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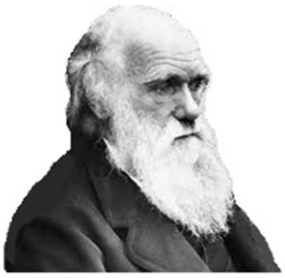

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Research on pre-processing and storage methods affecting the quality of Ngoc Linh Ginseng medicinal materials

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ABSTRACT

Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) is a valuable endemic medicinal plant of Vietnam, renowned for its high content of bioactive saponins and diverse pharmacological activities. This study was conducted to evaluate the effects of different pre-processing methods and storage conditions on the quality of Ngoc Linh ginseng medicinal materials. Four pre-processing treatments, including hot-air drying and heat-pump drying applied to whole roots and sliced roots, were investigated. In addition, three storage methods, namely vacuum packaging at room temperature, vacuum packaging under cool storage (12-14 °C), and conventional storage, were evaluated over a 12-month period. The results showed that all pre-processing methods maintained the characteristic sensory properties of Ngoc Linh ginseng. However, sliced roots subjected to heat-pump drying at 30-35 °C exhibited the shortest drying time (24 ±3 h) and the highest retention of bioactive compounds, with MR2 content reaching 4.02 ±0.03% and total saponin content reaching 13.08 ±0.30%. During storage, total saponin content gradually decreased in all treatments. Nevertheless, vacuum packaging combined with cool storage at 12-14 °C effectively preserved sensory quality, maintained total saponin content (12.1 ±0.2% after 12 months), and resulted in the lowest microbial count (3.5

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× 10^2 CFU/g). The study demonstrated that slicing combined with heat-pump drying at 30-35 °C is an appropriate pre-processing method, while vacuum packaging under cool storage at 12-14 °C is the most suitable storage condition for maintaining the quality and extending the shelf life of Ngoc Linh ginseng medicinal materials.

Keywords: *Panax vietnamensis*, Ngoc Linh ginseng, pre-processing, storage, saponin content

1. INTRODUCTION

Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) is an endemic medicinal plant species of Vietnam, naturally distributed in the Ngoc Linh Mountain range of Kon Tum and Quang Nam provinces. It is considered one of the most valuable ginseng species worldwide due to its rich and diverse phytochemical composition, particularly its high content of saponins.

To date, more than 50 saponin compounds have been identified in Ngoc Linh ginseng, including unique ocotillol-type saponins such as majonoside-R2 (MR2), which are rarely found in other ginseng species. These compounds contribute significantly to the medicinal value of the plant.

Previous studies have demonstrated that Ngoc Linh ginseng possesses various biological activities, including antioxidant, immunomodulatory, hepatoprotective, anti-stress, and health-promoting effects. Therefore, maintaining the quality of Ngoc Linh ginseng medicinal materials is essential for ensuring their efficacy and commercial value.

The quality of medicinal materials is influenced not only by cultivation conditions and harvest age but also by post-harvest processing and storage practices. Factors such as drying temperature, drying duration, moisture content, and storage conditions can affect the stability of bioactive compounds, sensory characteristics, and shelf life of the product. Inappropriate handling after harvest may lead to degradation of active constituents and a decline in product quality.

Therefore, this study was conducted to evaluate the effects of different pre-processing methods and storage conditions on the quality of Ngoc Linh ginseng medicinal materials. The findings are expected to provide a scientific basis for developing appropriate post-harvest processing and storage protocols, thereby contributing to the preservation of product quality and enhancement of the economic value of Ngoc Linh ginseng.

2. MATERIAL AND METHODS

Study Material

The study material comprised the roots of Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) harvested from cultivated plants grown in the Ngoc Linh Mountain region, formerly Quang Nam Province and currently under the administrative jurisdiction of Da Nang City, Vietnam (Christensen LP *et al.,* 2009).

Figure 1. Ngoc Linh ginseng roots used in the experiment.

Research location: Ngoc Linh Ginseng and Medicinal Plant Development Center, Quang Nam Province, Vietnam. Experimental period: June 2024 - June 2026.

Research Contents

- Content 1. Determination of appropriate pre-processing methods for Ngoc Linh ginseng cultivated under forest canopy conditions in Quang Nam.
- Content 2. Investigation of the effects of different storage methods on the quality of Ngoc Linh ginseng.

