International Journal of Pharmacology

ISSN 1811-7775

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Asian Network for Scientific Information

OPEN ACCESS International Journal of Pharmacology

ISSN 1811-7775
DOI: 10.3923/ijp.2019.441.448

Research Article
Comparison of Immunomodulating Activities of *Dendrobium devonianum* and *Dendrobium officinale In vitro* and *In vivo*

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Abstract

Background and Objective: *Dendrobium devonianum* and *Dendrobium officinale* are widely used as Chinese medicinal materials and health foods. These two species have similar appearances and chemical constitutions. However, their immunomodulating activities have never been compared. This study aims to investigate and compare the immunomodulating activities of *D. devonianum* and *D. officinale*. **Materials and Methods:** Ten batches of *D. devonianum* and *D. officinale* were collected from different regions. The botanical origins of the species were authenticated by DNA sequence analysis and the total polysaccharide contents were determined to guarantee the quality of each batch. Their immunomodulating activities were evaluated and compared *in vitro* and *in vivo* by splenocytes proliferation and hydrocortisone-induced immunosuppressed mice, respectively. **Results:** The two species have significant different sequences of DNA ITS region but with very close polysaccharide contents. *In vitro* study showed that the aqueous extracts of the 10 batches of *D. devonianum* and *D. officinale* significantly stimulated splenocyte proliferation with no differences in efficiencies. Furthermore, oral administration of *D. devonianum* or *D. officinale* not only significantly alleviated hydrocortisone-induced leukopenia and spleen and thymus atrophy but also significantly increased macrophage phagocytosis and delayed-type hypersensitivity response (DTH) in mice. **Conclusion:** *Dendrobium devonianum* and *D. officinale* regulated the innate and adaptive immune responses *in vitro* and *in vivo* with no differences in efficiencies.

Key words: *D. devonianum*, *D. officinale*, immunomodulating activity, innate immunity, adaptive immunity

Received: December 18, 2018 Accepted: January 30, 2019 Published: March 15, 2019

Citation: Zheng-Rong Zhao, Shi-Fang Xu, Ping Zhang, Hua Liu, Yue-Guo Wu, Gui-Jiao Zhou, Yi-Heng Cai, Ju-Run Zhao and Feng-Yang Chen, 2019. Comparison of immunomodulating activities of *Dendrobium devonianum* and *Dendrobium officinale In vitro* and *In vivo*. Int. J. Pharmacol., 15: 441-448.

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Competing Interest: The authors have declared that no competing interest exists.

Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

Dendrobium is among the largest genera in the Orchidaceae family, with 1500 of the currently described species distributed mainly in the tropical and subtropical regions[1]. A total of 74 *Dendrobium* species and 2 variants are found in China (Flora of China, http://frps.eflora.cn/frps/Dendrobium). The stems of approximately 30 species are used as Chinese medicinal materials to promote the production of body fluids, benefit the stomach, moisten the lungs and relieve cough and other yin-deficiency diseases. Among all these medicinal *Dendrobium* species, *D. officinale* Kimura et Migo is considered to have the best and widest medicinal applications. Its ethnopharmacological use, phytochemistry, pharmacology and industrialization have been widely explored and reported. This species has been used solely or combined with other Chinese materia medicas to treat many diseases, such as Sjogren's syndrome, gastric ulcer, alcoholic liver injury, chronic obstructive pulmonary disease, diabetes and hypertensive stroke[2]. Among these activities, the immunomodulating effects of *D. officinale* have attracted considerable attention[3].

In addition to *D. officinale*, three other *Dendrobium* species, namely, *Dendrobium nobile*, *Dendrobium chrysotoxum* and *Dendrobium fimbriatum* are listed in the Chinese Pharmacopoeia as Chinese medicinal materials[4]. Yu *et al*.[3] compared the immunomodulating activities of these four *Dendrobium* species (each contained only a single sample) in healthy mice and cyclophosphamide-induced immunosuppressed mice. The results showed that all species promoted lymphocyte proliferation, enhanced phagocytic function of macrophage and increased the number of peripheral white blood cell and leukocytes. However, only *D. officinale* was found to increase the number of neutrophils in the peripheral blood of mice.

Dendrobium devonianum Paxt. is another widely consumed *Dendrobium* species, although it has not been listed in the Chinese Pharmacopoeia. Contrary to *D. officinale*, which is distributed mainly in China, *D. devonianum* is distributed widely in Bhutan, India, Burma, Thailand, Vietnam and China (Flora of China, http://frps.eflora.cn/frps/Dendrobium). Similar to *D. officinale*, *D. devonianum* is also used as Chinese medicinal material, health food and nutrient in southwestern China[5]. These two species have similar appearances and chemical constitutions[6,7]. Both species are mass-produced in China by tissue cultivation. However, limited studies on the immunomodulating effects of *D. devonianum* have been conducted. Especially, the immunomodulating activities of *D. devonianum* and *D. officinale* have never been compared previously.

