

Study of the Preparation and Quality of *Gastrodia elata* with Different Drying Processes

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Research Article

Keywords: *Gastrodia elata*, drying method, *Gastrodin*, functional component, antioxidation

Posted Date: October 14th, 2023

DOI: <https://doi.org/10.21203/rs.3.rs-3399558/v1>

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Additional Declarations: No competing interests reported.

Abstract

The objective of this study was to evaluate the effects of different drying methods on the quality of fresh *Gastrodia elata* after drying and processing. Four drying methods, including natural air drying, hot air drying, vacuum freeze drying, and vacuum microwave drying, and two pre-treatment methods (unprocessed and steam processed) were used. Scanning electron microscopy was used to observe the microstructure of dried *Gastrodia elata*, and high-performance liquid chromatography was used to measure the content of eight functional components such as gastrodin, p-hydroxybenzyl alcohol etc. The in vitro antioxidant and hypotensive experiments were also conducted. The results showed that pre-treatment methods and different drying methods had a significant effect on the morphology and functional component content of *Gastrodia elata*. The steam processed-vacuum freeze drying (PGB-CFD) treatment group had the highest functional component content, with a total content of 42.71 mg/g. The unprocessed-vacuum freeze drying (NGB-CFD) treatment group had the highest antioxidant capacity, while the steam processed-vacuum freeze drying (PGB-CFD) treatment group had the highest ACE enzyme inhibition rate. This study provides reference methods and basic data for the further processing of fresh *Gastrodia elata*.

Introduction

Gastrodia elata (*G. elata*), a herbaceous tuber of the orchid family, is a highly valued traditional medicine in China. It is rich in active components such as gastrodin, p-hydroxybenzyl alcohol, and parishins, which can be used to lower blood pressure, resist oxidation, and improve cardiovascular and cerebrovascular diseases ^[1, 2]. In 2019, the National Health Commission of the People's Republic of China has included it in the pilot directory of medicinal and food homology for the first time. At present, Sichuan, Yunnan, Anhui and Guizhou provinces have initiated pilot projects on the production and operation of *G. elata*, which will promote the research and development of innovative food products based on *G. elata* raw materials ^[3]. Investigating the fundamental properties of *G. elata* under different drying approaches has great scientific importance and practical application value.

G. elata is mainly distributed in the mountainous regions of East Asia, including Japan, South Korea, India, and China ^[1]. In China, it is mainly cultivated in Guizhou, Yunnan, Sichuan, Shaanxi, and other areas ^[4]. The harvesting period of *G. elata* is relatively short, and the freshly harvested *G. elata* can only be stored for 30–60 days. Therefore, drying is essential to extend its shelf life ^[5]. In traditional Chinese medicine, natural air drying is a common drying method, and processing is necessary prior to this drying ^[6]. Previous studies have shown that pre-treatment and drying techniques are essential to obtain the highest quality and functional components of *G. elata* ^[7]. However, there are few studies on the optimal drying and processing methods for fresh *G. elata* for various processing purposes. Few scholars also have paid attention to the important auxiliary role of vanillyl alcohol and vanillin in the treatment of dizziness, insomnia and memory improvement of *G. elata* and their content levels in *G. elata* raw materials.

By referring to the quality evaluation indicators of *G. elata* in the Chinese Pharmacopoeia (2020 Edition), this study added two new evaluation indices of vanillyl alcohol and vanillin, and established a high-performance liquid chromatography method for the simultaneous determination of the content of eight functional components. To further investigate the changes in the microstructure and the eight functional components of *G. elata* under different pre-treatment and drying methods, two pre-treatments (unprocessed and steam processed) were applied, followed by natural air drying (NAD), hot air drying (HAD), vacuum freeze drying (CFD), and vacuum microwave drying (VMD). This study aims to select the most suitable drying method for fresh raw *G. elata* material according to different processing needs.

Material and methods

The material and methods section was presented as supplementary material 1.

Results and discussion

All figures and tables were presented in the supplementary material 2.

