in plasma was calculated according to the peak area of cimifugin. Data was expressed as mean ± SD. Differences between two groups were assessed by unpaired two-tailed Student's t-test. Significant differences were indicated in the tables by *P<0.05 and **P<0.01. The pharmacokinetic parameters of chromone were calculated according to non-compartment model by DAS software V2.0. The peak plasma concentration (C_{max}) and the time to reach C max (T_{max}) after oral administration were obtained. The area under the concentration-time curve ($AUC_{0\text{-}24h}$ and $AUC_{0\text{-}\infty}$) and the terminal elimination half-life ($T_{1/2}$) were calculated, too.

Results

Different of chromone contents of RS and $Na_2S_2O_4$-tress-RS

As shown in Table 1, the $Na_2S_2O_4$ stress promoted the synthesis of chromone in RS. Compared with RS group, the content of PGCN increased by 18.12%, from 7.03 mg/g to 8.35 mg/g. And the content of cimifugin increased by 82.35%, from 0.17 mg/g to 0.31 mg/g. And the content of GML increased by 29.92%, from 4.98 mg/g to 6.47 mg/g. Overall, the contents of chromone promoted under $Na_2S_2O_4$ stress, among which the most prominent increase was found with that of cimifugin.

Difference of antipyretic effect

Compared with the RS group, the antipyretic effect of the $Na_2S_2O_4$-stress-RS was significantly increased in each group at the same dosage after 1 h of administration. And this increase persisted until 5 h after administration with more pronounced in the low-dose group (Table 2).

Difference of anti-inflammatory effect

Compared with the RS group, the anti-inflammatory effect of the $Na_2S_2O_4$-stress-RS was markedly enhanced in each group at the same dosage after 1 h of administration. And the largest promotion lasted until 3 h after administration with more pronounced in the low-dose group (Table 3).

Difference of analgesic effect

The latencies of mice licking paws time in $Na_2S_2O_4$-stress-RS group were significantly prolonged than that of RS group. Therefore, the analgesic effect of the $Na_2S_2O_4$-stress-RS was stronger than that of RS (Table 4).

Pharmacokinetic of chromone in rat plasma

Only cimifugin can be detected in rat plasma after oral administration of RS and $Na_2S_2O_4$-stress-RS (Figure 1). In two groups, cimifugin concentration reached two peaks at 1.5 h and

Table 4: Analgesic effect of the $Na_2S_2O_4$-stress-RS and RS in hot plate test(x±s, n=10).

Groups	Latencies of licking paws time (s)					
	0h	0.25h	0.5h	1h	1.5h	2h
Model group	9.67 ± 2.11	10.04 ± 1.98	9.77 ± 1.45	9.98 ± 2.42	10.11 ± 1.32	10.16 ± 1.75
1 g/Kg RS	9.45 ± 1.64	10.97 ± 1.36	11.21 ± 2.36	12.48 ± 2.12	13.97 ± 1.76	14.35 ± 2.53
2 g/Kg RS	9.73 ± 1.88	11.33 ± 2.01	12.67 ± 2.23	13.37 ± 1.89	15.38 ± 1.25	17.02 ± 2.41
4 g/Kg RS	9.56 ± 2.14	11.47 ± 2.25	12.98 ± 2.44	14.54 ± 1.99	15.89 ± 2.18	17.58 ± 2.65
1 g/Kg $Na_2S_2O_4$-stress-RS	9.71 ± 1.86	11.75 ± 2.05	12.71 ± 2.00	12.81 ± 2.22	15.45 ± 1.81	16.71 ± 2.24*
2 g/Kg $Na_2S_2O_4$-stress-RS	9.76 ± 2.14	11.96 ± 1.52	13.15 ± 2.17	14.68 ± 2.03	16.47 ± 2.58	17.55 ± 1.93
4 g/Kg $Na_2S_2O_4$-stress-RS	9.66 ± 2.32	12.35 ± 1.15	13.83 ± 1.64	15.25 ± 2.16	16.88 ± 2.32	17.47 ± 2.13

Table 5: Pharmacokinetic parameters of RS and $Na_2S_2O_4$-stress-RS.

Pharmacokinetic parameters	Unit	RS group	$Na_2S_2O_4$-stress-RS group	*T*-value
$T_{1/2}$	h	4.91 ± 0.23	5.17 ± 0.24	2.463
C_{max}	μg/mL	0.65 ± 0.02 0.46 ± 0.03	0.95 ± 0.13 0.63 ± 0.16	3.234 1.745
T_{max}	h	1.5 ± 0.00 8.0 ± 0.00	1.5 ± 0.00 8.0 ± 0.00	-
$AUC_{0\text{-}24h}$	μg/(mL·h)	6.25 ± 0.87	7.86 ± 0.85	1.434
$AUC_{0\text{-}\infty}$	μg/(mL·h)	7.06 ± 1.08	8.23 ± 1.15	1.664

8 h respectively. And the cimifugin concentration in rat plasma of $Na_2S_2O_4$-stress-RS was significantly higher than that of RS. Within 0 h to 24 h, the $AUC_{0h\text{-}24h}$ was 6.25 μg/(mL·h) in RS group, whilst 7.86 μg/(mL·h) in $Na_2S_2O_4$-RS group, increased by 25.8%.