Therefore, to compare the immunomodulating activities between *D. devonianum* and *D. officinale*, in the present study, 10 batches of *D. devonianum* and *D. officinale* were collected from different regions. The botanical origins of these materials were first authenticated by DNA sequence analysis and the total polysaccharide contents were determined to guarantee the quality of each batch. Then, their immunomodulating effects were evaluated *in vitro* through splenocyte proliferation assay. In addition, hydrocortisone-induced immunosuppressed mice were used to further compare the immunomodulating effects between *D. devonianum* and *D. officinale in vivo.*

MATERIALS AND METHODS

DNA sequence analysis: Ten samples of *D. devonianum* and *D. officinale* (Fig. 1, Table 1) were collected (during Nov., 2016 to Jan. 2017) from different regions in China, mainly in and around Yunnan or Zhejiang province. The voucher specimens were deposited at the Laboratory of Natural Drugs, Institute of Materia Medica, Zhejiang Academy of Medical Sciences, China.

Table 1: Sources, rDNA ITS sequence identification and polysaccharide content of *Dendrobium* samples

Sample ID	Locality	Voucher number	Match species	Accession number	Sequence identity (%)	E-value	Polysaccharide content (%)
Dv1	Longling, Yunnan	D 20161130	*D. devonianum*	KP743545.1	100	0.0	42.5
Dv2	Pingbian, Yunnan	D 20161213	*D. devonianum*	KP743545.1	99	0.0	35.4
Dv3	Bannan, Yunnan	D 20161107	*D. devonianum*	KJ210443.1	99	0.0	44.1
Dv4	Lianghe, Yunnan	D 20170109	*D. devonianum*	KJ210443.1	99	0.0	42.0
Dv5	Jinping, Yunnan	D 20161226	*D. devonianum*	KP743545.1	98	0.0	44.2
Oc1	Panan, Zhejiang	O20170106	*D. officinale*	MH198114.1	100	0.0	39.9
Oc2	Ruian, Zhejiang	O20161221	*D. officinale*	MH198114.1	100	0.0	36.1
Oc3	Guangnan, Yunnan	O20161201	*D. officinale*	MH198108.1	99	0.0	34.3
Oc4	Shangrao, Jiangxi	O20161215	*D. officinale*	MH198114.1	100	0.0	32.5
Oc5	Wujiang, Jiangsu	O20161216	*D. officinale*	MH198114.1	99	0.0	43.5

The species identity was confirmed by NCBI-BLAST search program based on rDNA ITS sequence. Total polysaccharide content in each *Dendrobium* sample was determined by phenol-sulfuric acid colorimetric method