Methods

Content 1. Determination of appropriate pre-processing methods for Ngoc Linh ginseng cultivated under forest canopy conditions in Quang Nam

The experimental material consisted of six-year-old Ngoc Linh ginseng roots (*Panax vietnamensis* Ha et Grushv.) harvested from cultivation areas under forest canopy conditions on Ngoc Linh Mountain. Following harvest, the ginseng roots were thoroughly cleaned with water to eliminate adhering soil and surface contaminants. After being naturally drained under well-ventilated conditions for 15–30 min, the roots were prepared in two forms: intact whole roots and diagonal slices approximately 4–5 mm thick (Le, K *et al.,* 2021).

The experiment was arranged in a completely randomized design (CRD) (Kim JH *et al.*, 2012) consisting of four treatments with three replications:

T1 (Control): Whole roots, hot-air drying in a convection dryer at 40-45 °C.
T2: Sliced roots (4-5 mm), hot-air drying in a convection dryer at 40-45 °C.
T3: Whole roots, heat-pump drying at 30-35 °C.
T4: Sliced roots (4-5 mm), heat-pump drying at 30-35 °C.

Drying was continued until the moisture content of the medicinal material reached ≤ 10%.

Each treatment consisted of 30 roots per replication, corresponding to approximately 1.5-2.0 kg of fresh material per replication (Ratan ZA *et al.,* 2021).

Content 2. Effects of Different Storage Methods on the Quality of Ngoc Linh Ginseng Medicinal Materials. The medicinal materials obtained after pre-processing were stored under three different conditions:

T1: Vacuum packaging and storage at room temperature.
T2: Vacuum packaging and storage in a cool chamber at 12-14 °C.
T3 (Control): Conventional storage under ambient room conditions.

The experiment was arranged in a completely randomized design with three treatments and three replications. Each replication consisted of 1 kg of dried medicinal material or approximately 30 pre-processed ginseng roots meeting the required quality standards (Park SK *et al.,* 2021). The storage period was monitored for 12 months.

Sensory characteristics and moisture content were evaluated at 2, 4, 6, 8, 10 and 12 months of storage. The contents of bioactive compounds were determined at the beginning of the experiment and after 6 and 12 months of storage (Vega G.A *et al.,* 2008).

Parameters Evaluated

Sensory evaluation: Color, odor, taste, surface appearance and the degree of quality changes in the medicinal materials were visually assessed and recorded. Photographs were also taken for comparison among treatments (Irem *et al.,* 2022; Siddiqui S.A *et al.,* 2024).

Moisture content (%): Determined by the loss-on-drying method to constant weight according to the requirements of the Vietnamese Pharmacopoeia V (Appendix 9.6; 2 g sample, 105 °C for 5 h). Drying time: The period from the start of the drying process until the medicinal material reached the required dryness level (hours) (Małgorzata N *et al.,* 2023). Bioactive compound content: Quantification of characteristic saponins of Ngoc Linh ginseng according to the monograph *Vietnamese Ginseng* in the Vietnamese Pharmacopoeia V. Total microbial count: Determined using the agar plate method in accordance with Appendix 13.6 of the Vietnamese Pharmacopoeia V.

Statistical Analysis

Experimental data were analyzed using SPSS version 26.0 (or Statistix version 10.0). Mean values were compared using the Least Significant Difference (LSD) test at a significance level of $p \leq 0.05$ (Arun M *et al.,* 2010).

3. RESULT AND DISCUSSION

Effect of Pre-processing Methods on the Sensory Quality of Ngoc Linh Ginseng Medicinal Materials

The results of the sensory quality evaluation of Ngoc Linh ginseng medicinal materials after pre-processing are presented in Table 1 and Figure 2.

Table 1. Effect of Pre-processing Methods on the Sensory Quality of Ngoc Linh Ginseng Medicinal Materials.

Treatment	Color	Odor	Taste	Physical Characteristics
Treatment 1 (T1)	Grayish-yellow brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet	Dry, firm, compact medicinal material
Treatment 2 (T2)	Yellowish-gray cut surface	Characteristic mild aroma	Bitter, slightly sweet	Dry, firm, compact medicinal material
Treatment 3 (T3)	Grayish-brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet	Dry, firm, compact medicinal material
Treatment 4 (T4)	Yellowish-gray cut surface	Characteristic mild aroma	Bitter, slightly sweet	Dry, firm, compact medicinal material

Note: T1: whole roots dried in a convection dryer at 40-45 °C (control); T2: sliced roots dried in a convection dryer at 40-45 °C; T3: whole roots dried using a heat-pump dryer at 30-35 °C; T4: sliced roots dried using a heat-pump dryer at 30-35 °C.