Morphology and microstructure of *G. elata*

Figure S1 shows that the surface of *G. elata* tablets was relatively flat without any significant shrinkage prior to steam treatment. In all steamed groups, except the PGB-CFD treatment group, the appearance of *G. elata* was exhibited slightly yellow due to the dissolution of polysaccharides attached to its surface during the steaming process. The surface polysaccharide content was reduced. Research by Wu et al. [8] and Ai Ziping et al. [9] also supported the conclusion. The microstructure was most compact in the PGB-CFD treatment group. PGB-VMD treatment group had a porous and loose spongy structure with protrusions and pores. Yue et al. [10] showed that *Codonopsis pilosula* was comparable after microwave vacuum drying with rotation. The surface tissue morphology and microstructure of *G. elata* did not differ significantly between the PGB-NAD and PGB-HAD treatment groups, with both showing a slightly transparent appearance and clearly visible veins.

In the unprocessed groups, the surface morphology of *G. elata* in the NGB-NAD and NGB-HAD treatment groups showed different degrees of shrinkage and bending, and the degree of shrinkage and bending of *G. elata* after NAD was greater than that after HAD. However, the results of turmeric drying study [11] differed from our study, which could be due to the different experimental equipment and parameters. With the exception of the NGB-NAD treatment group, the appearance of the other groups was all white in the NGB treatment method, as the unprocessed treatment reduced the loss of *G. elata* polysaccharides compared to the steam processed treatment. The polysaccharides of *G. elata* was potentially declined over time due to a slow drying process and not-enzyme killing treatment in NGB-NAD treatment group. Additionally, the color of ginger was adversely affected after natural air drying [12], which is consistent with the results of this study.

The hardness and moisture contents

As shown in Fig. S2, the moisture content of *G. elata* was highest after CFD and significantly different from HAD and VMD. The moisture content of *G. elata* after drying did not differ significantly between the CFD and VMD treatment groups, even when the raw material was processed. However, there was a significant difference between the NAD and HAD treatment groups. During the steaming of *G. elata* tablets, a large number of air pockets were created, which, when combined with the *G. elata* polysaccharides, formed a solid structure that facilitated the transfer of internal water to the surface of the *G. elata*, thereby accelerating the drying process.

For hardness, there was a clear variation between the different drying methods within the unprocessed treatment group, with hardness decreasing in the following order: NAD > HAD > VMD > CFD. Zeng et al. ^[13] found that the hardness of *Agaricus bisporus* after hot air drying was 5.4 times that of freeze drying, which is consistent with our conclusions. The order of hardness from highest to lowest in the steam treated group was: NAD and HAD > CFD and VMD. The hardness of the unprocessed group after NAD and HAD was significantly greater than that of the steam processed group, because the case hardening was weakened after steam processing. Regardless of whether the *G. elata* tablets had been processed or not, there was no significant difference in their hardness after VMD. This was due to the fact that the heat was evenly distributed and, under the same vacuum conditions, the processing of the *G. elata* had no significant effect on its hardness after drying.

The contents of eight functional components

The chromatogram in Fig. S3 showed a resolution of over 1.2 for the peaks of gastrodin, p-hydroxybenzyl alcohol, vanillin, vanillyl alcohol, parishin A, parishin B, parishin C, and parishin E, which was considered to be good resolution. The results of the regression equations, R^2 values, precision, reproducibility, stability, mean recoveries of standard addition and recovery rate are shown in Table S1.

As shown in Fig. S4, the total content of the eight functional components in *G. elata* tablets was the highest in the PGB-CFD treatment group, with the highest amount of parishin A. This was due to the fact that the CFD had a low drying temperature, which minimized the deterioration of *G. elata* caused by high temperature and reduced the biochemical reaction rate within the *G. elata* material. In addition, steam processing significantly reduced the activity of microorganisms and enzymes ^[14]. Next was the NGB-VMD group, where the VMD was highly efficient, and prevented internal deterioration and microbial activity of the material. The NGB-NAD treatment group had the lowest total content. The main reason for this was the longer drying time required for NAD and the fact that *G. elata* had not been processed. The active ingredient of the samples was degraded by the action of microorganisms and enzymes, resulting in a decrease in functional ingredients and a reduction in the quality of the dried products.