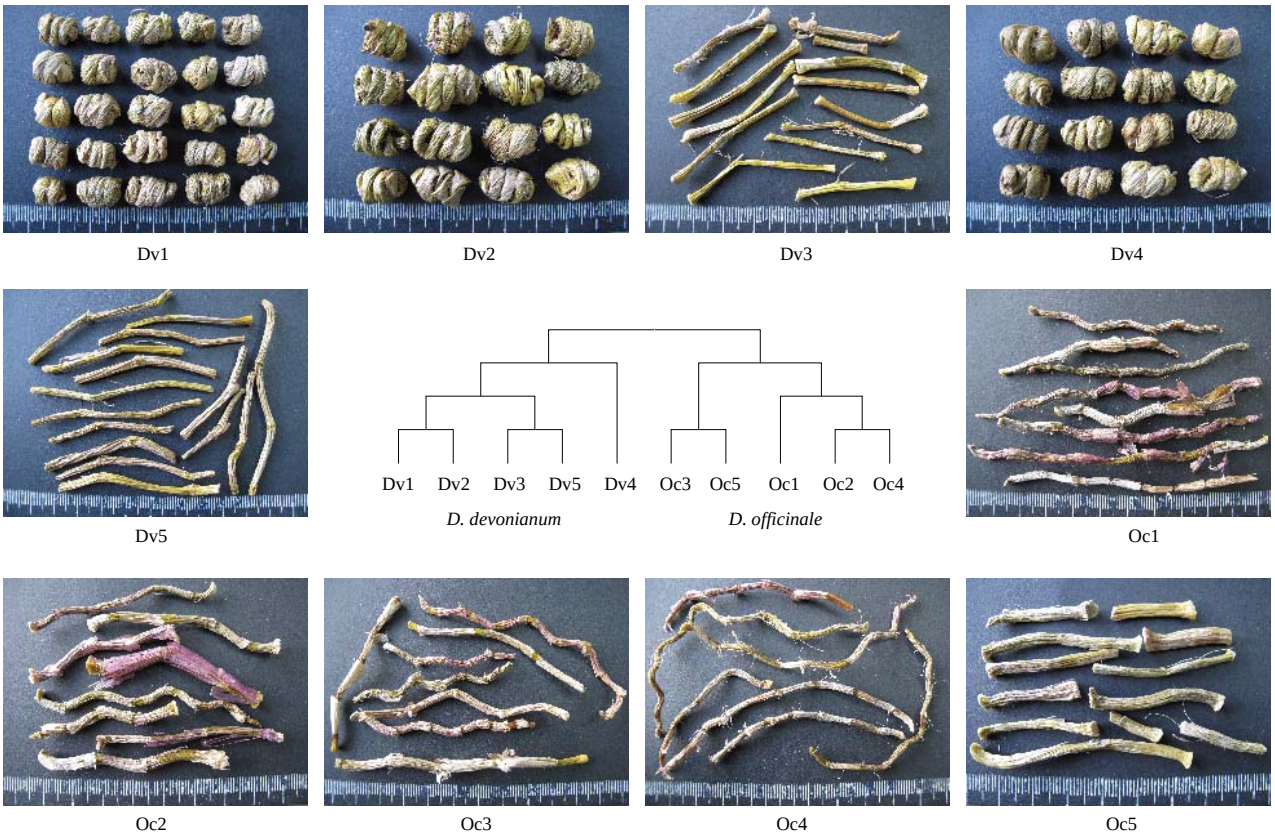

Fig. 1: Representative photographs of 10 *Dendrobium* samples. Clustering map was made by MEGA-phylogeny reconstruction program based on rDNA ITS sequence

Total genomic DNA was isolated by Hi-DNA secure Plant Kit (TIANGEN Biotech, China). The ITS region (ITS1-5.8S rDNA-ITS2) of the nuclear rDNA was amplified and sequenced as previously described[8]. The DNA sequences were aligned using Clustal W and MEGA[9]. The botanical origin of each sample was deduced by the direct comparison with ITS sequences of *Dendrobium* in the Genbank and analyzed with the National Center for Biotechnology Information (NCBI) BLAST sequence analysis search algorithm.

Measurement of polysaccharide contents: Total polysaccharide contents in the *D. devonianum* and *D. officinale* samples were determined by phenol-sulfuric acid colorimetric method as described in the Chinese Pharmacopoeia[4].

Preparation of aqueous extracts of *D. devonianum* and *D. officinale*: The processed dried stems of the samples were first cut into small pieces. Then, the pieces (10 g) were extracted thrice with 500 mL of water under boiling for 3 h. Finally, the extract was filtered through Whatman filter paper and the filtrate was concentrated to 100 mL in a rotary evaporator under reduced pressure.

Experimental animals: Female C57BL/6 mice (6 weeks old) were purchased from the Shanghai Slac Laboratory Animal Co., Ltd. (Shanghai, China). Male ICR mice (6 weeks old) were purchased from the Experimental Animals Center of Zhejiang province (Hangzhou, China). The animals were acclimatized for 7 days before use. All procedures were in strict accordance with the P.R. China legislation on the use and care of laboratory animals and with the guidelines established by the Experimental Animals Center of Zhejiang province. Moreover, the procedures were approved by the Animal Care and Use Committee of Zhejiang Academy of Medical Sciences, China.

Splenocyte proliferation assay: Splenocytes proliferation assay was tested by MTT assay as previously described[10].

Hydrocortisone-induced immunosuppressed mice and treatment protocols: The model of hydrocortisone-induced immunosuppressed mice was established as previously described[11]. Aqueous extracts of *D. devonianum* (Dv1) or *D. officinale* (Oc3), its 3 and 9 times dilution were designated as high, medium and low doses, respectively. Mice were orally treated with them once daily for 25 days. The phagocytic activity of monocyte-macrophages was assessed by carbon clearance method[12]. The DTH reaction was elicited by sheep red blood cells (SRBC) and evaluated as previously described[11].

Statistical analysis: The data were expressed as mean±standard deviation. Statistical analyses were performed using one-way ANOVA and Student's t-test with SPSS data analysis software (version 13.0). The p-values less than 0.05 were regarded as statistically significant.