Discussion

Under environmental stress, more electron in plant cells can be transform oxygen into reduction state, producing superoxide anion ($O_2^{\cdot-}$), hydroxyl radical ($^{\cdot}HO$), singlet oxygen ($^1O_2$) and hydrogen peroxide (H_2O_2), which were collectively called Reactive Oxygen Species (ROS). The overproduction of ROS would elicit oxidative damage to plant. In order to avoid the oxidative damage of ROS and maintain the dynamic balance of oxidation and reduction, plants have evolved a complex antioxidant defense mechanism. This antioxidant defense mechanism includes enzymatic and non-enzymatic antioxidant protection systems [18]. The enzymatic protection system includes superoxide dismutase, catalase, peroxidase and other antioxidant enzymes. And the non-enzymatic protection system includes glutathione, ascorbic acid and secondary metabolites. As animals produce less ROS because they are able to move away from adversity, so the secondary metabolites are the specific substances to eliminate ROS in plants. Flavonoid, as a kind of secondary metabolites in plants, is the main ROS scavengers which was discovered in recent years [19,20]. And the previous investigations showed that chromone, as a kind of flavonoid, eliminates ROS through POD enzyme [11]. And the chromone is just the active ingredients required by people.

The components of RS are complex, various chromones and other components have antipyretic, analgesic and anti-inflammatory activities. Their contents and activities are different [21]. And polysaccharides also influence the medical effects [15]. Therefore, the total contents of one or several components can not reflect the overall efficacy of RS.

Excessive synthesis of secondary metabolites under suitable conditions would cause the waste of energy and nutrients of *S. divaricata*. So, these secondary metabolites are usually synthesized under stress. The proportion and contents of these secondary metabolites also vary with the stress in order to maintain the relative stability of ROS [22]. The more ROS produced by severe stress, the more contents and activities of secondary metabolites were. In this study, ROS produced by $Na_2S_2O_4$ probably simulated the nature stress and triggered the secondary metabolism of *S. divaricata*. The results showed that the total contents of chromone promoted under $Na_2S_2O_4$ stress, among which the most prominent increase was found with that of cimifugin with 82.35%, from 0.17 mg/g to 0.31 mg/g. That probably because the excessive ROS regulated the expression and activity of phenylalanine enzyme, which facilitated the synthesis of chromone. And these chromone acted as the substrate of antioxidant enzymes to scavenge ROS [11]. Also, the results showed that the $AUC_{0\text{-}24h}$ of $Na_2S_2O_4$-stress-RS increased by 25.8% compared to that of RS (Figure 1). And the anti-pyretic, analgesic and anti-inflammatory effects of $Na_2S_2O_4$-stress-RS increased significantly (Table 3). That indicated that superabundant ROS under $Na_2S_2O_4$ stress triggered the antioxidant protection systems of RS. Further the flavonoid was synthesized to eliminate excessive ROS. Therefore, $Na_2S_2O_4$ stress could significantly improve the quality of RS by regulating the secondary metabolism.

Conclusion

Exposure of RS fresh roots to $Na_2S_2O_4$ stress promoted the chromone and adopted cimifugin of RS and its antipyretic, analgesic and anti-inflammatory effects were enhanced. Therefore, exposure of RS fresh roots to $Na_2S_2O_4$ stress would be a new way to improve the quality of cultivated RS.

Acknowledgment

This work was supported by Natural Science Foundation of Liaoning province (Grant no. 20180550230) and The Doctoral Scientific Research Foundation of Liaoning Province (Grant no.20170520132).

References

1. Kim MK, Yang DH, Jung M, Jung EH, Eom HY, Suh JH, et al. Simultaneous Determination of Chromones and Coumarins in Radix Saposhnikoviae by High Performance Liquid Chromatography with Diode Array and

Tandem Mass Detectors. J Chromatogr A. 2011;1218(37):6319-30.

