Postprint: Study on Formaldehyde Absorption and Stress Resistance of Indoor Ornamental Plants

Authors: He Hui, Peng Qian

Date: 2018-12-19T00:00:00+00:00

Abstract

This study employed a sealed chamber method to simulate indoor formaldehyde-polluted environments (formaldehyde concentration in the fumigation chamber was set to 0.10–0.50 mg · m ^{3}, fumigation duration 12 h), conducting formaldehyde fumigation experiments on six common indoor ornamental plant species, and measured indicators including formaldehyde absorption efficiency, leaf injury index, and peroxidase (POD). The results demonstrated that all six common ornamental plant species exhibited favorable formaldehyde purification efficacy; at formaldehyde fumigation concentrations of 0.10–0.30 mg · m ^{3}, Spathiphyllum kochii displayed the optimal purification performance; at a fumigation concentration of 0.50 mg · m ^{3}, Epipremnum aureum and Chlorophytum comosum demonstrated superior purification and stress resistance capabilities; Adiantum capillus-veneris exhibited weaker tolerance to formaldehyde, making it suitable as an indicator species for indoor formaldehyde pollution. Furthermore, the study revealed that POD enzyme activity in several tested plant species showed a significant positive correlation with formaldehyde absorption rate ($P < 0.05$), indicating that alterations in plant POD enzyme activity constitute one of the primary stress response mechanisms following formaldehyde stress.

Full Text

Preamble

DOI:10.11931/guihaia.gxzw201806030

Study on the Absorption and Resistance Effects of Indoor Ornamental Plants on Formaldehyde

HE Hui[1], PENG Qi' an[2*]

(1. Hubei Ecology Polytechnic College, Wuhan 430200, China; 2. Wuhan Textile University, Wuhan 430073, China)

Abstract

This study examined six common indoor ornamental plants for formaldehyde fumigation in a simulated indoor environment (formaldehyde concentration in the fumigation chamber set at 0.10–0.50 mg · m ^{3}, fumigation duration 12 h), measuring formaldehyde removal efficiency, leaf injury index, and peroxidase (POD) activity. Results showed that all six ornamental plants effectively purified formaldehyde. *Spathiphyllum kochii* exhibited the best purification performance at concentrations of 0.10–0.30 mg · m ^{3}, while *Epipremnum aureum* and *Chlorophytum comosum* demonstrated superior purification and stress resistance at 0.50 mg · m ^{3}. *Adiantum capillus* showed weak tolerance to formaldehyde, making it suitable as an indicator plant for indoor formaldehyde pollution. The study also found a significant positive correlation between POD enzyme activity and formaldehyde absorption rate in several tested plants ($P < 0.05$), suggesting that changes in POD activity constitute a primary stress response mechanism following formaldehyde exposure.

Keywords: ornamental plants, indoor formaldehyde, absorption, peroxidase

---

Formaldehyde is a typical volatile organic compound (VOC) present in various indoor furnishing materials, characterized by widespread pollution sources, long-term continuous release, and strong toxic and carcinogenic effects. In recent years, formaldehyde has garnered widespread public concern due to indoor and public space pollution caused by decoration and furnishing materials. China' s indoor air quality standard GB/T18883-2002 (hereinafter referred to as the national standard) stipulates that indoor formaldehyde concentration should not exceed 0.1 mg · m ^{3}. In reality, formaldehyde concentrations in most newly decorated homes and public spaces in China exceed the national standard (Su et al., 2017). Therefore, developing convenient and effective methods for indoor formaldehyde removal represents an urgent challenge.

Current formaldehyde removal methods primarily include the following: ventilation is a common approach, but the release process is relatively slow and easily affected by seasons and outdoor air quality; activated carbon adsorption is prone to saturation and subsequent adsorbent failure. Given the slow-release characteristics of indoor formaldehyde, utilizing plants to absorb formaldehyde and improve air quality has emerged as an economical and effective method in recent years (Huang et al., 2015).

The primary mechanism of formaldehyde absorption in plants involves stomatal uptake of formaldehyde molecules and subsequent decomposition by various intracellular enzymes, converting formaldehyde into harmless substances. Scholars both domestically and internationally have screened several plant varieties

with strong formaldehyde adsorption capacities, demonstrating certain purification effects (Wu, 2013; An et al., 2010). However, literature reports on plant stress resistance mechanisms remain scarce. Studies by Wei et al. (2007) and Liang et al. (2018) have shown that peroxidase (POD), as an important oxidase in plants, constructs a plant stress resistance system together with superoxide dismutase (SOD) and other enzymes. Since plant POD enzymes exhibit direct stress responses and transformation effects to formaldehyde gas (Linghu et al., 2011; Su and Liang, 2015), this study selected POD enzymes from several typical indoor ornamental plants as research targets, setting up five different formaldehyde concentration groups for fumigation experiments to analyze their formaldehyde absorption efficiency and plant stress resistance characteristics, aiming to screen for optimal indoor formaldehyde-absorbing plants and indicator plants, thereby providing scientific insights for establishing efficient methods to select formaldehyde-purifying plants.

