Effects of Vacuum Freeze Drying on Basic Constituents and Antioxidant Activity of Dendrobium Officinale

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Keywords: Vacuum freeze drying, Basic constituents, Dendrobium officinale

Abstract: The influence of drying process is crucial for the retention of nutritional active substances and antioxidant capacity. In the present study, "Yanshangxian"- Dendrobium officinale (YSX) was dried using different drying methods, including high temperature drying (HTD), hot air drying (HAD) and vacuum freeze drying (VFD). The results exhibited that the drying process did not affect total protein, crude fibers content, but significantly influenced levels of other active components. The results suggested that VFD was a superior method of drying than HTA or HAD for the industrial production of high quality D. officinale in term of the contents of active components.

1. Introduction

D.officinale, a traditional Chinese herbal medicine, is a member of Orchidales Dendrobium plants [1]. D. officinale used as a medicine was first presented in "Sheng Nong's herbal classic". Since then, it has been widely exploited in the pharmaceutical and functional food fields for thousands of years. D. officinal not only contains basic nutritional ingredients such as crude fiber and proteins, but also a number of active components which are beneficial to human body, like polysaccharides, alkaloids, polyphenols and flavonoids [2]. Previous studies indicated that those ingredients have many important biological activities, including immunoregulatory, anti-oxidation, hypoglycemic effect, anti-tumor and blood pressure lowering [3]. These fresh medicinal materials are easily mildewed and corrupted if not dehydrated in time, resulting in a considerable waste of resources. But, an inappropriate dehydration can also inevitably lead to the thermal damage of the herb, especially a loss of thermosensitive components, resulting in decreases in health beneficial activities of the product [4].

Moreover, various drying methods may result in considerable differences in the retention of bioactive components in herbs. The content of thiols, total phenolic and ascrobic acid from the frozen tomatoes and ginger samples were obviously higher than that obtained by thermal drying methods [4]. Compared with thermal drying methods, freeze drying can maximally preserve the original properties such as hydration, flavor, activity and shape. Borchani et al. [5] reported that between freeze drying and sun drying, freeze dried date fibre concentrates had higher polyphenol content, water holding and viscosity.

2. Materials and Methods

2.1 Materials

YSX cultivated in the wild environment was provided by Zhejiang Province, China. Fresh YSX was washed and drained at room temperature, and then cut into segments >1 cm in length for further usage.

2.2 Drying Methods

The treated YSX segments were placed in a thermostatic drying oven at 100℃. The frequency of air exchange inside and outside of the oven was once per 10 min.Before the experiment, the temperature of the hot air drying oven was adjusted to 60℃. After the temperature is steady, the treated YSX stem segments were dried on a dry mesh plate. The same YSX samples were firstly pre-frozen at -80℃ for 12 h, and then dried in a vacuum freeze dryer.

The 3 kinds of samples were required to constant weight. After dried, the samples were ground into powder by a pulverizer and then passed through a 100-mesh sieve. Resultant powders were stored in 4℃ refrigerator for further analysis.

2.2.1 Basic Nutritional Components

The protein content was measured using the Kjeldahl method. Crude fiber content was determined according to the modified method described by Sumczynski [6]. Minerals were measured by atomic absorption spectrophotometry as described previously [7]. Polysaccharides were determined according to the method of Kou et al [8].

2.2.2 Basic Active Components

The total polyphenol was determined according to the folin-ciocalteu method as described by Nguyen [9]. Total flavonoids content of YSX was performed as described by Vuong et al [10]. The extraction and determination of alkaloids content were carried out by the method of John [11].

3. Result and Discussion

3.1 Effects of Different Drying Methods on Nutritional Ingredients

The moisture content in the fresh YSX was determined. From Fig.1A, the moisture content was about 86%, which is consistent with previous studies (86.48%)[2]. Proteins are an important nutritional component of YSX. There was no clear difference in total protein content (around 51 mg/g) of YSX prepared using different drying methods (Fig. 1B). A very small proportion (about 2.5%) of soluble protein in total protein of YSX was observed, but it was strongly affected by different drying methods. Soluble protein was significantly lower in samples dried by HTD (1.30 mg/g) compared with VFD (2.30 mg/g) and HAD (2.90 mg/g). This may be because temperatures above 60-70℃ destroy the hydrogen, electrostatic and hydrophobic bonds of proteins, destroying the water structure by hydrogen bond deformation between water molecules, increasing the frequency of molecular collisions, thiol-disulfide bond interactions, leading to denaturation [12].