2. Okuyama E, Hasegawa T, Matsushita T, Fujimoto H, Ishibashi M, Yamazaki M. Analgesic Components of Saposhnikovia Root (Saposhnikovia divaricata). Chemical Pharmaceutical Bulletin. 2001;49:154-60.
3. Linfneg L, Xiao YQ. TLC identification of Saposhnikovia divaricata and its chemical constituents. China Pharm J. 2000;35:656-8.
4. Li L, Liu YY, Geng LD, Xiao YQ. [Determination of Four Components in Root of Saposhnikovia divaricata by HPLC Gradient Elution]. Zhongguo Zhong Yao Za Zhi. 2006;31(3):194-6.
5. Li W, Wang Z, Chen L, Zhang J, Han L, Hou J, et al. Pressurized Liquid Extraction Followed by LC-ESI/MS for Analysis of Four Chromones in Radix Saposhnikoviae. J Sep Sci. 2010;33(17-18):2881-7.
6. Zhao B, Yang XB, Yang XW, Zhang LX, Liu JX.Simultaneous Determination of Six Major Constituents in the Roots of Saposhnikovia divaricata by HPLC. Chin J Pharm Anal. 2013;33(3):382-7.
7. Gao Y, Li WM, Rong XL. Traditional Herbal Drugs 2[M]. Beijing: 2005, 254. Forthcoming.
8. Guo LQ, Taniguchi M, Chen QY, Baba K, Yamazoe Y. Inhibitory potential of herbal medicines on human cytochrome P450-mediated oxidation: properties of umbelliferous or citrus crude drugs and their relative prescriptions. Jpn J Pharmacol. 2001;85(4):399-408.
9. Meng XC, Sun H, Wang ZY. To Explore the Characteristics of Animal Medicine from the Biological Point of View. J Chinese Medicinal Materials. 2014;37(1):18-22.
10. Dat J, Vandenabeele S, Vranová E, Van M, Inzé D, Breusegem F. Dual action of the active oxygen species during plant stress responses. Cell Mol Life Sci. 2000;57(5):779-95.
11. Jiang H, Yang JM, Jia GZ, Dai HL, Cao L, Meng XC. Physical and Ecological Impacts of Chromones of Fresh Root of Saposhnikovia divaricata Exposure to High Temperature. Russ J Plant Physiol. 2018;65(5):680-7.
12. Meng XC, Wang XJ. Postulate About Active Oxygen Improving Quality of Genuine Chinese Medicinal Materials and its Exploration. Chinese Traditional and Herbal Drugs. 2011;42(4):799-804.
13. Song WH, Yan W, Jia ZS. Determination of superoxide anion radicals in sodiumhyposulfite solution by chemiluminescent methods [J]. J Zhejiang University (Science Edition). 2007;34(5):538-40.
14. Zhang S, Fu W, Li N, Zhang F, Liu TX. Antioxidant Responses of Propylaea japonica (Coleoptera: Coccinellidae) Exposed to High Temperature Stress. J Insect Physiol. 2015;73:47-52.
15. Yang JM, Jiang H, Dai HL, Wang ZW, Jia GZ, Meng XC. Feeble Antipyretic, Analgesic, And Anti-Inflammatory Activities wereFound with Regular Dose 4'-O-β-D-Glucosyl-5-O-Methylvisamminol, One of the Conventional Marker Compounds for Quality Evaluation of Radix Saposhnikoviae. Pharmacogn Mag. 2017;13(49):168-74.
16. Yang JM, Jiang H, Dai HL, Wang ZW, Jia GZ, Menga XC. Polysaccharide Enhances Radix saposhnikoviae Efficacy Through Inhibiting Chromones Decomposition in Intestinal Tract. Sci Rep. 2016;6:32698.
17. Kentaro M, Nami GY, Masahiko K, Hashizume K. Loss of Anthocyanins in Red-Wine Grape Under High Temperature. J Exp Bot. 2007;58(8):1935-43.
18. Sharma P, Jha AB, Dubey RS, Mohammad P. Reactive Oxygen Species, Oxidative Damage, and Antioxidative Defense Mechanism in Plants under Stressful Conditions. J Botany. 2012;2012:1-26.
19. Gill SS, Tuteja N. Reactive Oxygen Species and Antioxidant Machinery in Abiotic Stress Tolerance in Crop Plants. Plant Physiol Biochem. 2010;48:909-30.
20. Song Q, Cao WL, Meng XC, Jiang H, Ai-hua Z. H2O2 Improves Quality of Radix Scutellariae through Anti-Oxidant Effect. Pharmacognosy Magazine. 2016;12(45):84-90.
21. Jiang H, Hu LL, Yang JM, Wang J. Comparative Study on the Pharmacological Activities of Intravenous Administration of Chromone of Radix saposhnikoviae. Lishizhen medicine and material medical research. 2016;27(7):1575-7.
22. Min Z, Li R, Chen Li, Zhang Y, Li Z, Liu M, et al. Alleviation of Drought Stress in Grapevine by Foliar-applied Strigolactones. Plant Physiol Biochem. 2019;135:99-110.