RESULTS

DNA sequence analysis and species identification: The samples of *Dendrobium* species (Fig. 1, Table 1) were collected from 10 different regions in China. We extracted the genomic DNAs and analyzed the nucleotide sequences of the ITS region of the 10 samples to guarantee their botanical origin. Significant differences were found between samples Dv1-5 and samples Oc1-5 (Fig. 2). The sequences were aligned using MEGA-Clustal W and Phylogeny Reconstruction program and the results showed that Dv1 and Dv2, Dv3 and Dv5, Oc2 and Oc4 and Oc3 and Oc5 displayed the highest similarity (Fig. 1). Using NCBI-BLAST search program, samples Dv1-5 were found to be identical to the sequence of *D. devonianum* (sequence identity ≥98%) and samples Oc1-5 were identical to the sequence of *D. officinale* (sequence identity ≥99%) (Table 1). These results clearly indicated that samples Dv1-5 belong to *D. devonianum* and samples Oc1-5 belong to *D. officinale*.

Total polysaccharide content: The results are shown in Table 1. The polysaccharide content in each sample exceeded 25%. The total polysaccharide contents of five samples of *D. devonianum* were close to those of *D. officinale*, with corresponding average values of 41.6 and 37.3%. These results suggested that all *Dendrobium* samples have very close polysaccharide contents..

***D. devonianum* and *D. officinale* stimulated splenocytes proliferation *in vitro*:** The results were showed in Fig. 3, five *D. devonianum* samples and five *D. officinale* samples significantly stimulated splenocyte proliferation in a concentration-dependent manner ($p<.05$, $p<.01$ or $p<.001$). Moreover, no obvious differences were observed in the efficiency between *D. devonianum* and *D. officinale*. This result indicated that *D. devonianum* exhibited similar immunomodulating capacities to *D. officinale in vitro*.

***D. devonianum* and *D. officinale* alleviated hydrocortisone-induced immunosuppression in mice:** The results were shown in Fig. 4 and 5. Compared with the normal control group, injection with hydrocortisone significantly reduced peripheral white blood cell number (Fig. 4a) and spleen and thymus indices (Fig. 4b, c) ($p<0.01$). Furthermore, the rate of blood carbon clearance (Fig. 5a) and phagocytic index (Fig. 5b) showed that hydrocortisone inhibited the phagocytic activity of monocyte-macrophages ($p<0.01$). Hydrocortisone also inhibited the DTH response as represented by footpad swelling (Fig. 5c) ($p<0.01$). However, oral administration of *D. devonianum* or *D. officinale* at medium and high doses significantly alleviated hydrocortisone-induced leukopenia (Fig. 4a) and spleen (Fig. 4b) and thymus atrophy (Fig. 4c) ($p<0.05$ or $p<0.01$). *Dendrobium devonianum* or *D. officinale* also significantly increased the phagocytic function of monocyte-macrophages (Fig. 5a, b) and DTH response (Fig. 5c), compared with the hydrocortisone only-treated group ($p<0.05$, $p<0.01$ or $p<0.001$). These results suggested that *D. devonianum* or *D. officinale* improved innate and adaptive immune responses and counteracted hydrocortisone-induced immunosuppression *in vivo*. Moreover, in agreement with the results of splenocyte proliferation *in vitro*, *D. devonianum* and *D. officinale* exhibited similar immunomodulating effects in hydrocortisone-induced immunosuppressed mice.

DISCUSSION

In this study, the immunomodulating activities of *D. devonianum* and *D. officinale* were compared for the first time. Despite the slight differences in their appearances (Fig. 1) and chemical constitutions[6,7], there are significant differences of DNA ITS region between *D. devonianum* and *D. officinale* as showed by earlier reports[8] and these present studies (Fig. 2). The present results showed that the aqueous extracts of *D. officinale* stimulated splenocyte proliferation *in vitro*, as well as alleviated hydrocortisone-induced leukopenia, spleen and thymus atrophy, decrease of macrophages phagocytic function and DTH response in mice, which are in accordance with previous studies on cyclophosphamide-induced immunosuppressed mice[3,13]. In addition, the five batches of *D. devonianum* and five batches