The content of crude fiber in YSX was very abundant (above 174 mg/g) and samples dehydrated by HTD retained the lowest (Fig. 1C). The reason for this loss was that high temperatures can destroy the structure of cellulose, hemicellulose and lignin [13].

In general, both fresh and dried herbs have high amounts of K, Ca, Na, Mg and P minerals, these macrominerals are structural components of tissues and accomplish functions in cellular and basal metabolism and acid-base balance [14]. The content of mineral K in different drying samples was investigated. As seen in Fig. 1D, there was no evident difference between HAD and VFD, which was 26.70 mg/g and 25.80 mg/g. But interestingly, the content of potassium in YSX dried at 100℃ was 17.10 mg/g, which was 56.1% lower than the samples dried by HAD. The reason for this result is that mineral K may be evaporated with steam generated at a high temperature.

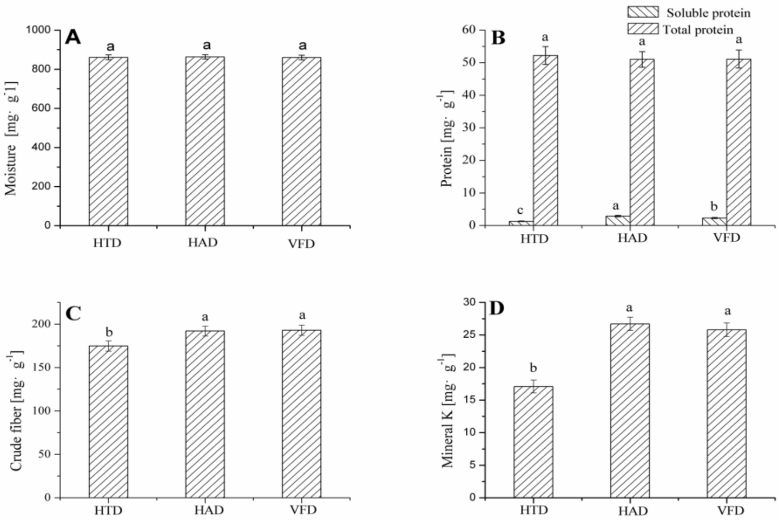

Fig. 1 Effect of different drying methods on the nutrients content of YSX A: Moisture; B: Protein; C: Crude fiber; D: Mineral K (HTD: high temperature drying; HAD: hot air drying; VFD: vacuum freeze drying)

3.2 Effect of Different Drying Methods on Active Components

The polysaccharides in D. officinale have attracted attention recently due to their notable pharmacological activities. The content of polysaccharides was about 300 mg/g (Fig. 2 A), different drying methods had a significant influence on the content of polysaccharides. Samples dehydrated by HTD retained the highest soluble polysaccharide content with 341.70 mg/g, which was 13%, 18% more (301.70 mg/g and 289.90 mg/g, respectively) compared to HAD and VFD. The tendency obtained in this study is consistent with the results of previous reports [2]. This may be because the balance of carbohydrate metabolism in YSX was broken at a high temperature, which led to the accumulation of polysaccharides at a high temperature [15]. HAD resulted in the lowest polysaccharides content (289.90 mg/g), which may be due to the longer drying time (72h).

The total polyphenol-content dried samples with different drying methods were shown in Fig. 2B. The content of total polyphenols in VFD samples was 5.86 mg/g, followed by HTD and HAD (4.38 mg/g and 3.93 mg/g), respectively. Among them, the total polyphenol content of VFD (5.86 mg/g) was increased by 49.1% compared with that of HAD (3.93 mg/g). These results were similar to those from previous studies, that freeze-dried samples contained higher polyphenol contents than hot air-dried or microwave-dried samples [16]. This result clearly showed that different drying methods had significant impact on the total polyphenol content of YSX. HAD resulted in the lowest total polyphenol content in YSX, which was similar to that described by Alfaro et al [16]. The reason may be that HAD process had a higher temperature and longer drying time than VFD, which causes the degradation of the compounds in YSX. The above data revealed that VFD could provide better quality of dried product of YSX in terms of total polyphenol content.

In addition to phenolic acids, flavonoids also belong to polyphenols, which may prevent diseases and pests of plants [17]. Hsu et al. reported that favonoids may reduce the risk of cardiovascular diseases, and inhibit inflammation, cancer, oxidation and bacterial diseases [18]. These biological activities can be attributed to their chemical structure, the degree of polymerization and binding form (malonylation or glycosylation) [17]. As can be clearly seen from Fig. 2C, the total flavonoid content in the VFD sample is the highest (7.95 mg/g); while, the total flavonoid content in HTD (6.26 mg/g) and HAD (6.49 mg/g) were around 20% lower than that in YSX dried using VFD. According to Lou et al. (2016), the flavonoids will increase sharply in a lower temperature (80℃).