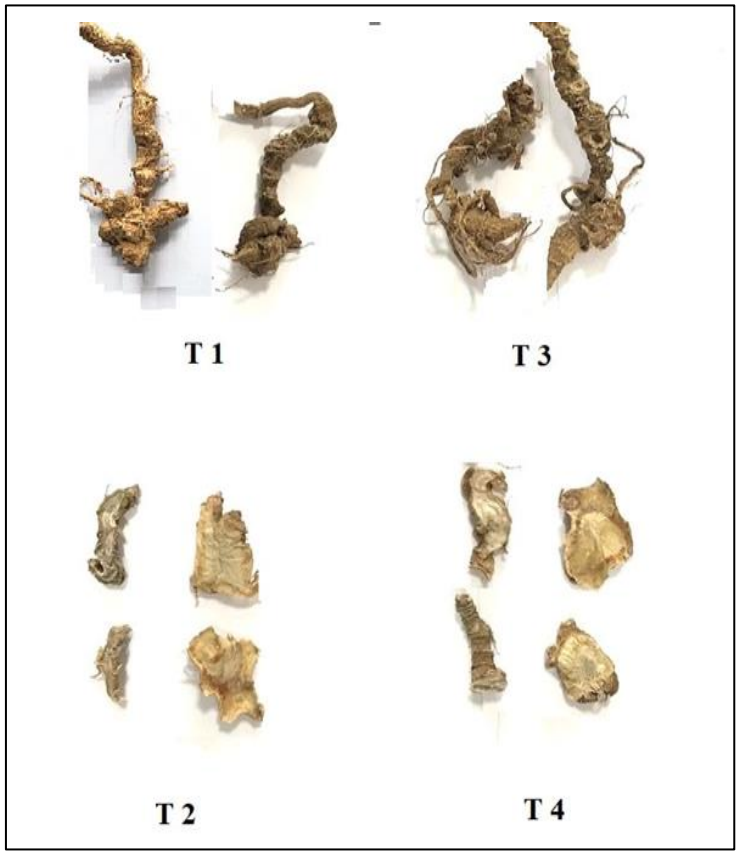

Figure 2. Sensory Quality of Ngoc Linh Ginseng Medicinal Materials as Affected by different Pre-processing methods.

The results showed that the different pre-processing methods did not significantly affect the basic sensory characteristics of Ngoc Linh ginseng medicinal materials. In all treatments, the products retained their characteristic mild aroma, slightly sweet bitter taste, and dry, firm texture, indicating that the applied pre-processing methods were suitable and did not adversely affect the inherent sensory properties of the medicinal material (Lichun Z *et al.,* 2025).

However, differences in color were observed among treatments. Whole-root drying treatments (T1 and T3) produced materials with grayish-yellow brown or grayish-brown outer surfaces and pale yellowish-gray interiors. In contrast, sliced-root treatments (T2 and T4) exhibited a more uniform yellowish-gray color (Qi LW *et al.,* 2011). Notably, heat-pump drying (T3 and T4) better preserved the natural color of the medicinal material compared to hot-air drying.

The superior color retention observed under heat-pump drying (30-35 °C) may be attributed to the lower drying temperature and humidity control, which reduce pigment degradation and oxidation (Chen J *et al.,* 2018). In addition, slicing before drying enhanced moisture removal efficiency and shortened the exposure time to drying conditions. These findings are consistent with previous studies reporting that low-temperature drying methods are more effective in preserving the sensory quality of saponin-rich medicinal plants, particularly their natural color and aroma (Lee SJ *et al.,* 2015). For *Panax* species, low-temperature drying has been recognized as an effective approach to maintaining product quality during processing.

Overall, all pre-processing methods met the sensory quality requirements for Ngoc Linh ginseng medicinal materials. Among them, T4 (sliced roots subjected to heat-pump drying at 30-35 °C) provided the best sensory quality, characterized by uniform color, stable appearance and well-preserved sensory attributes, making it suitable for subsequent storage and processing (Esraa A.M *et al.,* 2024).

Effect of Pre-processing Methods on Selected Quality Parameters of Ngoc Linh Ginseng Medicinal Materials

The results of the evaluation of selected quality parameters of Ngoc Linh ginseng medicinal materials after pre-processing are presented in Table 2.

Table 2. Effect of Pre-processing Methods on the Quality of Ngoc Linh Ginseng Medicinal Materials.