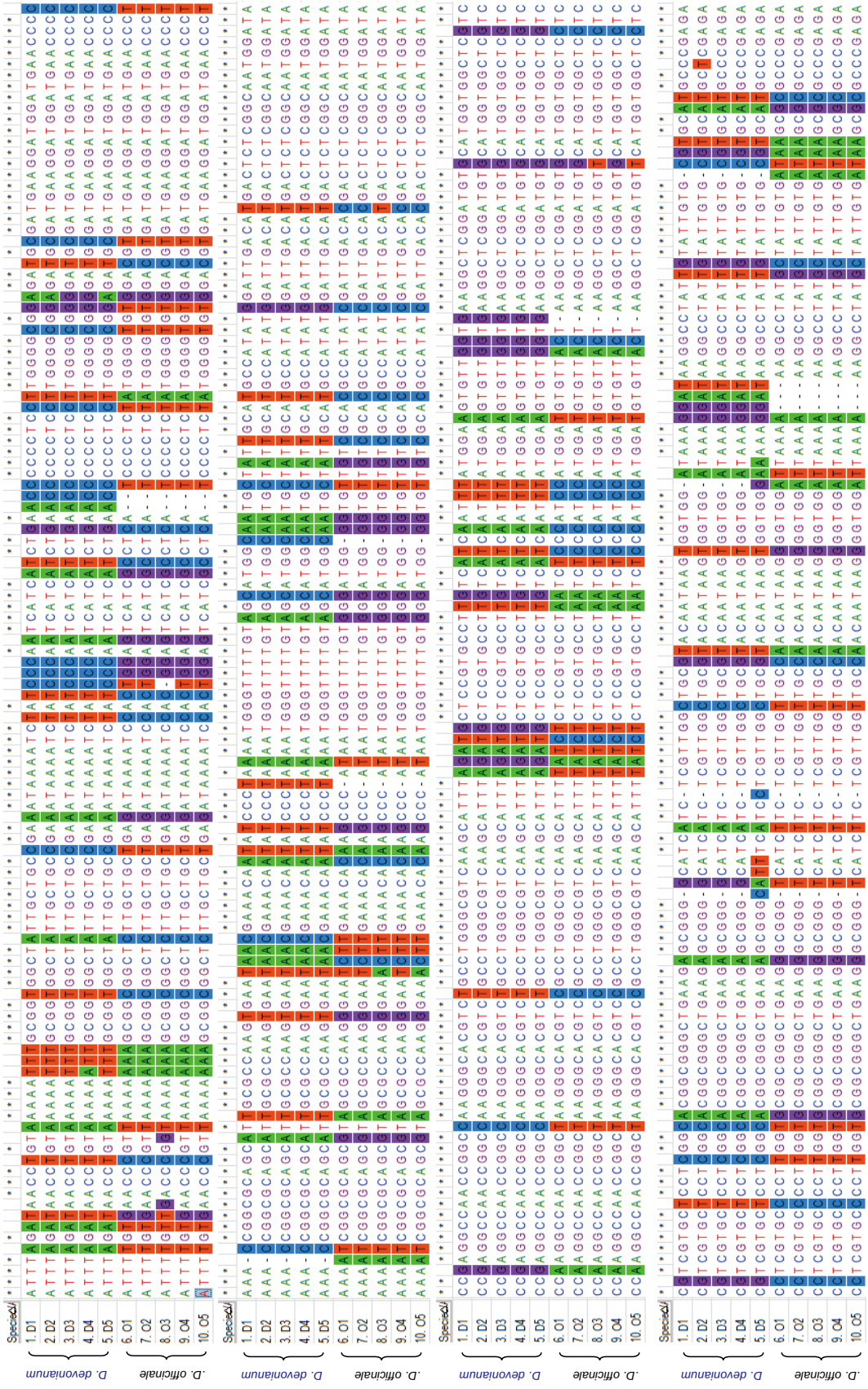

Fig. 2: Partial rDNA ITS sequences of ten *Dendrobium* samples. Sequence variation sites were aligned by MEGA-clustal W program

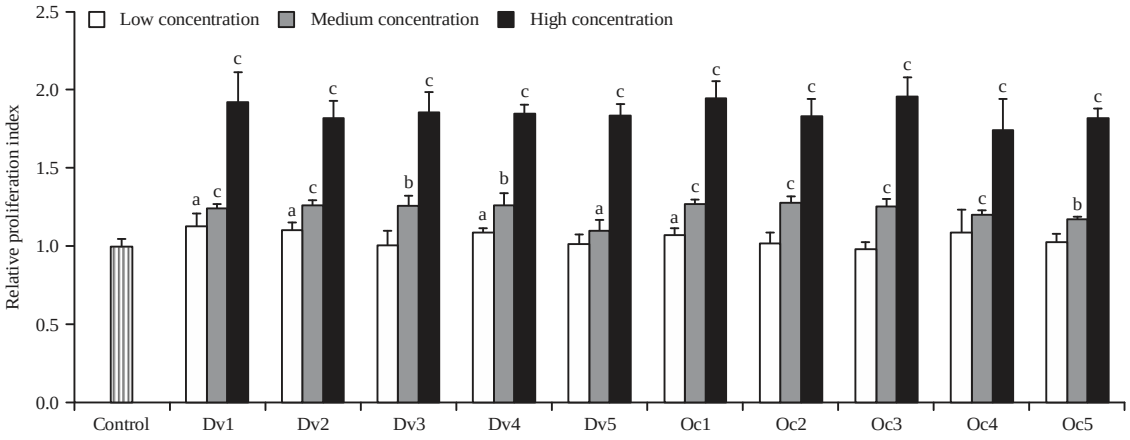

Fig. 3: *Dendrobium devonianum* and *D. officinale* stimulated splenocytes proliferation *in vitro*

