Effect of Drying Methods on Appearance Characteristics of *Fritillaria cirrhosa* Bulbs with Different Diameters

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Abstract [**Objectives**] To investigate suitable drying methods for *Fritillaria cirrhosa* bulbs of different diameters. [**Methods**] In this study, we analyzed the appearance of *F. cirrhosa* bulbs and powder under different diameters and drying processing methods. [**Results**] The bulbs dried naturally were dark with faintly brown color whereas those that were dried using hot-air and vacuum methods were pale yellow or off-white color. The L^* values of the powdered *F. cirrhosa* group subjected to hot air drying and vacuum drying were significantly higher than those of the naturally dried group. [**Conclusions**] Hot air drying at 35 – 40 ℃ as a processing method for *F. cirrhosa* production regions can maintain the color of bulbs and powder.

Key words *Fritillaria cirrhosa*, Drying method, Browning index

1 Introduction

Fritillaria cirrhosa, as a consumable herbal food known for its medicinal compatibility, has attracted growing interest[1]. This plant has a rich history in traditional Chinese medicine and has been used for over 2 000 years in China for cough treatment[2-3]. Fritillariae Cirrhosae Bulbus, commonly referred to as Chuan-Bei-Mu, is a threatened high-altitude medicinal species celebrated for its anti-tumor, anti-asthmatic, and antitussive effects[4]. The drying method significantly affects the content of active ingredients in fritillary bulbs[5]. Drying processes involve simultaneous heat and mass transfer, leading to various physicochemical and enzymatic changes that impact the overall quality of the dried product[6-7]. The main factors influencing the quality of dried goods are the oxygen environment, temperature, and pressure. Oxygen plays a key role in oxidation and nutrient degradation, while temperature is crucial for maintaining drying quality. High temperatures can accelerate the drying process but may also cause damage to the product; conversely, low temperatures help preserve quality but can prolong drying time[8]. Heat and oxidation are considered key factors promoting browning[9]. Notably, *F. cirrhosa* has a larger market share and high price, underscoring its significance in the industry. The size of *F. cirrhosa* bulbs significant color variations exist between the bulbs and powders across different diameters and species of Fritillaria[10]. Compared with other *Fritillaria* species, *F. cirrhosa* has smaller bulb diameters[11]. Therefore, further research is needed to determine the appropriate drying methods for *F. cirrhosa* bulbs of varying sizes to delay browning and maintain color. To address this knowledge gap, this study aimed to investigate suitable drying methods for *F. cirrhosa* of different diameters.

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2 Materials and methods

2.1 Materials and drying methods Fresh *F. cirrhosa* bulbs were harvested on July 18, 2025, from Litang County, Garzê Tibetan Autonomous Prefecture, Sichuan Province, China, at an average altitude of 4 200 m. After cleaning, Qingbei-type *F. cirrhosa* bulbs were categorized into two grades based on bulb diameter: diameter ≤8 mm (D1) and diameter > 8 mm (D2), then dried using the following methods: (i) Natural drying (N): Bulbs were dried in sunlight for 10 d at approximately 25 ℃. (ii) Hot air drying (H): Conducted in a constant-temperature drying oven (BGZ-70, Shanghai Boxun Medical Biological Instrument Co., Ltd., China) at three temperature settings: 35 ℃ (H35), 40 ℃ (H40) and 45 ℃ (H45). (iii) Vacuum drying (V): performed in a vacuum dryer (DZF-6050BZ, Shaoxing Bote Instrument Equipment Co., Ltd., China), at temperatures 35 ℃ (V35), 40 ℃ (V40), and 45 ℃ (V45) under a vacuum pressure of 0.025 mbar. For all treatments, Bulbs of Qingbei (100 g) were placed in a single layer in each oven, and all drying methods were stopped when the moisture content dropped below 15 g/100 g.

