The Filter for Removing Ethylene Gas by the Enzyme Immobilization

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We have found that the extracted liquid from bamboo had an effect to oxidize ethylene to ethylene oxide. This effect is considered to be caused by the enzyme contained in the bamboo. In this study, a new type of filter for removing ethylene gas was developed by using bio degradable expanded plastic as the substrate and immobilized the enzyme from the extracted liquid on the thin film. It decreased the concentration of the ethylene gas and increased that of the ethylene glycol because of ethylene oxide produced by the oxidation of the ethylene gas combined with H_2O into ethylene glycol. The effect was enlarged by the enzyme immobilization. It was also found that the effect was drastically improved by using the substrate with higher specific surface area. The developed filter had an effect to preserve the freshness of fruits and vegetables.

Keyword: ethylene, bamboo, filter, immobilized enzyme, thin film

1. Introduction

Ethylene gas effused from fruits and vegetables deteriorates their freshness and has bad influences on to the perishables during the long distance transportation or the preservation in a closed box.[1] Some prevalent products removing ethylene gas is poisonous such as KMnO₄. Conventionally, a system to preserve the freshness of fruits and vegetables require large space such as Controlled Atmosphere (CA) Storage. Therefore effective filters are strongly required in order to remove the ethylene gas.

Recently, we have found that bamboo had a plenty of substances to oxidize ethylene to ethylene oxide. In this study, the material extracted from bamboo is used, and a filter for removing ethylene gas was newly fabricated. It was known that some plants such as banana or kiwi has an enzyme to oxidize ethylene to ethylene oxide and the plant metabolism requires the enzyme. [2][3] The ethylene oxide produced by the oxidation of the ethylene gas combined with H_2O into

ethylene glycol. The mechanism of the oxidation of the ethylene gas was shown in Fig.1. The enzyme was



Fig.1 The mechanism of the oxidation of the ethylene gas

immobilized in a citosan thin film which is a harmless polycation [4][5] A filter for removing ethylene gas was also developed by using bio degradable expanded plastic covered with a thin film immobilizing the enzyme. An useful product was fabricated by extruding the substrate like a sheet.

2. Experimental Method

2-1 Effect of the immobilized enzyme

A bio degradable expanded plastic made from cellulose acetate was used as a substrate. The substrate was immersed in 1wt% citosan (MW. 24,000-100,000) aqueous solution. This was annealed for 2 hours. The surface of the substrate was covered with a citosan thin film. It was immersed in the 100ml of the extracted liquid from bamboo. It was dried for over a day at room temperature. This was a filter with a citosan thin film with immobilized the enzyme. On the other hand, a filter without the citosan thin film was fabricated in the similar way. The citosan and the enzyme form an ionic bond.

These 2 kinds of filters were stowed in the cartridges (ϕ 60mm×100mm) made of acrylic resin. An air fan(ϕ 600mm) was attached in the Cartridge. The experiment of the evaluation of the filter was carried out in a closed box(200mm×200mm×200mm, 8dm³) which was made of acrylic resin. The cartridges were attached on the closed boxes, respectively. Ethylene gas (concentration 100ppm) was modulated in the closed boxes. After 5 days, the ethylene gas removal rates were measured in the closed boxes. The concentrations of ethylene were measured by using detector tubes (Gastec, 172, 172L).

2-2 Influence of substrate on ethylene gas removal rate

Granular activated carbon (15g, Wako) and Silica gel (15g) was used as substrates, respectively. The similar preparation was carried out in the same method which is already explained in the section 2-1. Similarly, 2 kinds of filters were fabricated. These filters were stowed in the cartridges. The ethylene gas removal rates were measured in the closed boxes. The ethylene gas removal rates of these filters were compared with those of one of the filter made from cellulose acetate substrates with a citosan thin film with immobilized the enzyme. The concentrations of ethylene were measured by using detector tubes (Gastec, 172, 172L).

