Effect of Removing Indoor HCHO by Several Korean Foliage Plants

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Abstract

The objective of this study is to study the air cleaning ability of indoor plants and to find easier ways of its application. Carbon dioxide, the index of gas pollutant and formaldehyde, found in almost every indoor equipment were chosen to implement the air cleaning experiments. Selected plants in this study were 6 types; Ficus benjamina, Epipremnum aureum, Chamaedorea elegans, Fatsia japonica, Spathiphyllum spp. and Hedera helix. Measuring photosynthesis and breathing volume of each plant for 24 hours, total volume of carbon dioxide reduction for each plant was calculated; Ficus benjamina 49ppm, Epipremnum aureum 99ppm, Chamaedorea elegans 34ppm, Fatsia japonica 123ppm, Spathiphyllum spp. 115ppm, and Hedera helix 42ppm (leaf area unit: 1000Cm²). The time frame, in which the maximum instantaneous consumption of carbon dioxide was shown, was different for each plant; in most cases, the highest absorption rate of carbon dioxide was seen in 0.67~1.54 mW/Cm³ of light quantity. Injecting low concentration formaldehyde (250ppb) and comparing control group in darkened chamber, total volume of formaldehyde reduction for each plant was calculated; Ficus benjamina 128.6ppb, Epipremnum aureum 152ppb, Chamaedorea elegans 127.8ppb, Fatsia japonica 165.9ppb, Spathiphyllum spp. 156ppb, Hedera helix 115ppb (leaf area unit: 1000Cm²). Using statistical program SPSS 7.0, correlation analysis regarding instantaneous consumption volume of carbon dioxide and formaldehyde for each plant was implemented. Thanks to the conversion formula stated below, concentration of formaldehyde in indoor air and purification power of each plant were easily calculated. For 250ppb of formaldehyde, Y(HCHO consumption rate of all plants, ppb) = 0.387X (CO₂ consumption rate of all plants, ppm) + 0.758. It was confirmed that plants can reduce indoor air pollutant from the simple fact; plants must absorb gas pollutants in the process of photosynthesis. Although it takes longer time to eliminate indoor air pollutants than mechanical air cleaners, it is the most environment-friendly method; less costs, continuous air purification and making no secondary pollutants.

Keywords: Component, Eco-friendly removing Indoor Air Pollutants, Indoor Air Pollution, Purifying CO₂ by Plants, Purifying HCHO by Plants

1. Introduction

Unlike outdoor air has high natural dilution rate, indoor air only circulates within limited space which can cause significant air pollution unless it’s ventilated well. Moreover, the extent of freshness or pollution should not be so sensed easily that it could be neglected. Even in the low rate of pollutants detected as ppb level, it can damage human body, therefore, thorough study as to this problem should be conducted.

To enhance the quality of indoor air, the best solution is to ventilate such air to take inflow of fresh air and to maintain its freshness. However, ventilation should not mean anything in downtown area and in terms of underground facility, additional pollution can be placed if the ventilation system is not clean enough.

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In particular, when the indoor space is used for private purpose or large scale, consistent indoor air purifying is not expected due to the cost of running artificial purifier. For these reason, environmentally safe, economical, sustainable and biological indoor pollutant elimination technologies have to be developed.

The purpose of this study is to develop the biological and natural purifying plants which cost significantly lower installation and maintenance cost and to introduce the conversion coefficient of purification which can refer to the plant’s air purifying efficiency and be easily used for daily life. In this study, the following contents will be described.

First of all, effective elimination of carbon dioxide, the index of gas pollutant and formaldehyde, the main cause of sick house syndrome, will be introduced to suggest the possibility of indoor air purification by plant.

Second of all, the conversion coefficient of carbon dioxide and formaldehyde will be described to calculate the consumption of formaldehyde from the consumption of carbon dioxide. Since most of gas pollutants are absorbed by photosynthesis, the conversion coefficient delivers significant meaning.

2. Research Methods

2.1 Removing Carbon Dioxide (CO\textsubscript{2}) by Plants

To examine the removing ability of selected plants, carbon dioxide (1,000~12,000 ppm) was put to sealed chamber and the change of its concentration was measured every 10 minutes for 24 hours (from 6AM to 6AM of following day). 1500lux of artificial light along with natural light was maintained for 12 hours and every light was blocked after 6PM. Other environmental conditions were 24°C of temperature, 40% of humidity and 0.5m/s of air current speed and those conditions were maintained consistently for 24 hours.