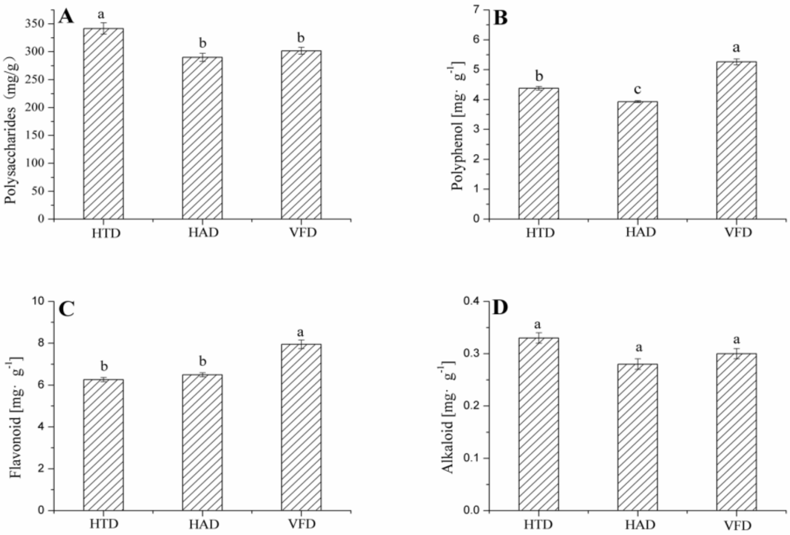

Fig. 2 Effect of different drying methods on the active constituents of YSX A: Polysaccharide; B: Polyphenol; C: Flavonoid; D: Alkaloid (HTD: high temperature drying; HAD: hot air drying; VFD: vacuum freeze drying)

Alkaloids are the main active components in the medicinal plant officinale, which is the first category of compounds extracted from D. officinale with confirmed chemical structures [18]. As was previously mentioned, alkaloids can inhibit the growth of tumor cells, good therapeutic effect on tumors and antimicrobial activity. Alkaloids protect cardiovascular and cerebrovascular organs [19]. The alkaloid content found with three drying methods was not significantly different. Among them, the content of alkaloids in YSX dried by HTD was the highest, which may result from a high temperature drying the treatment and lead to protein denaturation and the release of alkaloids bounded to proteins. There is a little difference between HTD and VFD samples in alkaloid content, with an average of about 0.3 mg/g. The results showed that different drying processes had no evident effect on the content of alkaloids in YSX, indicating that the total amount of alkaloids as plant hormones remained unchanged during the drying process [20].

4. Conclusion

The findings of the present study indicated that various drying methods results in considerable difference in the preservation of valuable components in YSX. VFD and HAD could retain the nutritional ingredients and active components of YSX to a great extent, including total soluble protein, crude fiber, mineral K, total polyphenols, and total flavonoids, while the content of polysaccharides in HTD samples showed the best ideal effect. In addition, the antioxidant activity of YSX water extract was better in HTD samples than HAD and VFD samples, while its alcohol extracts was better when the samples were dried with VFD samples than HTD and HAD samples. Moreover, antioxidant activity in YSX was positively correlated with total polyphenols, total flavonoids, and polysaccharides contents.

Acknowledgments

The “Yanshangxian”- Dendrobium officinale provided by Zhejiang Jiafeng Eco-agriculture Co., Ltd., Zhejiang Province, China. And many thanks to Fushou Xiao professor for the guidance of the writing. This work was supported by the National Key Research and Development Program of China (Project No. 2017YFD0400902-4-1).

References

[1] Zhang, L. Y., Wang, F. B., and Ren, X. B. 2017. Inhibitory effect of Dendrobium officinale

polysaccharide on human gastric cancer cell xenografts in nude mice. Food Science and Technology 38(1): 78-83.

[2] Wang, H. Q., Jin, M. Y., Paek, K. Y., Piao, X. C. and Lian, M. L. 2016. An efficient strategy for enhancement of bioactive compounds by protocorm-like body culture of Dendrobium candidum. Industrial Crops and Products 84: 121-130.

[3] Li, Y., Wang, C. L., Wang, Y. J., Guo, S. X., Yang, J. S. and Xiao, P.G. 2009. Four New Bibenzyl Derivatives from Dendrobium officinale. Chemical and Pharmaceutical Bulletin 57(9): 997-999.

[4] Meng, Q., Fan, H., Li, Y. and Zhang, L. 2017. Effect of drying methods on physico-chemical properties and antioxidant activity of Dendrobium officinale. Journal of Food Measurement and Characterization 12(1): 1-10.