The values are presented as Means±SD (n = 4). Significant differences with control group were designated as [a]p<0.05, [b]p<0.01 or [c]p<0.001

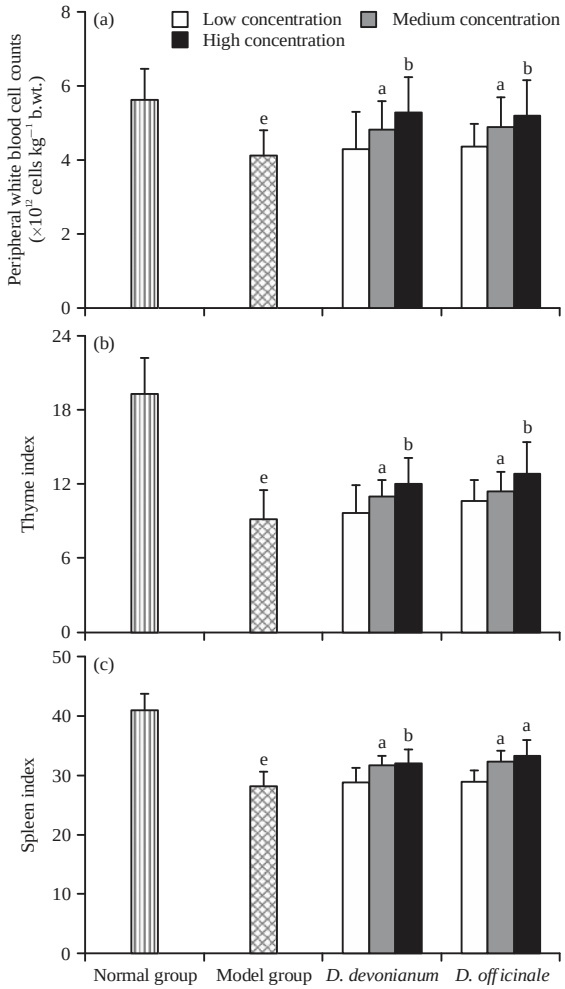

Fig. 4(a-c): *Dendrobium devonianum* and *D. officinale* alleviated hydrocortisone-induced (a) Leukopenia and (b) Thymus and (c) Spleen atrophy in mice

The values are presented as Means±SD (n = 10). Significant differences with model group were designated as [a]p<0.05 or [b]p<0.01, with normal control group were designated as [c]p<0.001

of *D. officinale* stimulated splenocyte proliferation with the same levels of efficiency. Furthermore, similar to *D. officinale* and *D. devonianum* exhibited comparable immunomodulating activities on hydrocortisone-induced immunosuppressed mice.

Polysaccharides are the richest constituents of *D. devonianum* and *D. officinale*. According to the Chinese Pharmacopoeia, polysaccharide in *D. officinale* should not be less[4] than 25%. The monosaccharide compositions of both species were previously reported to be mainly composed of glucose and mannose[14]. In this study, the results showed that the total polysaccharide contents in 5 batches of *D. devonianum* were very close to those in five batches of *D. devonianum* (Table 1). Therefore, we infer that the comparable activities of *D. devonianum* and *D. officinale* could be mainly ascribed to their similar contents and constitutions of polysaccharides. The constitutions and immunomodulating effects of polysaccharides from *D. officinale* have been investigated widely[6,15-19]. However, contrary to *D. officinale*, the constitutions and immunomodulating activities of polysaccharides from *D. devonianum* are seldom reported. Only in this year, Deng *et al.*[20] identified a polysaccharide with globular conformation from *D. devonianum* and found that this compound could promote the NO release and phagocytosis of macrophages. Thus, further studies are necessary to elucidate the structures and bioactivities of polysaccharides from *D. devonianum*.