1.1 Experimental Materials

The experiment utilized six types of vigorously growing ornamental plants purchased from Wuhan Yuanbaoshan Flower Market: *Epipremnum aureum*, *Chlorophytum comosum*, *Hedera nepalensis* var. *sinensis*, *Aloe vera*, *Spathiphyllum kochii*, and *Adiantum capillus*.

1.2 Experimental Apparatus

Following the experimental apparatus described in Su et al. (2015), the study employed a self-made organic glass fumigation chamber (length × width × height = 0.4 m × 0.4 m × 0.5 m). A circular hole (diameter 1 cm) was drilled on one side of the chamber for sampling analysis, sealed with transparent tape before sampling, and all chamber connections were sealed with silicone.

1.3.1 Experimental Design

1. Formaldehyde solution was prepared at specific concentrations and placed in an evaporating dish. After complete volatilization in the sealed chamber, the formaldehyde content in the chamber air was measured. Chamber formaldehyde concentrations were set at five gradients from 0.10 $mg \cdot m^{3}$ to 0.50 $mg \cdot m^{3}$, representing 1-5 times the upper limit of the national standard "Indoor Air Quality Standard" (GB/T18883-2002).
2. Flower pots and soil were sealed with plastic wrap to exclude the influence of soil and rhizosphere microorganisms.
3. Plants were quickly placed into the fumigation chamber from step (1).
4. Control experiment: Simultaneously, another fumigation chamber containing an equivalent amount of formaldehyde but no plants was used as the control treatment.
5. Experimental conditions, sampling methods, and data processing: Experimental temperature was maintained at a constant 25 °C. Formaldehyde concentrations in different fumigation chambers were measured hourly

within 12 h using a syringe through the sampling hole. Immediately after the experiment, relevant plant physiological indicators (such as leaf injury index and POD enzyme activity) were measured. All measurements were repeated three times and averaged.

1.3.2 Index Measurement Methods

(1) Formaldehyde concentration measurement and absorption rate

Formaldehyde concentration was determined using the national standard GB/T15516-1995 acetylacetone spectrophotometric method (Zhang and Yang, 2011).

(2) Related physiological indicators

Leaf peroxidase (POD) activity measurement: Following the guaiacol method (Liu and Li, 2007), POD activity per unit area was calculated before and after fumigation.

Peroxidase activity ($FW \cdot g^{1} \cdot min^{1}$) = $\Delta A \times V / (W \times V \times 0.01 \times t)$

Where ΔA is the OD value change during the reaction time; V is the total extracted enzyme liquid volume (mL); W is the plant fresh weight (g); V is the enzyme liquid volume used for measurement (mL); and t is the reaction time (min).

Leaf injury index

Injury index = injured leaf area / total leaf area

Leaf area was determined using the paper weighing method: The coordinate paper edge length was measured with a ruler to calculate the total paper area, and the total paper weight was measured. Leaves were cut and spread flat on coordinate paper, leaf outlines were drawn on the paper with a pencil, the leaf shapes were cut out and weighed with the same precision. Leaf area (S) was calculated using the following formula:

)()()()(22ggcmcmS 全纸重叶形纸重全纸面积

1.3.3 Data Processing

Experimental data were analyzed using Origin 8.0 and SPSS 17 software.

2.1 Plant Formaldehyde Absorption Experiments

Formaldehyde at concentrations of 0.10–0.40 $mg \cdot m^{3}$ was injected into the fumigation chambers. After equilibration, the measured control chamber concentrations were 0.086, 0.17, 0.27, and 0.36 $mg \cdot m^{3}$, respectively. Analysis suggested that slight adsorption of formaldehyde on chamber walls may have caused differences between actual initial formaldehyde concentrations and theoretical values.

As shown in [Figure 1: see original paper], all six plants exhibited certain formaldehyde absorption capacities after 12 h, with absorption rates increasing as chamber formaldehyde concentration increased. *Spathiphyllum kochii* and *Epipremnum aureum* showed stronger formaldehyde adsorption capacities, with absorption rates of 72.52% and 73.43%, respectively, at 0.4 mg · m ^{3} formaldehyde concentration. *Chlorophytum comosum*, *Hedera nepalensis* var. *sinensis*, and *Adiantum capillus* showed absorption rates of 67.99%, 65.72%, and 45.33%, respectively, while *Aloe vera* exhibited only 31.73% absorption.

