The Effect of Improving Indoor Air Quality using some C₃ Plants and CAM Plants

Jinhee Lee* and Hyunkyung Kang
Department of Environment Planning and Design, Sangmyung University, Korea; ljh0830@smu.ac.kr, hkgang@smu.ac.kr

Abstract
This paper will describe the physiological characteristics of general ornamental plants and fleshy plants that have contrary effects from the preceding researches, and describe the purification effects of volatile organic compound, formaldehyde. The total removal of carbon dioxide per plant was measured by adding and subtracting amount of photosynthesis and respiration for 24 hours in airtight chamber as follows: from change in concentration of carbon dioxide during the 24 hours after the chamber has been shut, the ornamental plant Spathiphyllum spp., Epipremnum aureum, Hedera helix showed decrease in carbon dioxide concentration under environment with light by photosynthesis and increase under environment without light. In case of fleshy plant Sansevieria trifasciata var., Notocactus leninghausii, Myrtillocactus polylopha, opposite from the ornamental plant, carbon dioxide concentration changed due to respiration under light and photosynthesis under environment without light. For Spathiphyllum spp. 94ppm per 1,000 cm² of leaf, and 70ppm for Epipremnum aureum, 28ppm for Hedera helix, 52ppm for Sansevieria trifasciata var., 66ppm for Notocactus leninghausii, and 114ppm for Myrtillocactus polylopha. After injecting 400ppb of formaldehyde, removal of formaldehyde due to adsorption and absorption caused by photosynthesis was calculated with comparison against standard value. Graph of change in formaldehyde concentration showed that ornamental plants Spathiphyllum spp., Epipremnum aureum, and Hedera helix flesh plants such as Sansevieria trifasciata var., Notocactus leninghausii, Myrtillocactus polylopha showed different physiological activities but removal of formaldehyde due to photosynthesis was high for both sorts. Per 1,000 cm² of leaf area, Spathiphyllum spp., removed 173ppb of formaldehyde, Epipremnum aureum 158ppb, Hedera helix 128ppb, Sansevieria trifasciata var. 94ppb, Notocactus leninghausii 93ppb, and Myrtillocactus polylopha removed 106ppb of formaldehyde. From the above results, the air purification ability for plants can vary significantly under different conditions of temperature, humidity, radiation intensity and continuous researches on the interactions among such conditions and the complex effects of air purification ability is necessary.

Keywords: Component, Formatting, Style, Styling, Insert (4-6 Keywords)

1. Introduction
Generally, most indoor plants release carbon dioxide into the interior during the night because they are foliage plants only breathing purely without photosynthesis at night. Therefore, placing plants indoors may be effective in improving indoor air quality during the day but may have a negative effect to ordinary persons at night due to an increase in carbon dioxide. Also, given current trends that the introduction of indoor plants is increasing rapidly and concerns of ordinary persons due to the increase in night carbon dioxide, the interest in appropriately using fleshy plants such as cactus is increasing as part of reducing the indoor carbon dioxide concentration at night. Thus, the purpose of this study is to find out the influence of C₃ and CAM plants for improving indoor air quality by using foliage plants in C₃ form and fleshy plants with CAM plant form with different physiological properties to analyze carbon dioxide changes of plants according to light and concentration changes of formaldehyde, an indoor gas pollutant depending on photosynthesis.

2. Test Methods
2.1 Selection of Experimental Plants
In this experiment, indoor foliage plants of year-
The Effect of Improving Indoor Air Quality using some C₃ Plants and CAM Plants

Round minimum temperature 10 °C and minimum light intensity 500 lux and CAM plants of year-round minimum temperature 20 °C and minimum light intensity 10,000 lux were selected as disclosure plants through a literature search. Three kinds of foliage plants such as *Spathiphyllum* spp., *Epipremnum aureum*, *Hedrera helix* and three kinds of fleshy plants such as *Sansevieria trifasciata* var., *Notocactus leninghausii*, *Myrtillocactus polylopha* were selected.