Treatment	Moisture Content (%)	Drying Time (h)	Total Ash (%)	MR2 Content (%)	Total Saponin Content (%)
T1	9.8 ±0.3	44 ±2	6.0	3.78 ±0.02	9.29 ±0.3
T2	10.0 ±0.3	31 ±2	6.5	3.53 ±0.02	10.92 ±0.3
T3	11.2 ±0.2	33 ±3	6.1	3.88 ±0.03	12.80 ±0.3
T4	10.5 ±0.3	24 ±3	6.3	4.02 ±0.03	13.08 ±0.3

Note: T1: whole roots dried in a convection dryer at 40-45 °C (control); T2: sliced roots dried in a convection dryer at 40-45 °C; T3: whole roots dried using a heat-pump dryer at 30-35 °C; T4: sliced roots dried using a heat-pump dryer at 30-35 °C.

The moisture content of all dried samples met the requirements for dried medicinal materials. Drying time was strongly influenced by the pre-processing method with sliced-root treatments drying faster than whole-root treatments. T4 (sliced roots subjected to heat-pump drying) achieved the shortest drying time, whereas T1 (whole roots subjected to hot-air drying) required the longest drying period (Erbay, Z *et al.,* 2010).

Total ash content showed little variation among treatments, indicating that the pre-processing methods had minimal effects on the mineral composition of the medicinal material. In contrast, significant differences were observed in MR2 and total saponin contents. T4 exhibited the highest levels of both MR2 and total saponins, while the hot-air drying treatments generally resulted in lower values. The results suggest that heat-pump drying at 30-35 °C is more effective in preserving bioactive compounds than hot-air drying at 40-45 °C. The lower drying temperature likely reduced saponin degradation and oxidation during processing (Laxmi S *et al.,* 2018). In addition, slicing before drying accelerated moisture removal and shortened thermal exposure, thereby enhancing the retention of active constituents.

Overall, T4 (sliced roots combined with heat-pump drying) was the most effective pre-processing treatment, providing faster drying and superior preservation of MR2 and total saponin contents, thereby improving the post-harvest quality of Ngoc Linh ginseng medicinal materials.

Effect of Storage Methods on the Sensory Quality of Ngoc Linh Ginseng Medicinal Materials

The results of the sensory quality evaluation of Ngoc Linh ginseng medicinal materials after 6 and 12 months of storage are presented in Table 3 and Figure 3.

Table 3. Effect of Storage Methods on the Sensory Quality of Ngoc Linh Ginseng Medicinal Materials.

Treatment	6 Months			12 Months		
	Color	Odor	Taste	Color	Odor	Taste
T1	Grayish-brown outer surface, pale yellowish-gray interior	Very faint characteristic aroma	Bitter, slightly sweet	Grayish-brown outer surface, pale yellowish-gray interior	Extremely faint characteristic aroma	Slightly bitter and sweet
T2	Grayish-brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet	Grayish-brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet
T3	Grayish-brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet	Grayish-brown outer surface, pale yellowish-gray interior	Characteristic mild aroma	Bitter, slightly sweet

Note: T1: vacuum packaging and storage at room temperature; T2: vacuum packaging and storage under cool conditions (12-14 °C); T3 (control): conventional storage under ambient conditions.

The results showed that the color of the medicinal materials remained largely unchanged across all storage treatments throughout the storage period. The materials retained their characteristic grayish-brown outer surface and pale yellowish-gray interior, indicating that the storage conditions had no significant effect on their appearance (Singh, A *et al.,* 2020).

The characteristic aroma and taste gradually declined during storage. After 12 months, T2 (vacuum packaging combined with cool storage at 12-14°C) best preserved the characteristic mild aroma and slightly sweet bitter taste of Ngoc Linh ginseng. T3 (conventional storage) showed moderate retention, whereas T1 (vacuum packaging at room temperature) exhibited a more noticeable reduction in aroma and taste.

The superior performance of T2 may be attributed to the combined effects of low temperature and vacuum packaging, which reduce oxidation and slow the degradation of volatile compounds and taste-related constituents (Van L, T. *et al.,* 2010). Vacuum conditions also limit exposure to oxygen and environmental moisture, thereby helping maintain sensory quality during long-term storage. These findings are consistent with previous studies on saponin-rich medicinal materials, which have reported that sealed packaging combined with low-temperature storage is effective in preserving color, aroma and other sensory attributes.

	0 months
T1	
T2	
T3	

	6 months	12 months
T1		
T2		
T3		

Figure 3. Sensory Quality of Ngoc Linh Ginseng Medicinal Materials as Affected by different storage methods.

Overall, all storage methods maintained acceptable sensory quality after 12 months. However, T2 (vacuum packaging with cool storage at 12-14 °C) was the most effective treatment for preserving the characteristic color, aroma and taste of Ngoc Linh ginseng medicinal material.