This study showed that *D. devonianum* and *D. officinale* influenced the peripheral white blood cell number, spleen and thymus indices, splenocyte proliferation, macrophage phagocytosis and T cell-mediated DTH response, indicating they regulated both innate and adaptive immune responses. Polysaccharides from *Dendrobium* plants may directly or indirectly regulate many immunocytes, such as T cells, B cells,

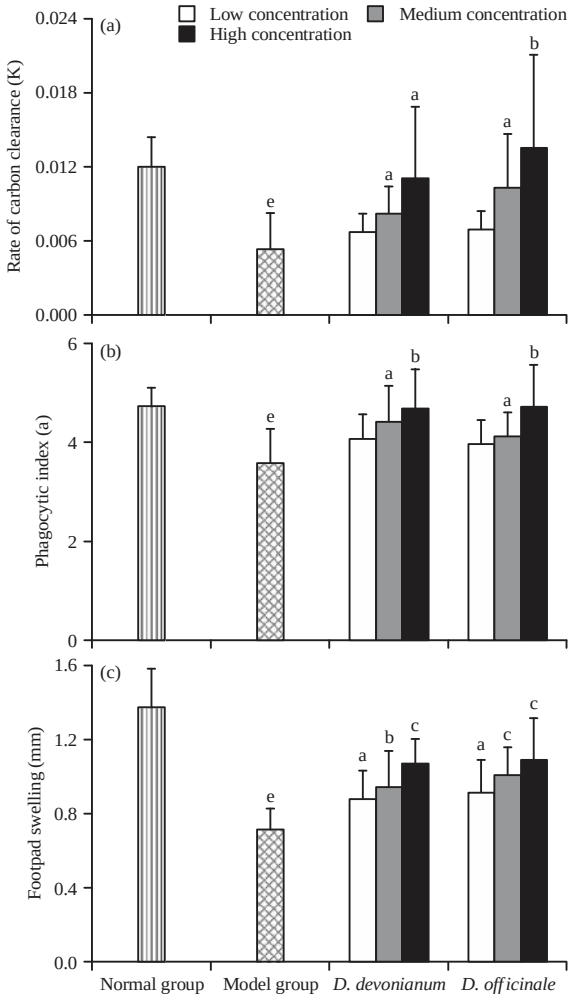

Fig. 5(a-c): *Dendrobium devonianum* and *D. officinale* increased (a-b) Macrophages phagocytosis and (c) T cells-mediated DTH response in hydrocortisone-induced immunosuppressed mice

The values are presented as Means±SD (n = 10). Significant differences with model group were designated as $^{a}p<0.05$, $^{b}p<.01$ or $^{c}p<0.001$, with normal control group were designated as $^{e}p<0.001$

macrophages, granulocytes, dendritic cells and NK cells[21]. However, their definite molecular mechanisms have been rarely explored and deserve further study.

In addition to the immunomodulating activities, *D. officinale* is used clinically to treat many chronic diseases, such as Sjogren's syndrome, gastric ulcer, alcoholic liver injury, chronic obstructive pulmonary disease, diabetes and hypertensive stroke[2]. This study indicated that *D. devonianum* and *D. officinale* possess comparable immunomodulating activities. Given the slight differences in their chemical constitutions and contents[7], it is possible that *D. devonianum* may display other bioactivities as *D. officinale*, such as anti-fatigue, anti-neoplastic, anti-oxidative and anti-mutagenic activities.

CONCLUSION

By ten batches of *D. devonianum* and *D. officinale*, this study discovered that *D. devonianum* and *D. officinale* have significant different sequences of DNA ITS region but with very close polysaccharide contents. They regulated the innate and adaptive immune responses *in vitro* and *in vivo* with no differences in efficiencies. The similar contents and constitutions of polysaccharides may be responsible for their comparable immunomodulating activities.

SIGNIFICANCE STATEMENT

This study firstly compared the immunomodulating activities between *D. devonianum* and *D. officinale*. The findings are beneficial for better using of *D. devonianum* and *D. officinale* as Chinese medicinal materials or health foods for immunocompromised people.

ACKNOWLEDGMENTS

We appreciated helpful discussions with Prof. Yan-Fei Xin from Zhejiang Academy of Medical Sciences. The work was supported by Grant-in Aid from Zhejiang Provincial Medicinal Health Program of China (2017KY039).

REFERENCES

1. Da Silva, J.A.T., X. Jin, J. Dobranszki, J. Lu and H. Wang *et al*., 2016. Advances in *Dendrobium* molecular research: Applications in genetic variation, identification and breeding. Mol. Phylogenet. Evol., 95: 196-216.
2. Tang, H., T. Zhao, Y. Sheng, T. Zheng, L. Fu and Y. Zhang, 2017. *Dendrobium officinale* Kimura et Migo: A review on its ethnopharmacology, phytochemistry, pharmacology and industrialization. Evidence-Based Complement. Altern. Med., Vol. 2017. 10.1155/2017/7436259.
3. Yu, Q., P.J. Mao, J.M. Jiang and Z.H. Jin, 2017. Comparison of the effects of four medicinal species of *Dendrobium* on improving immunological functions on mice. Chin. J. Mod. Applied Pharm., 34: 191-195.
4. Chinese Pharmacopoeia Commission, 2015. Chinese Pharmacopoeia. Vol. 1, Chinese Medical Science and Technology Press, Beijing, China.