### 2.2 Chamber Making and Internal Conditions

For the chamber made for an air purification experiment, tempered glass was used in order to maintain the closed state and the volume was set to a total of 20 ℓ. Four small holes were made at the top of the chamber to extract samples and measure the concentration inside the chamber. Since the concentration of carbon dioxide and formaldehyde may be distributed unevenly by stopped air current within the chamber during experiment time except for extraction, a fan was installed in the chamber to prevent this and the speed of the fan was adjusted to 0.1 m/s. The internal chamber was kept completely sealed and artificial light of 1500 lux was maintained for 12 hours with natural light and all the lights were blocked after 6 p.m. 1000~1100 ppm with proper photosynthetic performance was selected as the hierarchical concentration because damage caused by carbon dioxide can be measured with the photosynthetic rate. Formaldehyde of about 400 ppb was to be used in the experiment because the degree of visible damage of plants due to formaldehyde can be checked only after being exposed for a long time. The temperature and humidity of the laboratory where the chamber is placed were maintained to 28°C, 40%, respectively.

![Figure 1. Empty chamber.](image1)

![Figure 2. Measuring formaldehyde concentration using air bag.](image2)

![Figure 3. Plants refining treatment inside of the lab for 4 week.](image3)

![Figure 4. Plants refining treatment inside of the lab for 4 week.](image4)

### 2.3 Acclimation Treatment of Experimental Plants

Prior to the gas contact experiment, acclimation treatment has been carried out to selected disclosure plants for 4 weeks to reducing the changes in photosynthetic performance of plants due to changes in environmental conditions. Figure 3 and Figure 4 show acclimation treatment for 4 weeks to adapt disclosure plants to the environment.
2.4 Carbon Dioxide (CO$_2$) Concentration Change Experiment using Plants

In order to find out each experimental plant's ability to remove carbon dioxide, the carbon dioxide concentration of 1000ppm was injected into the sealed chamber and concentration changes for 24 hours were measured at intervals of 10 minutes. As the light conditions within the chamber, artificial light of 1500lux was maintained for foliage plants and artificial light of 20,000lux was maintained for fleshy plants with natural light outside the chamber. In environmental conditions except for the amount of light, data were obtained and standard values were calculated for each disclose plant through repeated experiments of three times under the same conditions.

2.5 Formaldehyde (HCHO) Concentration Change Experiment using Plants

The formaldehyde concentration inside the chamber was determined to the initial concentrations of around 4000ppb, the limit value of the indoor air quality and was measured through 2,4-DNPH derivatization HPLC test method. In order to set experimental conditions, the simple experiment of gas chromatography (GC/ECD) was used. In order to find out each experimental plant's ability to remove formaldehyde, concentration changes were measured within the sealed chamber at intervals of 1 hour for 24 hours starting with the concentration of about 400ppb.

3. Result

3.1 Comparative Analysis of changes in Carbon Dioxide Concentrations C$_3$ Plants and CAM Plants

Foliage plants show the reduction in carbon dioxide through photosynthesis during the day but the respiration phenomenon increasing the carbon dioxide concentration at night without light. In contrast, fleshy plants show an increase in carbon dioxide concentration when there is light in the daytime and reduction in the carbon dioxide concentration in the chamber through photosynthesis different from foliage plants when switched to night with no light. Therefore, the problem of increased indoor carbon dioxide concentration at night due to carbon dioxide emitted by respiration when introducing foliage plants indoors seems to be solved by introducing fleshy plants absorbing carbon dioxide at night at the same time. Figure 5 is the collection of change curves of carbon dioxide concentrations shown by the difference in light of 6 disclosure plants over time.

Figure 5. Changes in Self-Efficacy.

Absorption and emission of carbon dioxide of plants show dramatic moment concentration changes depending on the amount of light. This property may be the indicator of physiological responses of plants and therefore, it provides very important information to the composition of light conditions required for the application of indoor plants in order to reduce carbon dioxide.

Figure 6. Momentary changes in CO$_2$ concentration by Spathiphyllum spp.

In the case of C$_3$ plants, carbon dioxide increases during the dark period and reduction in carbon dioxide is noticeable during the bright period and on the contrary, CAM plants showed the phenomenon that carbon dioxide decreases during the dark period and increases during the bright period.
The Effect of Improving Indoor Air Quality using some C₃ Plants and CAM Plants

Figure 7. Momentary changes in CO₂ concentration by *Hedera helix*.

Figure 8. Momentary changes in CO₂ concentration by *Sansevieria trifasciata var.*

Figure 9. Momentary changes in CO₂ concentration by *Epipremnum aureum*.

Figure 10. Momentary changes in CO₂ concentration by *Notocactus leninghausii*.

Figure 11. Momentary changes in CO₂ concentration by *Hedera helix*.

Figure 12. Total Quantities of CO₂ removal for 24 hours.