Effect of Storage Methods on Selected Quality Parameters of Ngoc Linh Ginseng Medicinal Materials

The results of the evaluation of selected quality parameters of Ngoc Linh ginseng medicinal materials after 6 and 12 months of storage are presented in Table 4.

The results showed that the moisture content of all samples remained within the acceptable range for dried medicinal materials throughout the storage period. Only slight increases in moisture content were observed after 12 months, particularly in T3 (conventional storage), although all treatments still met the quality requirements for dried medicinal materials (Sparks, T., *et al.* 2008).

Total saponin content gradually decreased during storage in all treatments. After 12 months, T2 (vacuum packaging combined with cool storage at 12-14 °C) retained the highest

total saponin content, followed by T1 while T3 (conventional storage) showed the lowest value. The lower reduction observed in T2 indicates that low-temperature storage combined with vacuum packaging effectively minimizes oxidation and degradation of bioactive compounds.

Table 4. Effect of Storage Methods on the Quality of Ngoc Linh Ginseng Medicinal Materials.

Treatment	Storage Period (months)	Moisture Content (%)	Total Saponin Content (%)	Total Microbial Count (CFU/g)
	6	10.6 ± 0.2	12.5 ± 0.2	4.2×10^2
	12	10.4 ± 0.2	11.6 ± 0.2	4.5×10^2
	6	10.7 ± 0.3	12.6 ± 0.2	3.2×10^2
	12	11.1 ± 0.2	12.1 ± 0.2	3.5×10^2
	6	10.6 ± 0.2	11.7 ± 0.2	4.8×10^2
	12	11.7 ± 0.2	10.5 ± 0.2	5.6×10^2

Note: T1: vacuum-packaged and stored at room temperature; T2: vacuum-packaged and stored in a cool storage chamber at 12-14 °C; T3(control): conventionally stored under ambient room conditions.

The total microbial count remained at the 10^2 CFU/g level and within the permissible limits for medicinal materials throughout the storage period. However, microbial populations increased slightly over time (Craig A Anderson *et al.* 1983). After 12 months, T2 exhibited the lowest microbial count, whereas T3 recorded the highest. These results demonstrate that vacuum packaging combined with cool storage effectively suppresses microbial growth during long-term storage(Shanmugaratnam, S. *et al.* 2013).

The differences among storage treatments can be attributed to the effects of temperature and oxygen on saponin stability. Low-temperature and vacuum conditions reduce oxidation, hydrolysis and microbial activity, thereby preserving the quality of the medicinal material. In contrast, conventional storage conditions are more conducive to chemical and biological deterioration, resulting in greater losses of active compounds and higher microbial counts (Borror D.J. *et al.* 1989).

These findings are consistent with previous studies on the storage of saponin-rich medicinal materials, which have reported that low-temperature storage combined with sealed packaging is an effective approach for maintaining bioactive compound content, controlling microbial contamination, and extending shelf life (Li-Min Lin *et al.* 2008). Overall, T2 (vacuum packaging combined with cool storage at 12-14 °C) was the most suitable storage method for Ngoc Linh ginseng medicinal materials, ensuring stable moisture content, better retention of total saponins, and effective control of microbial growth throughout the 12-month storage period.

4. CONCLUSIONS

This study evaluated the effects of different pre-processing methods and storage conditions on the quality of Ngoc Linh ginseng (*Panax vietnamensis* Ha et Grushv.) medicinal materials. The pre-processing methods did not significantly affect the basic sensory characteristics of the medicinal materials. However, they had a marked influence on drying efficiency and the retention of bioactive compounds. Among the tested treatments, sliced roots subjected to heat-pump drying at 30-35 °C (T4) showed the best performance, providing the shortest drying time and the highest contents of MR2 and total saponins. In addition, the processed materials retained their natural color, characteristic mild aroma and stable physical appearance.

Storage conditions significantly affected the preservation of medicinal material quality over time. After 12 months of storage, T2 (vacuum packaging combined with cool storage at 12-14 °C) was the most effective treatment, maintaining desirable sensory properties, stable moisture content, the highest retention of total saponins and the lowest microbial count. Compared with the other storage methods, T2 better minimized bioactive compound degradation and suppressed microbial growth during storage.

Overall, the combination of slicing followed by heat-pump drying at 30-35 °C and subsequent storage under vacuum packaging at 12-14 °C is recommended as an effective post-harvest strategy for preserving quality and extending the storage life of Ngoc Linh ginseng medicinal materials.

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