論 文 の 内 容 の 要 旨

生物・環境工学　専　攻
平成 19 年度博士課程　入学
氏　　　名　ソラヤ センムアン
指導教員名　大下誠一

Examination of models for spinach respiration under modified atmosphere and the effect of nano-mist on respiration

（MA 雰囲気下におけるホウレンソウの呼吸モデル及び呼吸に及ぼすナノミストの影響に関する検討）

This study aimed to analyze and improve the postharvest conditions for a leafy vegetable concerning with minimizing the respiration of spinach. The study was divided into 2 parts: (1) Examination of models for spinach respiration (2) The effect of nano-mist on the respiration of spinach.

1. Examination of models for spinach respiration

Anaerobic respiration is a major problem of fresh produces packaged under low O_2 atmosphere. The problem becomes more severe and causes high losses in the packages handling at ambient conditions without any cooling systems. In designing the modified atmosphere packaging, the risk of anaerobic development greatly depends upon the accuracy of respiration rate prediction, therefore, the respiration rate model for a particular produce has to be identified. The objective of this study was to examine the respiration rate models in order to indentify the simple and suitable model for spinach storage under low O_2 atmosphere at ambient temperature (25^{o}C).

1.1 Material and methods

The spinach samples were stored in closed system using acrylic chambers, controlled at 25°C for 77 hours. Seven different initial atmospheric conditions were given to examine the dynamic change of gas compositions, respiration rate and respiratory quotient (RQ) at different initial O_2 concentrations and different void volumes in relation to the amount of spinach stored.

Six respiration rate models were applied to the experimental data: Michaelis-Menten without inhibition, Michaelis-Menten with competitive inhibition of CO_2, Michaelis-Menten with uncompetitive inhibition of CO_2, Michaelis-Menten with noncompetitive inhibition of CO_2, Michaelis-Menten with mixed inhibition of CO_2 and Langmuir adsorption [1]. One of the seven storage conditions was selected for estimating the models' parameters using non-linear regression. From the parameters obtained the model(s) was validated by simulation (MATLAB 2007b, The Mathworks Inc, USA) to predict the gas composition of the other six storage conditions. The agreement between the simulated and the experimental results was evaluated by the mean relative percentage deviation of modulus (%E).

1.2 Results

The very low void volume of storage atmosphere (21% initial O_2 with amount of spinach per unit mass of spinach 236.8 mmol/kg) caused the respiratory metabolism shifted from aerobic respiration to anaerobic respiration or fermentation in the latter period of storage. In this condition, the RQ value sharply increased and became higher than 1.3. The lower limit O_2 to maintain aerobic respiration was found to be around 1.0-0.8 mmol/l. For the rest of conditions, the RQ value was constant throughout the storage period of 77 hours.

From the six respiration rate models proposed, only three models that the experimental data could be fitted and the parameters could be estimated, viz. Michaelis-Menten without inhibition, Michaelis-Menten with uncompetitive inhibition of CO_2 and Langmuir adsorption. These models gave good fitting results with correlation coefficient (R^2) higher than 0.95. The adaptability of models was dependent on the CO_2 level. Therefore, the Michaelis-Menten model with uncompetitive inhibition was selected as it can be applied in extensive range of CO_2. Moreover, it gave the best fitting result and widely accepted.

The estimated parameters with the average RQ of 0.8 were used to simulate the gases concentration change during storage at different initial conditions. The simulated results showed fairly good agreements to the experimental data both in O_2 and CO_2 concentrations. The E values for O_2 concentration lower than 20% suggesting adequacy of the model and parameters to describe the respiration rate and predict the O_2 concentration.

1.3 Conclusions

For aerobic conditions, the prediction of spinach respiration rate was described with a constant RQ by Michaelis-Menten model without inhibition, Michaelis-Menten model with un-competitive inhibition and Langmuir adsorption model. Among these models, the Michaelis-Menten with un-competitive inhibition was found to be more generic and suitable for practical applications as it can be applied in extensive range of CO_2 and O_2 concentrations.

2. The effect of nanomist on the respiration of spinach

Water loss is an important issue in relation to the deterioration fruits and vegetables, especially in leafy vegetables. Water mist humidification is a technique commonly used to diminish water loss by increasing relative humidity of the storage atmosphere. The previous studies on water mist humidification discussed the advantages of this technique on maintaining fresh produce quality. However, the size of water mist particle and its influence on the respiratory metabolism have not been investigated. This study aimed to (1) characterize the storage atmosphere as influence by the nano-mist humidification, analyzing through particle size distribution and (2) investigate the influence of nano-mist on the respiration and quality of spinach.

2.1 Materials and methods

The nano-mist was produced by the nano-mist generating system using ultrasonic principle. The water used to produce the nano-mist was control at 20^{o}C. The nano-mist was introduced into the storage chamber that was installed in an incubator controlling at 20^{o}C, the rate of introduction was controlled by 95% relative humidity (RH) of the storage atmosphere. The particle size distribution of the water mist particle in the storage chamber before, during and after the nano-mist introduction was examined.

For investigation of particle size distribution of the water mist particle during storage of spinach, spinach sample was stored in a storage chamber at 20^{o}C for four days. The nano-mist was introduced into the storage chamber in daytime and stopped in nighttime. The particle size distribution of water mist particle inside the storage chamber during and after stop the introduction was examined and compared to the control condition without misting.

For the influence on the spinach respiration and quality, spinach sample was stored in a storage chamber at 20^{o}C for six days. The nano-mist was introduced and stopped 6 hours daily for respiration rate determination. The respiration rate was determined by O_2 consumption rate. The quality attributes: moisture content, leaves color and electrolyte leakage were measured on the first and the final day of the storage. The result was compared to the control condition without the nano-mist introduction.

2.2 Results and Discussions

The particle size distribution of water mist particle was analyzed through the total concentration and the geometric mean diameter. The nano-mist generating system can supply the water mist particle in the larger geometric mean diameter than water mist particle of an ambient air, while the total concentration was lower.

In comparison to control condition without misting during storage of spinach, it was found that, during the nano-mist introduction, the total concentration was lower while the difference was not observed after stop the nano-mist introduction. The geometric mean diameter was larger in the misting condition for both during and after stop the nano-mist introduction.

For the six days of storage, the O_2 consumption rate decreased in the first four days and then increased in the last two days of storage due to the increasing of microbial population for both the misting and control condition [2], but the different between misting and control conditions was not observed. This was explicated as a result of similar total concentration and geometric mean diameter of water mist particle during stop the nano-mist introduction. The moisture content and leaves colors were not influenced by misting, but the tissue electrolyte leakage was higher in the misting sample after the six days of storage.

2.4 Conclusions

Nanomist application was found to alter the storage atmosphere by reducing the total concentration and increasing the geometric mean diameter of water mist particle. However, its influence on respiration rate and quality of spinach was still unclear.

3. General conclusions

The un-competitive inhibition Michaelis-Menten model with a constant RQ was found to be the most suitable model for the prediction of spinach respiration under modified atmosphere. The influence of nano-mist on the respiration was still unclear. Besides the misting treatment, the experimental set up could be the factors influencing on the results. To assure the influence of misting, the experimental set-up should be improved.

References

[1] Fonseca, S.C. et al. 2002. Modelling respiration rate of fresh fruits and vegetables for modified atmosphere packages: a review. J. Food Engineering 52, 99-119.

[2] Pandrangi, S. and Laborde, L.F. 2004. Retention of folate, carotenoids and other quality characteristics in commercially packaged fresh spinach. J. Food Science 69(9), 702-707.