Compared with the unprocessed group, the total content of eight functional components in the steam processed group was significantly higher when the NAD, HAD and CFD methods were used. The results of a study conducted by Xie et al. ^[15] suggested that steam decreased the β -glucosidase activity, which

suppressed the enzymatic hydrolysis reaction and consequently amplified the content of gastrodin, which is consistent with this study. The VMD group showed an opposite result. On the one hand, the loss of water-soluble functional components such as gastrodin and p-hydroxybenzyl alcohol was minimised without any processing. On the other hand, VMD could accelerate the process of reducing the moisture content of *G. elata* tablets and inhibit enzymatic and microbial activity. Thus, it may also serve as a protective functional component.

The content of polysaccharides, total phenols, and total flavonoids in *G. elata*

As shown in Fig. S5a, the order of total phenol content from highest to lowest was NGB-CFD, NGB-VMD, NGB-NAD, PGB-CFD, NGB-HAD, PGB-HAD, PGB-NAD, and PGB-VMD. This study confirmed the changes in total phenolic content of *Bletilla striata* scented tea following different drying treatments^[16]. However, Ncube Buyile and colleagues^[17] showed that the total phenolic content of *Corchorus olitorius* leaves was increased by cooking. The difference may be related to the phenolic species. In *G. elata*, a variety of phenols were found, such as gastrodin, epicatechin, cinnamic acid and so on. The concentration of free phenolics in *G. elata* from different sources was usually higher than that of bound phenolics^[18]. During steaming, the free phenols present in *G. elata* tended to be lost, leading to a decrease in the total phenolic content.

As shown in Fig. S5b, the flavonoid content of NGB-CFD was the highest, followed by NGB-HAD, PGB-VMD, PGB-CFD, PGB-NAD, NGB-NAD and finally PGB-HAD and NGB-VMD. *G. elata* is known to contain flavonoids such as rutin, epicatechin, glycyrrhizin, heteroflavonoid C, and glicladone. The NGB-CFD group exhibited the highest levels of total flavonoids and total phenolics due to the unprocessed treatment, which prevented the loss of flavonoids during steaming and the CFD, which ensured the maximum retention of active ingredients. Guo et al.^[19] found that freeze drying of *Sophora japonica* flowers resulted in higher total flavonoid content than hot air and vacuum drying. Other studies had shown that heating fresh turmeric resulted in a decrease in total phenolics and total flavonoids^[11], reinforcing the findings.

As depicted in Fig. S5c, the polysaccharide content of *G. elata* raw material was relatively high, and the content range under different drying methods was 6%-20%, slightly higher than Fang Wei's research results of 12%-17%^[20]. NGB-CFD had the highest polysaccharide content, followed by PGB-CFD, NGB-VMD, PGB-NAD, NGB-HAD, PGB-HAD, PGB-VMD, and NGB-NAD with the lowest. CFD was advantageous for preserving polysaccharide content in both the unprocessed and steam processed methods. This was followed by the NGB-VMD group. Compared to the PGB-VMD treatment group, the NGB-VMD treatment group was able to prevent the loss of polysaccharides during the steaming process. Although it could not inactivate the microorganisms and enzymes on the *G. elata* tablets, VMD was able to rapidly reduce the water activity of the material, thereby significantly reducing the action time of the microorganisms and enzymes and consequently the loss of polysaccharides. The NGB-NAD treatment group had the lowest polysaccharide content. Due to the lack of steam treatment, the polysaccharides of *G. elata* had been

subjected to decomposition by microorganisms and enzymes such as β -glucosyl enzyme during a prolonged drying process ^[20], resulting in the lowest content.