2-3 Influence of relative humidity on ethylene gas removal rate

The substrate which was made from cellulose acetate was

extruded like a sheet for the practical application. This substrate was cast the extracted liquid from bamboo which was mixed with 1 wt% citosan aqueous solution. It was dried for over a day at room temperature. A sheet type filter was fabricated and used in this experiment.

3 sheets(210mm \times 210mm) were attached on 3 closed boxes. As LiCl saturated aqueous solution, K₂CO₃ saturated aqueous solution, and NaCl saturated aqueous solution were attached to closed boxes inside, relative humidity in closed boxes were regulated at 11%, 43%, 75%, respectively. The picture of the experimental system is shown in Fig.2. Ethylene gas concentration 100ppm was modulated in the closed boxes. After 5 days, the ethylene gas removal rates were measured in the closed boxes. Air fans(ϕ 600mm) were attached to the closed boxes inside. The concentrations of ethylene were measured by using a gas chromatography (Hitachi, G-3900).



Fig.2 A closed box(200mm×200mm×200mm, 8dm³) which was made of acrylic resin was used as experimental system

2-4 Effect of the filter to fruits

2 closed boxes(310mm \times 240mm \times 80mm) with and without a sheet type filter, respectively, which were made of glass were prepared. Melons were set in the both closed boxes. Air fans(ϕ 600mm) were attached to the closed boxes inside. These were kept for 15 days at 25°C.

3. Result and Discussions

3-1 Effect of the enzyme immobilized

Ethylene gas removal rates of 2 kinds of filters were shown

in Fig.3. The enzyme immobilized filter had a higher removal rate of ethylene gas than the filter without the citosan thin film. It is considered that, since the citosan thin film immobilized the enzyme, the deactivated enzyme was decreased when the filter was fabricated. A schematic diagram of the enzyme immobilized by citosan is shown in Fig.4. In this figure, the loose curve shows the citosan, and the dark area shows the enzyme. The enzyme and the citosan form an ionic bonding.

the various substrates. Fig.6 shows the specific surface areas of the substrates. The data of the two figures indicate that the removal rate of the gas increases with increasing the surface areas because the contacting chance between the gas and the enzyme increases as the surface area increases. However, it was found that the removal rate of ethylene gas when using the cellulose acetate substrate was not so low considering its extremely low surface area.



Fig.3 Influence of immobilized film on ethylene gas removal rate







Fig.4 The enzyme immobilized by citosan

3-2 Influence of substrate on ethylene gas removal

Fig.5 shows he ethylene gas removal rates of filters made of

3-3 Influence of relative humidity on ethylene gas

The ethylene gas removal rates of sheet type filters at relative humidity 11%, 43%, 75% were shown in Fig.7. The removal rate at relative humidity 43% was higher than the values at 11% and 75%. Generally, the effect of the enzyme requires appropriate relative humidity. However, it is considered that plenty of water in the air at high relative humidity prevented ethylene gas from contacting the enzyme on the filter.



3-4 Effect of the filter to fruits

The pictures of the melons with and without the sheet type filter after 15 days were shown in Fig.8(a) and Fig.8(b). As shown in these figures, the melon with the fabricated filter sheet seemed to preserve the freshness. The melon without the sheet type filter was covered with mold. It is considered that the sheet type filter removed ethylene gas which was effused from the melon, and inhibited the melon to mature and wither.





Fig.8(a) With filter

Fig.8(b) Without filter

4. Conclusion

A filter for removing ethylene gas was developed by using bio degradable expanded plastic covered with a thin film immobilizing the enzyme. The enzyme immobilized filter had a higher removal rate of ethylene gas than the filter without the citosan thin film. This effect was considered to be caused by the enzyme contained in the bamboo. The removal rate of the gas increases with increasing the surface areas because the contact chance between the gas and the enzyme increases as the surface area increases. The removal rate of sheet type filter was the highest when the relative humidity was 43%. It was clear from the picture that the melon with the sheet type filter preserved the freshness.

5. References

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