2.2 Color measurement After drying, the *F. cirrhosa* bulbs were photographed using a digital camera and ground into powder. The color of dried bulbs powder was determined using a spectrophotometer (CS-580, Hangzhou CHNSpec Technology Co., Ltd., China). L^* a^*, and b^* value indicate lightness, redness/greenness, and yellowness/blueness, respectively[12]. Total color change (ΔE) and browning index (BI) were calculated using Eqs. (1) and (2)[13-14], respectively.

$$\Delta E = \sqrt{(\Delta L^{*2} + \Delta a^{*2} + \Delta b^{*2}} \quad (1)$$

where ΔE represents the difference in each parameter between natural drying and hot air drying or vacuum drying samples.

$$BI = [100(X - 0.13)]/0.17 \quad (2)$$

$$X = (a^* + 1.75L^*)/(6.645L^* + a^* - 3.012b^*)$$

2.3 Statistical analysis All experiments were conducted in triplicate, and data were compiled using Microsoft Excel 2020. All values are mean ± standard deviation. Statistical significance was analyzed using SPSS software (Version 26.0) at $p < 0.05$.

3 Results and analysis

3.1 Effect of drying method on color changes in *F. cirrhosa* bulbs The color differences of dried *F. cirrhosa* bulbs vary with processing method (Fig. 1). The bulbs dried naturally were dark with faintly brown color whereas those that were dried using hot-air and vacuum methods were pale yellow or off-white color. It can be seen that vacuum drying and hot drying were effective methods to prevent browning of *F. cirrhosa*, among which vacuum drying had a better effect. According to Chinese Pharmacopeia, the color of *F. cirrhosa* bulb is pale yellow or off-white color, the color of the bulb can be maintained by hot drying and vacuum drying.

3.2 Effect of drying method on color changes in *F. cirrhosa* powder The results of powder color difference measurements using a colorimeter are shown in Table 1. In the measurement results, the higher the L^* value, the whiter the color. The L^* values of the powdered *F. cirrhosa* group subjected to hot air drying and vacuum drying were significantly higher than those of the naturally dried group. This is consistent with visual observation (Fig. 1). The Browning Index (*BI*) characterizes changes in product color. A higher *BI* value indicates more severe browning, while a lower *BI* value indicates less severe browning. The results indicate that for *F. cirrhosa* bulbs with a diameter ≤8 mm, the *BI* value after vacuum drying was significantly higher than that after convection drying and natural drying, though the numerical changes were relatively small and had minimal impact on color changes. In summary, it can be seen that convection drying and vacuum drying can enhance the brightness of *F. cirrhosa* powder and delay browning.

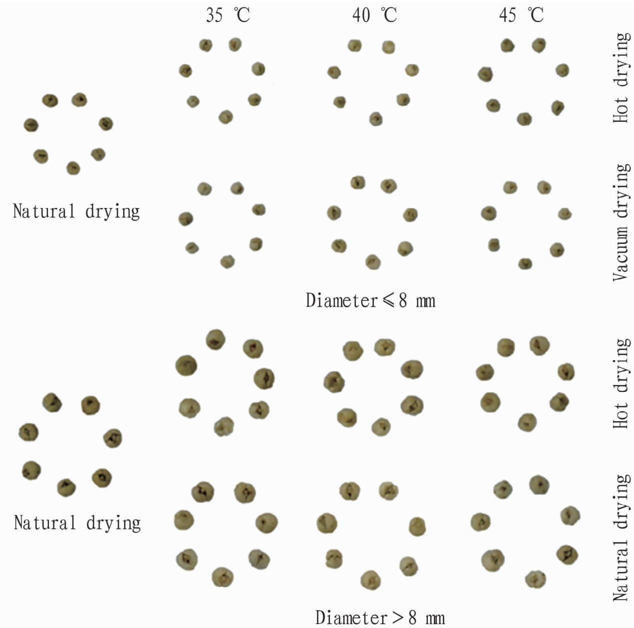

Fig. 1 Images of *Fritillaria cirrhosa* bulbs under different drying methods

Table 1 Effect of drying method on color and browning index changes in *Fritillaria cirrhosa* powder