In this study, we added carbon dioxide consumption under the light condition and carbon dioxide changes under the dark condition by each disclosure plant and analyzed the difference value with the amount of carbon dioxide removal.

Figure 12 is a graph showing the amount of carbon dioxide removal under the light condition of 24 hours and *Spathiphyllum spp.*, *Epipremnum aureum*, *Hedera helix*, *Sansevieria trifasciata var.*, *Notocactus leninghausii* and *Myrtillocactus polylopha* showed carbon dioxide removal of 94ppm, 70ppm, 28ppm, 52ppm, 66ppm and 114ppm, respectively.
3.2 Comparative Analysis of HCHO Concentration Changes of C₃ Plants and CAM Plants

When introducing foliage plants indoors; the function of formaldehyde concentration reduction due to photosynthesis by light and the effect of formaldehyde concentration reduction by photosynthesis in the environment without light at night of fleshy plants can be expected.

**Figure 13.** Removal curve at 400ppb formaldehyde by Spathiphyllum spp.

**Figure 14.** Removal curve at 400ppb formaldehyde by Epipremnum aureum.

**Figure 15.** Removal curve at 400ppb formaldehyde by Sansevieria trifasciata var.

In order to find out optimal light amount conditions for removal due to formaldehyde adsorption, absorption of 6 disclosure plants, we analyzed changes in formaldehyde moment concentration by each plant.

**Figure 16.** Removal curve at 400ppb formaldehyde by Notocactus leninghausii.

**Figure 17.** Removal curve at 400ppb formaldehyde by Myrtillocactus polylopha.

**Figure 18.** Total quantities of formaldehyde removed by several plants.

**Figure 19.** Total quantities of formaldehyde removed by several plants.

In the case of C₃ plants, a formaldehyde concentration increases during the dark period and reduction in a formaldehyde concentration is noticeable during the...
The Effect of Improving Indoor Air Quality using some C₃ Plants and CAM Plants

bright period and on the contrary, CAM plants showed the phenomenon that a formaldehyde concentration decreases during the dark period and increases during the bright period.

This study found out changes in formaldehyde concentrations changing over time through photosynthesis by light and respiration of disclosure plants including 3 kinds of foliage plants such as Spathiphyllum spp., Epipremnum aureum, Hedrera helix and 3 kinds of fleshy plants such as Sansevieria trifasciata var., Notocactus leninghausii, Myrtillocactus polylopha showing different physiologic action for 24 hours.

\[ \text{Figure 20. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Spathiphyllum spp. (initial amt. 400ppb HCHO, 1000ppm CO₂).

\[ \text{Figure 21. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Sansevieria trifasciata var. (initial amt. 400ppb HCHO, 1000ppm CO₂).

\[ \text{Figure 22. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Epipremnum aureum (initial amt. 400ppb HCHO, 1000ppm CO₂).

\[ \text{Figure 23. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Notocactus leninghausii (initial amt. 400ppb HCHO, 1000ppm CO₂).

\[ \text{Figure 24. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Hedrera helix (initial amt. 400ppb HCHO, 1000ppm CO₂).

\[ \text{Figure 25. Correlation between CO}_2 \text{ and HCHO.} \]

concentration changes by Myrtillocactus polylopha (initial amt. 400ppb HCHO, 1000ppm CO).

C₃ plants showed the results that formaldehyde concentration also decreased as carbon dioxide concentration decreased during the bright period and formaldehyde concentration was not changed significantly as carbon dioxide concentration increased during the dark period.
CAM plants showed the results that formaldehyde concentration decreased at first as carbon dioxide concentration increased during the bright period and then, formaldehyde concentration was also reduced when carbon dioxide concentration decreased during the dark period.

4. Prepare your Paper before Styling

Most indoor plants release carbon dioxide into the interior at night because they are foliage plants only breathing without photosynthesis action at night. Therefore, the introduction of plants indoors may be effective in improving indoor air quality during the day but may have a negative effect on ordinary people due to an increase in carbon dioxide at night. Also, given current trends that the introduction of indoor plants is increasing rapidly and concerns of ordinary persons due to the increase in night carbon dioxide, it is considered to be possible to use fleshy plants such as cactus is increasing as part of reducing the indoor carbon dioxide concentration at night. Thus, this study found out that CO$_2$ and HCHO by CAM plants and C$_4$ plants are changed for 24 hours and hence, mixed planting of these two kinds of plants with different physiologic action is effective in removing indoor pollutants of day and night.

5. References