Total purification volume (QT) was calculated by:

\[ QT = \sum \{(CP, t-1 - CP, t) - (CN, t-1 - CN, t)\} \times \text{factor} \times \text{volume} \]

\((CP, t-1 - CP, t)\) refers to the decreased volume in the chamber between t-1 to t hour and \((CN, t-1 - CN, t)\) indicates the concentration value of naturally consumed carbon dioxide for the same time frame. Therefore, \((CP, t-1 - CP, t) - (CN, t-1 - CN, t)\) stands for the concentration of removed carbon dioxide between t-1 to t hour.

When this value is summed for entire 24 hours, it stands for the total purification volume (unit: ppm). Moreover, when that ppm unit is converted to μg and divide it with total leaves area, it expresses the purification ability of each plant. The calculation of total purification volume is shown in Figure 2.

2.2 Removing Formaldehyde (HCHO) by Plants

HPLC examination method was used to measure precise volume of formaldehyde. Formaldehyde was collected with a 2,4-DNPH coated cartridge and precise concentration of formaldehyde was measured by examining it with high performance liquid chromatography.

Air bag (3ℓ) was washed repeatedly by using Zero-Air and 6μℓ of undiluted formalin solution (35%) was injected to the air bag. Then the concentration of formaldehyde was measured by collecting it with a certain interval at fixed flow velocity (200 ml/min).

Each selected plant was put into the chamber and the temperature, humidity, intensity of illumination and the concentration of HCHO and CO\textsubscript{2} was measured to utilize it as the primary data.

Figure 1. Measuring change of indoor pollutants in chamber.

Figure 2. The quantity of gas type pollutants removed in chamber.
2.3 Comparing the Plant’s Air Purifying Ability

For the efficient application of indoor air purifying plants, quantification of needed volume of plants is needed to attain same purifying level of air cleaner. Hence, air purification rate was quantified compared to that of air cleaner.

3. Results

3.1 Carbon Dioxide Purification Volume for Each Plant

The plant’s absorption and emission rate of carbon dioxide are significantly changed by the amount of light.

The change rate of photosynthesis as to 6 stated plants was examined for 24 hours to discover the optimal condition of photosynthesis by comparing and analyzing the consumption rate of carbon dioxide. The changed concentration rate of carbon dioxide for each time frame was shown in Figure 3.

The difference value of the consumption of carbon dioxide in illuminated condition and the increased amount of carbon dioxide in darkened condition is considered as carbon dioxide reduction volume. In other words, the more the plant eliminates carbon dioxide the more effective plant for purification it becomes. Figure 4 states the consumption and emission volume of carbon dioxide for each stated plant.

The grape which describes the carbon dioxide reduction volume is shown as follows (Figure 5.).

3.2 Formaldehyde (HCHO) Purification Volume for Each Plant

The standard concentration of formaldehyde, the main cause of sick house syndrome, was set to 250ppb, considering the maximum value of 308μg/m³ (247ppb) measured in daily life. Comparison study regarding formaldehyde absorption of each plant was conducted with that standard.

Injecting the set volume of formaldehyde into the sealed chamber, the change of formaldehyde concentration for each chamber was measured for 24 hours to compare and analyze the results. There was a big difference between the completely dark chamber and the chamber with illumination for 12 hours and dark for 12 hours. In the completely darkened chamber for 24 hours, the absorption and removal process was so completed within 3~4 hours that tiny change was measured after that. However, rapid reduction of formaldehyde concentration was seen by being increased photosynthesis rate of the plant in half illuminated chamber.

The difference value between the consumption of formaldehyde in the lightened condition and the change of formaldehyde in the darkened condition was considered as the formaldehyde reduction volume for each plant.

In other words, the more the plant eliminates formaldehyde the more effective plant for purification it becomes. Figure 18 states the total reduction volume of formaldehyde for each stated plant.
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**Figure 6.** Removal curve at 250ppb formaldehyde by Ficus benjamiana.