When chamber formaldehyde concentration increased to 0.50 mg · m ^{3}, the measured control chamber air concentration was 0.46 mg · m ^{3} after equilibration. Both *Epipremnum aureum* and *Chlorophytum comosum* achieved absorption rates of 97.78% after 12 h, while *Spathiphyllum kochii*, *Hedera nepalensis* var. *sinensis*, *Adiantum capillus*, and *Aloe vera* reached absorption rates of 90.00%, 86.67%, 57.78%, and 38.89%, respectively ([Figure 2: see original paper]).

As shown in , the six plants exhibited formaldehyde absorption per unit leaf area ranging from 8.55×10^{2} to 3.15×10^{1} mg · m ^{2}. Statistical analysis indicated no significant correlation between formaldehyde absorption and either total leaf area or formaldehyde absorption per unit leaf area at this concentration.

2.2 Plant POD Activity and Injury Index

and present plant POD activity and injury index under five formaldehyde concentrations, respectively. Results showed that both POD activity and injury index in different plants increased with increasing chamber formaldehyde concentration. At formaldehyde concentrations below 0.2 mg · m ^{3}, *Spathiphyllum kochii* and *Epipremnum aureum* leaves showed no formaldehyde injury while maintaining high absorption efficiency. In contrast, *Adiantum capillus* and *Aloe vera* exhibited 9.31% and 1.18% leaf area damage under high-concentration formaldehyde (0.5 mg · m ^{3}) fumigation.

2.3 Correlation Analysis Between Plant POD Activity and Formaldehyde Absorption Rate

Statistical analysis revealed significant correlations between POD enzyme activity and formaldehyde absorption rate in most plants. As shown in , POD activity in *Chlorophytum comosum*, *Hedera nepalensis* var. *sinensis*, *Adiantum capillus*, and *Spathiphyllum kochii* showed significant positive correlations with absorption rates under different formaldehyde concentrations ($P < 0.05$), while *Epipremnum aureum* POD activity exhibited extremely significant positive correlations with formaldehyde absorption rates across different gradients ($P < 0.01$).

3.1 Influence of Plant Species on Formaldehyde Absorption

The six plant species selected for this experiment exhibited certain differences in leaf area, yet statistical analysis found no correlation between formaldehyde

absorption rate and either total leaf area or formaldehyde absorption per unit leaf area, which is inconsistent with previous research findings that plant capacity to absorb gaseous pollutants is related to stomatal number and size on leaves (Soreanu et al., 2013).

Actual testing revealed that plant ranking in formaldehyde absorption efficiency changed when chamber formaldehyde concentration varied. For example, *Spathiphyllum kochii*, despite having the smallest total leaf area, showed the best formaldehyde absorption effect at 0.1–0.3 mg · m ^{3} concentrations ([Figure 1: see original paper]), while *Epipremnum aureum* and *Chlorophytum comosum* achieved highest absorption efficiency only at higher formaldehyde concentrations ([Figure 2: see original paper]). *Hedera nepalensis* var. *sinensis*, with the largest total leaf area, consistently showed medium-level absorption efficiency. These findings indicate that formaldehyde absorption in plants is primarily influenced by species characteristics, related to internal stress resistance features and transformation efficiency.

3.2 Relationship Between Plant Stress Resistance Characteristics and POD Activity

When plants are subjected to environmental stress, activities of antioxidant enzymes such as POD, CAT, and SOD change, indicating the formation of a defense system and certain tolerance capacity (Su et al., 2017). Statistical data from this experiment demonstrated significant positive correlations between POD activity and formaldehyde absorption rate in most selected plants (except *Aloe vera*), indicating that most plants possess certain stress resistance effects against formaldehyde. Considering both absorption efficiency and injury index across different formaldehyde concentrations, *Spathiphyllum kochii* is suitable for absorbing lower concentrations of indoor formaldehyde.

Statistical results also indicated that *Epipremnum aureum* leaf POD activity showed extremely significant positive correlations with formaldehyde absorption rates under different concentrations (0.1–0.5 mg · m ^{3}) (), closely matching findings from Tada and Kidu (2011). Plant injury index results from this study also confirmed that *Epipremnum aureum* exhibits stronger resistance at higher formaldehyde concentrations, making it suitable for removing high-concentration airborne formaldehyde.

Although *Adiantum capillus* showed absorption effects at different formaldehyde concentrations, its leaf surface damage was relatively obvious. Even at 0.1 mg · m ^{3} formaldehyde concentration (where the actual measured equilibrium value was close to the national standard upper limit), leaves exhibited noticeable necrosis, brown spots, or water-soaked symptoms. This indicates that *Adiantum capillus* has weak tolerance to formaldehyde and could be considered as an indicator plant for whether indoor formaldehyde concentration exceeds standards. These findings further confirm that plant leaf protection mechanisms in stressful environments may be closely related to corresponding POD activity

in leaves and that there likely exists a tolerance concentration threshold range, which is related not only to leaf age but also to plant species.

