論文内容の要旨

生物・環境工学専攻
平成 29 年度博士課程入学

氏名　孛儿只斤蘇日娜
指導教員　牧野義雄

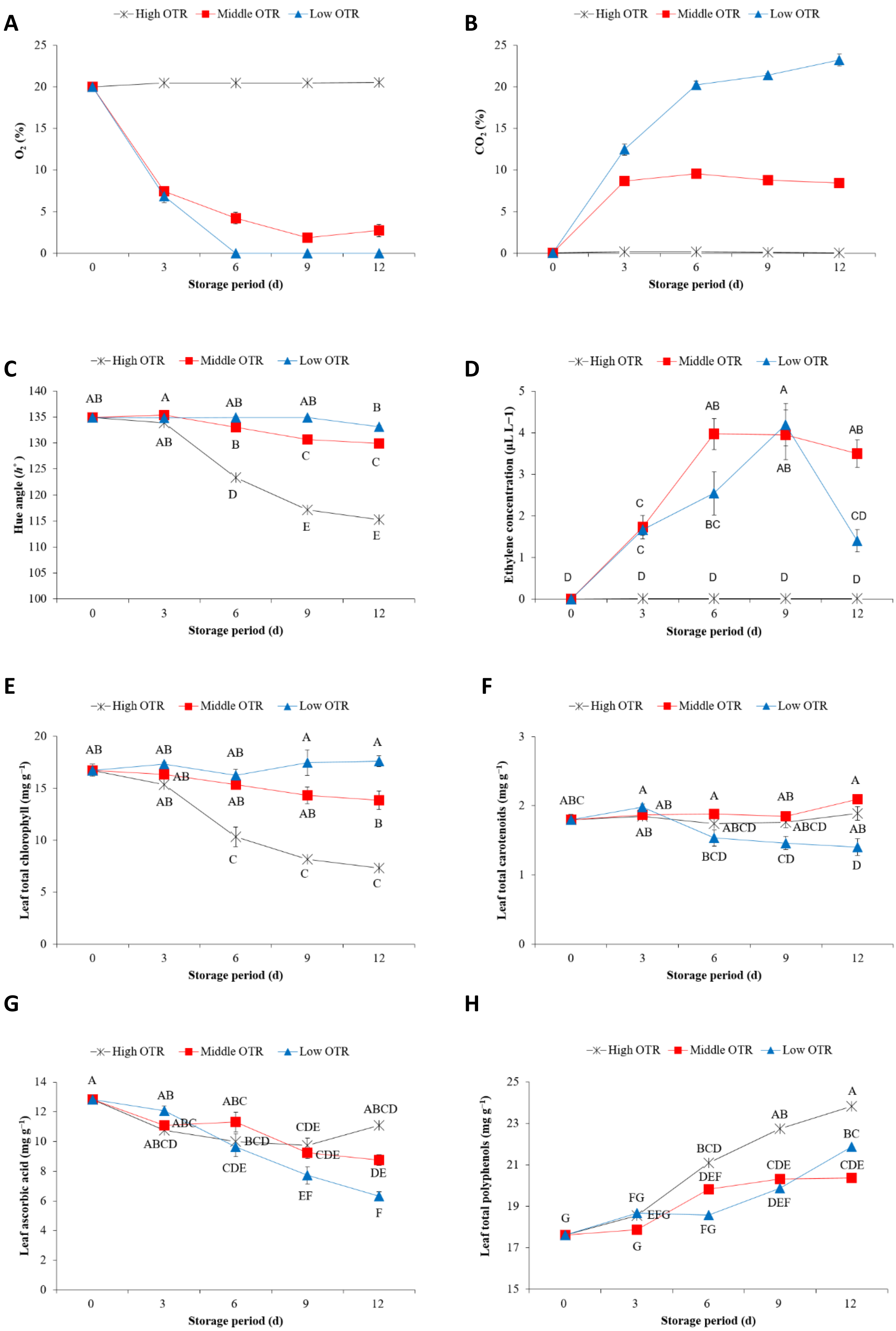
論文題目
Dynamic Changes in Quality and Metabolites of Soft Kale Stored in Perforation-Mediated Modified Atmosphere Packaging