5. Cheng, L.L., F.J. Yang, H.Y. Wang, W. Li and M. Li, 2015. Latest research progress on *Dendrobium devonianum*. Asia-Pac. Tradit. Med., 11: 31-33.
6. Wei, W., L. Feng, W.R. Bao, D.L. Ma, C.H. Leung, S.P. Nie and Q.B. Han, 2016. Structure characterization and immunomodulating effects of polysaccharides isolated from *Dendrobium officinale*. J. Agric. Food Chem., 64: 881-889.
7. Ye, Z., J.R. Dai, C.G. Zhang, Y. Lu and L.L. Wu *et al*., 2017. Chemical differentiation of *Dendrobium officinale* and *Dendrobium devonianum* by using HPLC fingerprints, HPLC-ESI-MS and HPTLC analyses. Evidence-Based Complement. Altern. Med., Vol. 2017. 10.1155/2017/8647212.
8. Ding, X., L. Xu, Z. Wang, K. Zhou, H. Xu and Y. Wang, 2002. Authentication of stems of *Dendrobium officinale* by rDNA ITS region sequences. Planta Med., 68: 191-192.
9. Hall, B.G., 2013. Building phylogenetic trees from molecular data with MEGA. Mol. Biol. Evol., 30: 1229-1235.
10. Chen, F., Y. Ni, Y. Ye, H. Sun, X. Li and S. Xu, 2012. Stephanthraniline a inhibits the proliferation and activation of T cells *in vitro* and *in vivo*. Eur. J. Pharmacol., 685: 186-197.
11. Yingjian, L., H. Junming, C. Min, L. Chenyue, Z. Dachao, H. Yuanhua and L. Zhi, 2013. A health food high-peptide meal alleviates immunosuppression induced by hydrocortisone and cyclophosphamide in mice. Food Funct., 4: 1352-1359.
12. Ganeshpurkar, A. and A.K. Saluja, 2018. Protective effect of catechin on humoral and cell mediated immunity in rat model. Int. Immunopharmacol., 54: 261-266.
13. Li, W., J. Zhang and W. Zhou, 2016. The effects of *Dendrobium officinale* on the immune response and cytokines production in immunosuppressed mice. J. Hyg. Res., 45: 137-139.
14. Wang, D., B. Fan, Y. Wang, L. Zhang and F. Wang, 2018. Optimum extraction, characterization and antioxidant activities of polysaccharides from flowers of *Dendrobium devonianum*. Int. J. Anal. Chem., Vol. 2018. 10.1155/2018/3013497.
15. Cai, T.Y., Q.L. Liu, D. Li, A.Z. Chen and B.H. Huang *et al*., 1989. Effects of *Dendrobium officinale* polysaccharides on the activities of T lymphocytes and macrophages. Acad. J. Sun Yat-sen Univ. Med. Sci., 10: 66-67.
16. Huang, M.Q., T.Y. Cai and Q.L. Liu, 1996. Effects of polysaccharides from *Dendrobium candidum* on white blood cells and lymph cell moving inhibition factor of mice. Nat. Prod. Res. Dev., 8: 39-42.
17. Xia, L., X. Liu, H. Guo, H. Zhang, J. Zhu and F. Ren, 2012. Partial characterization and immunomodulatory activity of polysaccharides from the stem of *Dendrobium officinale* (Tiepishihu) *in vitro*. J. Funct. Foods, 4: 294-301.
18. Xie, S.Z., B. Liu, D.D. Zhang, X.Q. Zha, L.H. Pan and J.P. Luo, 2016. Intestinal immunomodulating activity and structural characterization of a new polysaccharide from stems of *Dendrobium officinale*. Food Funct., 7: 2789-2799.
19. He, T.B., Y.P. Huang, L. Yang, T.T. Liu and W.Y. Gong *et al*., 2016. Structural characterization and immunomodulating activity of polysaccharide from *Dendrobium officinale*. Int. J. Biol. Macromol., 83: 34-41.
20. Deng, Y., M. Li, L.X. Chen, X.Q. Chen, J.H. Lu, J. Zhao and S.P. Li, 2018. Chemical characterization and immunomodulatory activity of acetylated polysaccharides from *Dendrobium devonianum*. Carbohydr. Polym., 180: 238-245.
21. Xing, X., S.W. Cui, S. Nie, G.O. Phillips, H.D. Goff and Q. Wang, 2013. A review of isolation process, structural characteristics and bioactivities of water-soluble polysaccharides from *Dendrobium* plants. Bioact. Carbohydr. Dietary Fibre, 1: 131-147.