Evaluation of the antioxidant capacity

Figure S6 shows that the best total antioxidant capacity was the NGB-CFD group (68.54%), followed by the NGB-NAD group (44.83%) and the PGB-HAD group was the worst, with only 29.38%. The best DPPH free radical scavenger was the NGB-CFD group (50.86%), followed by the NGB-VMD group (33.47%), and the worst was the PGB-HAD group (28.87%). The NGB-CFD group had the best ABTS free radical scavenging ability (41.05%). This was followed by the NGB-HAD group (46.43%) and the weakest was the PGB-NAD group (17.06%). Freeze drying of both coffee fruits ^[21] and green beans ^[22] showed a more effective scavenging capacity for DPPH free radicals compared to HAD and NAD. Freeze-dried blackberry extract had the greatest DPPH, ABTS free radical scavenging capacity and total reducing power ^[23], which supports this conclusion. The unprocessed group of *G. elata* had a higher antioxidant capacity than the steam-processed group, as shown in Fig. S5, which showed higher levels of total phenolics and flavonoids in the unprocessed group. This was in line with the conclusion of the study.

The capacity of reducing blood pressure levels

As can be seen in Fig. S7, the PGB-CFD, PGB-VMD, and NGB-CFD groups showed the highest rate of ACE enzyme inhibition, while the PGB-NAD group showed the lowest rate. The highest rate of ACE enzyme inhibition had been observed in lyophilized mushrooms ^[24], supporting this conclusion. The PGB-CFD and NGB-CFD groups had a relatively high polysaccharide content, and *G. elata* polysaccharides were found to have an inhibitory effect on ACE enzyme activity, with an IC₅₀ of 0.66 mg/mL ^[25]. The PGB-VMD group had a high concentration of gastrodin, p-hydroxybenzyl alcohol, and parishins, which can effectively reduce blood pressure by suppressing vascular inflammatory factors. The inhibition rate of ACE enzyme was the lowest in the PGB-NAD group because it contained less polysaccharide, gastrodin, p-hydroxybenzyl alcohol and parishins. The inhibition rate of ACE enzyme can be an indicator of a substance's potential to lower blood pressure, suggesting that the PGB-CFD, PGB-VMD, and NGB-CFD treatment groups have a promising ability to lower blood pressure.

The quality evaluation score

The content of each substance was scored from high to low and the acceptability of the appearance form, with a full score of 8 points. The results are shown in Table S2.

According to Table S2, the NGB-CFD treatment group, in which *G. elata* was directly sliced and vacuum freeze dried without steam treatment, had the highest overall evaluation score of 69 points. The NGB-VMD treatment group, in which *G. elata* was directly sliced without steam treatment and then vacuum microwave dried, had the second highest score of 56 points.

Conclusion

This study investigated the functional components, physicochemical indicators, antioxidant capacity and antihypertensive activity of fresh *G. elata* by different treatments. It was found that the structure and main functional components of *G. elata* were greatly affected by the pre-treatment and drying process. Therefore, the most appropriate drying process for fresh *G. elata* should be selected based on the raw materials characteristics of the different *G. elata* products. CFD of *G. elata* tablets resulted in higher water content and functional ingredient components content than the other three drying methods. Like the unprocessed and steam processed methods, the products without pre-treatment of *G. elata* had higher levels of polysaccharides, total phenolics, total flavonoids and antioxidant capacity. Finally, the NGB-CFD treatment group had the highest score when considering the overall score. However, the cost of CFD method is high. Considering the cost and economic benefits, vacuum microwave drying can also be implemented as an alternative for drying fresh *G. elata*.

Abbreviations

The abbreviations section was presented as supplementary material 1.

Declarations

Ethics Approval

Not applicable.

Data Availability

The datasets generated during the current study are available from the corresponding author on reasonable request.

Fund declaration

This work was supported by the National Natural Science Foundation of China (No. 31671780) and the Agricultural Product Quality and Safety Risk Assessment Foundation of the Ministry of Agriculture and Rural Affairs of the People's Republic of China (No. GJFP2020002, GJFP2020003).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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