（微細孔調整気相包装貯蔵におけるソフトケールの品質および代謝物質の動的変化）

Modified atmosphere packaging (MAP) is one of the most promising techniques that has been widely and successfully used to extend the shelf life of fresh vegetables and fruits by controlling the surrounding gas composition of products (Kader, 2002). The depleted O_2 and elevated CO_2 in MAP, derived from the respiration rate of the product and the gas permeability of the packaging film, can reduce the respiration rate of the fresh product (Zagory & Kader.1988). In recent years, the perforation-mediated MAP (PM-MAP) has proved to be an effective technology for packing high-respiring products due to the high gas exchange rates achieved. The use of perforation technology has optimized the limited permeability properties of traditional MAP films (Hussein, 2015).

Fresh kale is highly perishable after harvest, readily losing its green color as well as undergoing marked postharvest loss of bioactive compounds. This study aimed to examine the effect of three different micro-perforated packaging films with different oxygen transmission rate (OTR) on the overall appearance and bioactive compounds of intact kale. In addition, the metabolomics profile of soft kale leaf and stem associated with the three different OTR pouches were characterized during the 12 d storage period at 10 °C.

The micro-perforated pouches with different OTRs had a significant impact on the postharvest performance of kale leaf and stem during storage at 10 ºC for a period of 12 d under dark conditions. As shown in Figs. A, B, no gaseous (O_2 and CO_2) modification was observed within the OTR 1.66×10^6 pouch. As a consequence of the respiration of kale and the gradient-induced gas transmission characteristics of the packaging film (Zhang et al., 2015), the gaseous composition in the OTR 3×10^3 pouch modified to lie within the ranges of 1.9 ~ 7.4 % O_2 and 8.5 ~ 9.6 % CO_2, which are near the recommended internal atmospheres of 2~5 % O_2 and 3~8 % CO_2 in MAP for the preservation of fresh leafy vegetables to avoid the anaerobic respiration at low O_2 atmosphere and to avoid the CO_2 injury at high CO_2 concentrations (Mampholo et al., 2013). The OTR 64 pouch showed significant increases in CO_2 and decreases in O_2 concentrations, with the O_2 concentration decreasing to 0 % on day 6 and CO_2 increasing to 23.3 % on day 12. Usually, a low O_2 and/or a high CO_2 atmosphere suppresses respiration rate, decreases ethylene production. However, the OTR 1.66×10^6 pouch showed a significantly ($p < 0.05$) lower concentration of ethylene throughout the storage period, which might be reflecting the high permeability of the packaging film used (Fig. C). The ethylene concentration in the OTR 3×10^3 pouch and OTR 64 pouch showed a sharp rise until day 6 and 9 day, respectively. As shown in Fig. C, the OTR 1.66×10^6 pouch, yellowing of kale leaves was recorded with a significantly ($p < 0.05$) lower $h°$ value from day 6 onward. The overall evaluation of the effect on bioactive compounds of kale leaf showed that leaves stored in the OTR 3000 maintained the pigment concentrations (Figs. E, F); maximized the concentration of ascorbic acid (Fig. G), although it depressed the accumulation of the total polyphenols (Fig. H) during the postharvest storage. In addition, OPLS-DA showed 24.66% and 38.54% of the metabolites were contributed to the separation of the four class in leaf and stem, respectively (Figs, I, J). The middle OTR pouches (OTR 3000) located near from the fresh sample cluster and it showed little fluctuation compared with other two pouches. This result supported the fact that the micro-perforated pouch with an OTR of 3×10^3 mL m^{-2} d^{-1} atm^{-1} achieved the most promising storage effect on kale preservation.


A
High OTR
Middle OTR
Low OTR
O2 (%)
Storage period (d)
B
CO2 (%)
Storage period (d)
C
Hue angle (h°)
Storage period (d)
D
Ethylene concentration (µL L−1)
Storage period (d)
E
Leaf total chlorophyll (mg g−1)
Storage period (d)
F
Leaf total carotenoids (mg g−1)
Storage period (d)
G
Leaf ascorbic acid (mg g−1)
Storage period (d)
H
Leaf total polyphenols (mg g−1)
Storage period (d)