**Figure 7.** Removal curve at 250ppb formaldehyde by Epipremnum aureum.

**Figure 8.** Removal curve at 250ppb formaldehyde by Chamaedorea elegans.

**Figure 9.** Removal curve at 250ppb formaldehyde by Fatsia japonica.

**Figure 10.** Removal curve 250ppb formaldehyde by Spathiphyllum spp.

**Figure 11.** Removal curve at 250ppb formaldehyde by Hedera helix.

**Figure 12.** Momentary changes at 250ppb of formaldehyde by Ficus benjamiana.

**Figure 13.** Momentary changes at 250ppb of formaldehyde by Epipremnum aureum.
The instantaneous formaldehyde reduction volume in the lightened condition for 24 hours was shown: 128.6ppb for *Ficus benjamina*, 152ppb for *Epipremnum aureum*, 127.8ppb for *Chamaedorea elegans*, 165.9ppb for *Fatsia japonica*, 156ppb for *Spathiphyllum spp.* and 115ppb for *Hedera helix*.

### 3.3 Correlation Coefficient between Carbon Dioxide Consumption and Formaldehyde Consumption

Unlike carbon dioxide, there is a difficulty to measure the formaldehyde absorption ability of the plant, since measuring and analyzing the concentration of formaldehyde are not easily done. In this study, therefore, carbon dioxide, which delivers easily obtainable data in real time, was used to analyze the correlation between them and to calculate the conversion coefficient.

The following formulas refer to the conversion coefficient of each plant by measuring instantaneous reduction rate of formaldehyde (250ppb) and carbon dioxide (1200ppm).

- \[ Y \text{ (HCHO consumption rate of } *Ficus benjamina*, \text{ ppb) } = 0.384X(\text{CO}_2 \text{ consumption rate of } *Ficus benjamina*, \text{ ppm}) + 0.023] \]
- \[ Y \text{ (HCHO consumption rate of } *Epipremnum aureum*, \text{ ppb) } = 0.418X(\text{CO}_2 \text{ consumption rate of } *Epipremnum aureum*, \text{ ppm}) + 0.019] \]
• Y (HCHO consumption rate of *Chamaedoea elegans*, ppb) = 0.386X(CO₂ consumption rate of *Chamaedoea elegans*, ppm) + 0.054
• Y (HCHO consumption rate of *Fatsia japonica*, ppb) = 0.421X(CO₂ consumption rate of *Fatsia japonica*, ppm) + 0.043
• Y (HCHO consumption rate of *Spathiphyllum spp.*, ppb) = 0.394X(CO₂ consumption rate of *Spathiphyllum spp.*, ppm) + 0.032
• Y (HCHO consumption rate of *Hedera helix*, ppb) = 0.329X(CO₂ consumption rate of *Hedera helix*, ppm) + 0.047
• Y (HCHO consumption rate of all plants, ppb) = 0.387X(CO₂ consumption rate of all plants, ppm) + 0.758

For the concentration unit, carbon dioxide was measured as ppm and formaldehyde was gauged as ppb, therefore, 1000ppm of carbon dioxide was converted to 1830.21 mg/m³ and 100ppb of formaldehyde was converted to 124.91 mg/m³ for calculation.

For example, if the concentration of indoor carbon dioxide is 1200ppm, purification ability to carbon dioxide can be calculated by gauging the photosynthetic speed of *Ficus benjamina*. If the independent variable X shown in the formulae above is substituted by such purification ability value, the consumption rate of formaldehyde of *Ficus benjamina* should be derived. Thanks to the correlation regression formulae above, determining the air cleaning ability for each plant can be simply done by using portable carbon dioxide measuring instrument without direct gauging the concentration of formaldehyde.

### 4. Conclusion

In comparison of indoor plants and mechanical air cleaner, the latter performed much faster purification time in the same space and the same amount of gas pollutants. Plants used in this study take about 20 times longer period to purify same concentration of carbon dioxide and 16 times longer to clean formaldehyde. However, actual difference is not expected to be seen by using plants which have larger leaf area; the standard was set to 1000 cm² leaf area for this calculation.

Moreover, in the case of air cleaner, installable space and its effect are limited and it has major drawback; generating secondary pollutants. Besides, installation cost is expensive and additional maintenance costs are needed such as regular filter exchange. In contrast, indoor plants have such merits as the followings.

- Installation and maintenance are easier and cheaper.
- Continuous purification of gas and particle pollutants is possible.
- The natural cleaner generates no secondary pollutants.
- Good for health and mind (anion generation and psychotherapy effect).

For these reasons, active applications of such indoor plants will improve air condition in the long term.

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