Treatment		L^*	a^*	b^*	*BI*	△*E*
Diameter ≤8 mm	N	75.89 ±0.88 c	0.07 ±0.02 a	9.34 ±0.24 b	87.66 ±0.16 b	–
	H35	77.34 ±1.95 b	−0.63 ±0.07 c	8.15 ±0.12 e	85.67 ±0.14 d	2.00
	H40	78.65 ±0.07 a	−0.86 ±0.08 d	8.56 ±0.41 d	85.75 ±0.39 d	3.01
	H45	77.98 ±0.47 ab	−1.31 ±0.10 e	8.67 ±0.26 d	85.53 ±0.36 d	2.59
	V35	77.92 ±0.24 ab	0.10 ±0.04 a	9.62 ±0.05 b	87.71 ±0.06 b	2.05
	V40	77.95 ±1.02 ab	0.08 ±0.06 a	10.14 ±0.36 a	88.22 ±0.22 a	2.21
	V45	77.23 ±0.24 b	−0.22 ±0.06 b	9.02 ±0.28 c	86.91 ±0.35 c	1.41
Diameter >8 mm	N	75.88 ±0.61 b	−0.30 ±0.02 ab	8.98 ±0.33 c	86.96 ±0.39 b	–
	H35	79.41 ±1.34 a	−0.75 ±0.05 d	9.12 ±0.30 c	86.32 ±0.24 cd	3.56
	H40	78.87 ±0.48 a	−0.81 ±0.05 e	9.85 ±0.30 b	87.04 ±0.35 b	3.16
	H45	76.84 ±0.45 b	−1.18 ±0.09 f	9.52 ±0.16 b	86.62 ±0.17 c	1.41
	V35	79.08 ±0.93 a	−0.25 ±0.04 a	10.82 ±0.22 a	88.47 ±0.27 a	3.69
	V40	79.09 ±0.12 a	−0.37 ±0.07 b	8.65 ±0.08 d	86.21 ±0.10 d	3.23
	V45	79.13 ±0.86 a	−0.65 ±0.03 c	8.99 ±0.43 c	86.31 ±0.47 cd	3.27

NOTE Means represented by different letters within the same column show significant differences determined by the *LSD* multiple comparison test ($p < 0.05$). The values are expressed as mean ± standard deviation. N is short for natural drying; H refers to hot drying; V stands for vacuum drying.

4 Discussion

F. cirrhosa is a highly valued traditional Chinese medicinal material, favored in the market due to its excellent efficacy and low toxicity, which contributes to its relatively high price[15]. *F. cirrhosa* bulb powder can be used not only for medicinal purposes but also as a functional food ingredient[16–17]. Vacuum drying and hot air drying were effective in preventing browning of *F. cirrhosa* bulbs, and vacuum drying had a better effect. This result is consistent with the findings reported by Zhang *et al*[18], because it has a slower drying speed, and oxidation is the main factor causing browning[19]. In our results, the *BI* value of bulbs powder in vacuum drying was higher than hot air drying, especially in diameter≤8 mm, which may be attributed to the higher initial moisture content potentially promoting enzymatic browning reactions[20]. The *BI* index was lower in hot drying because although airflow increases oxygen supply, it also accelerates the drying process, resulting in a smaller *BI*.

In summary, drying methods significantly influence the appearance characteristic of *F. cirrhosa*. In this study, we analyzed the appearance of *F. cirrhosa* bulbs and powder under different diameters and drying processing methods. Our results suggested that hot air drying and vacuum drying could improve appearance. Hot air drying at 35 – 40 ℃ as a processing method for *F. cirrhosa* production regions could maintain the color of *F. cirrhosa* bulbs and powder. Vacuum drying for bulbs > 8 mm in diameter dried at 40 ℃ maintained the colour and could making it suitable for functional food development in future.

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