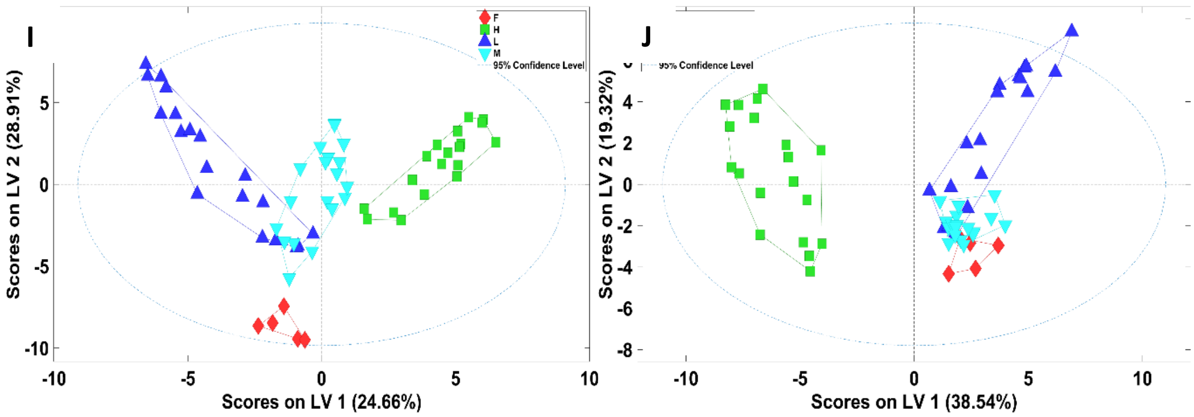


Figure. (A) Headspace O_2 content, CO_2 content (B), ethylene concentrations (C), hue angle (D), leaf total chlorophylls (E), total carotenoids (F), ascorbic acid content (G), total polyphenols (H) in three micro-perforated pouches with different OTRs (mL m^{-2} d^{-1} atm^{-1}) (High OTR: 1.66×10^6; Middle OTR: 3×10^3; Low OTR: 64). Mean values ± standard error of five biological replicates are shown. Leaf (I), stem (J) orthogonal partial least squares discriminant analysis score (F: fresh, H: high OTR, M: middle OTR, L: low OTR).

Abdelrahman, M., Hirata, S., Sawada, Y., Hirai, M. Y., Sato, S., Hirakawa, H., … Shigyo, M. (2019). Widely targeted metabolome and transcriptome landscapes of Allium fistulosum–A. cepa chromosome addition lines revealed a flavonoid hot spot on chromosome 5A. *Scientific Reports*, *9*(1), 1–15.

Bjerrum, J. T. veite. (2015). Metabonomics: methods and protocols. *Methods in molecular biology (Clifton, N.J.)* (Vol. 1277).

Hussein, Z., Caleb, O. J., & Opara, U. L. (2015). Perforation-mediated modified atmosphere packaging of fresh and minimally processed produce-A review. *Food Packaging and Shelf Life*, *6*, 7–20.

Koh, E., Wimalasiri, K. M. S., Chassy, A. W., & Mitchell, A. E. (2009). Content of ascorbic acid, quercetin, kaempferol and total phenolics in commercial broccoli. *Journal of Food Composition and Analysis*, *22*(7–8), 637–643.

Mampholo, B. M., Sivakumar, D., Beukes, M., & van Rensburg, W. J. (2013). Effect of modified atmosphere packaging on the quality and bioactive compounds of Chinese cabbage (Brasicca rapa L. ssp. c hinensis). *Journal of the Science of Food and Agriculture*, *93*(8), 2008–2015.

Watanabe, J., Oki, T., Takebayashi, J., & Takano-Ishikawa, Y. (2014). Extraction Efficiency of Hydrophilic and Lipophilic Antioxidants from Lyophilized Foods Using Pressurized Liquid Extraction and Manual Extraction. *Journal of Food Science*, *79*(9), C1665–C1671.

Zagory, D., & Kader, A. A. (1988). Modified atmosphere packaging of fresh produce. *Food Technology*, *42*(9), 70–77.

Zhang, M., Meng, X., Bhandari, B., Fang, Z., & Chen, H. (2015). Recent Application of Modified Atmosphere Packaging (MAP) in Fresh and Fresh-Cut Foods. *Food Reviews International*, *31*(2), 172–193.