[5] Borchani, C., Besbes, S., Masmoudi, M., Blecker, C., Paquot, M. and Attia, H. 2011. Effect of drying methods on physico-chemical and antioxidant properties of date fibre concentrates. Food Chemistry, 125(4): p.1194-1201.

[6] Sumczynski, D., Bubelova, Z., Sneyd, J., Erb-Weber, S. and Mlcek, J. 2015. Total phenolics, flavonoids, antioxidant activity, crude fibre and digestibility in non-traditional wheat flakes and muesli. Food Chemistry 174: 319-325.

[7] Paudel, M. R., Chand, M. B., Pant, B. and Pant, B. 2018. Antioxidant and cytotoxic activities of Dendrobium moniliforme extracts and the detection of related compounds by GC-MS. BMC Complementary and Alternative Medicine 18(1).

[8] Kou, X. H., Chen, Q., Li, X. H., Li, M. F., Kan, C., Chen, B. R., Zhang, Y. and Xue, Z. H. 2015. Quantitative assessment of bioactive compounds and the antioxidant activity of 15 jujube cultivars. Food Chemistry, 173: 1037-1044.

[9] Nguyen, V. T., Ueng, J. P. and Tsai, G. J. 2011. Proximate Composition, Total Phenolic Content, and Antioxidant Activity of Seagrape (Caulerpa lentillifera). Journal of Food Science 76(7): C950-C958.

[10] Vuong, Q. V., Hirun, S., Roach, P. D., Bowyer, M. C., Phillips, P. A. and Scarlett, C. J. 2013. Effect of extraction conditions on total phenolic compounds and antioxidant activities of Carica papaya leaf aqueous extracts. Journal of Herbal Medicine 3(3): 104-111.

[11] John, B., Sulaiman, C. T. and George, S. 2014. Spectrophotometric estimation of total alkaloids in selected justicia species. International Journal of Pharmacy and Pharmaceutical Sciences 6(5): 647-648.

[12] Mishyna, M., Itzhak Martinez, J. J., Chen, J., Davidovich-Pinhas, M. and Benjamin, O. 2019. Heat-induced aggregation and gelation of proteins from edible honey bee brood (Apis mellifera) as a function of temperature and pH. Food Hydrocolloids.

[13] Zhang, J., Choi, Y. S., Yoo, C. G., Kim, T. H., Brown, R. C. and Shanks, B. H. 2015. Cellulose–Hemicellulose and Cellulose–Lignin Interactions during Fast Pyrolysis. ACS Sustainable Chemistry & Engineering 3(2): 293-301.

[14] Uribe, E., Marín, D., Vega-Gálvez, A., Quispe-Fuentes, I. and Rodríguez, A. 2016. Assessment of vacuum-dried peppermint (Mentha piperita L.) as a source of natural antioxidants. Food Chemistry 190: 559-565.

[15] Cao, J. F., Fan, X. K., Sarsaiya, S., Pan, X. W., Yang, N., Jin, L. L., Zhao, J., Zhang, B. H., Shi, J. S. and Chen, J. S. 2018. Accumulative Component Analysis of Polysaccharide in Protocorm of Dendrobium candidum. Journal of Biobased Materials and Bioenergy 12(8): 348-355.

[16] Alfaro, S., Mutis, A., Quiroz, A., Seguel, I. and Scheuermann, E. (2014). Effects of drying techniques on murtilla fruit polyphenols and antioxidant activity. Journal of Food Research 3(5).

[17] Huang, J. and Zhang, M. 2015. Effect of three drying methods on the drying characteristics and quality of okra. Drying Technology 34(8): 900-911.

[18] Hsu, B. Y., Lin S. W., Inbaraj, B. S. and Chen, B. H. 2017. Simultaneous determination of phenolic acids and flavonoids in Chenopodium formosanum Koidz. (djulis) by HPLC-DAD-ESI-MS/MS. Journal of Pharmaceutical and Biomedical Analysis 132: 109-116.

[19] Assimopoulou, A. N., Sinakos, Z. and Papageorgiou, V. P. (2005). Radical scavenging activity of crocus sativus l. extract and its bioactive constituents. Phytotherapy Research 19(11): 997-1000.

[20] Xu, J., Han, Q. B., Li, S. L., Chen, X. J., Wang, X. N., Zhao, Z. Z. and Chen, H. B. 2013. Chemistry, bioactivity and quality control of Dendrobium, a commonly used tonic herb in traditional Chinese medicine. Phytochemistry Reviews 12(2): 341-367.