In summary, the six common ornamental plant species examined in this study showed substantial differences in formaldehyde absorption capacity and stress resistance effects: *Epipremnum aureum* and *Chlorophytum comosum* demonstrated excellent purification effects for indoor formaldehyde, while plants such as *Adiantum capillus* exhibited weak formaldehyde tolerance, making them suitable as indicator plants for formaldehyde pollution. This study provides a theoretical basis for evaluating the capacity of ornamental plants to purify indoor toxic and harmful gases and for efficiently screening highly tolerant plant varieties.

References

SU YH, LIU KY, ZHAO YY, et al, 2017. Foliar Uptake, downward transport of airborne formaldehyde and physiological response of plants [J]. Environ Sci & Technol, (1): 70-74. [苏玉红, 刘凯艳, 赵媛媛, 等, 2017. 空气中甲醛的植物吸收、传输作用及生理响应 [J]. 环境科学与技术, (1): 70-74.]

HUANG X, LIN M, LIAO ML, et al, 2015. Research regress on removal of formaldehyde by ornamental plant [J]. Mod Agric Sci Technol, (2): 174-175. [黄欣, 林茂, 廖美兰, 等, 2015. 室内观赏植物对甲醛吸收的研究进展 [J]. 现代农业科技, (2): 174-175.]

WU XF, 2013. The effect of 10 ornamental plants on purifying formaldehyde and simulation research[J]. J Environ Health, 30(12): 1113-1114. [吴晓烽, 2013. 10 种常见居室观赏植物吸收甲醛效果模拟研究 [J]. 环境与健康杂志, 30(12): 1113-1114.]

AN X, LI X, PAN HT, et al, 2010. The capacity of 16 ornamental plants on purifying indoor formaldehyde pollution and their physiological response to formaldehyde stress [J]. Ecol Environ Sci, 19(2): 379-384. [安雪, 李霞, 潘会堂, 等, 2010. 16 种室内观赏植物对甲醛净化效果及生理生化变化 [J]. 生态环境学报, 19(2): 379-384.]

WEI MH, ZHENG JJ, RAO Y, et al, 2007. Effects of formaldehyde on the activity of POD of *Aloe vera* var. chinensis (Haw) Berg [J]. J Fujian Norm Unive (Nat Sci Ed), 23(4):133-136. [魏梅红, 郑晶晶, 饶瑶, 等, 2007. 甲醛对芦荟 POD 酶活性的影响 [J]. 福建师大学报 (自然科学版), 23(4): 133-136.]

LIANG H, ZHAO S, SU Y, et al, 2018. Self-Enhancement effect and mechanism of potted *Chlorophytum comosum* on formaldehyde removal from air [J]. Intern J Environ Res, 12(3): 337-346.

LINGHU YW, LI B, LI SF, et al, 2011. Monitoring, purification and response of three indoor ornamental plants on formaldehyde pollution [J]. Acta Bot Boreal-Occident Sin, 31(4):776-782. [令狐昱慰, 黎斌, 李思锋, 等, 2011. 3 种观赏植物对室内甲醛污染的净化及生长生理响应 [J]. 西北植物学报, 31(4): 776-782.]

SU Y, LIANG Y, 2015. Foliar uptake and translocation of formaldehyde with bracket plants (*Chlorophytum comosum*) [J]. J Hazar Mat, 291: 120-128.

ZHANG J, YANG WW, 2011. Whole-course quality control in determining formaldehyde in air and waste gas [J]. Environ Sci Manag, 36(12):128-133. [张钧, 杨文武, 2011. 空气和废气中甲醛测定全程质量控制 [J]. 环境科学与管理, 36(12): 128-133.]

LIU P, LI MJ, 2007. The experimental techniques for plant physiology [M]. Beijing: Science Press of China. [刘萍, 李明军, 2007. 植物生理学实验技术 [M]. 北京: 科学出版社.]

SOREANU G, DIXON M, DARLINGTON A, 2013. Botanical biofiltration of indoor gaseous pollutants –A mini-review [J]. Chem Engineer J, 229(8): 585-594.

TADA Y, KIDU Y, 2011. Glutathione-dependent formaldehyde dehydrogenase from golden pothos (*Epipremnum aureum*) and the production of formaldehyde detoxifying plants [J]. Plant Biotechnol, 28(4): 373-378.

Note: Figure translations are in progress. See original paper for figures.