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Research Note

Active air flushing in a sensor-controlled fresh produce container system to maintain the desired modified atmosphere

Yun Hee Jo, Duck Soon An, Dong Sun Lee*

Department of Food Science and Biotechnology, Kyungnam University, 7 Kyungnamdaehak-ro, Masanhappo-gu, Changwon, 631-701 South Korea

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Modified atmosphere (MA) containers equipped with an on/off-controlled perforation that can respond to real-time gas concentrations can contribute to maintaining the quality of fresh produce. In this study, an active flushing system was devised to flush the air promptly responding to the real-time O_2 concentration, and its capability to maintain the target O_2 level was compared to that of an O_2 switched passive diffusion tube system. A model container with dimensions of 32 × 23 × 18 cm was filled with 350 g spinach and submitted to storage testing under different control regimes and temperatures. The gas concentration in the spinach container was programmed to stay either exactly at 11% or in the range of 11–13%. While the O_2 switched passive diffusion tube system could properly control the O_2 concentration in the container at the desired level or range when the container was at the low temperature of 10 °C, it could not do so at 20 °C, resulting in O_2 concentrations that were too low and CO_2 concentrations that were too high. The active flushing system was effective and satisfactorily controlled the gas concentration in the container at the desired level or range at both 10 and 20 °C. Compared to the O_2 switched passive diffusion tube system, the active flushing system was more prompt in its response to deviating atmospheric conditions, which was more pronounced in the range control mode. The container with the controlled MA was better at preserving the quality of the produce compared to a perforated control package.

1. Introduction

Creating and maintaining a desired modified atmosphere (MA) in a reusable fresh produce container using a sensor control based on the real-time gas composition has been proposed and shown to provide benefits for the quality preservation of foods (Jo, Kim, An, Lee, & Lee, 2013; Liu, Yan, Wang, & Han, 2011). The opening and closing of a gas diffusion tube or perforation can be controlled to provide the container with an atmosphere near the optimal MA conditions to avoid reaching the intolerable limit for the O_2 or CO_2 concentration (Jo et al., 2013). The control was found to work under certain constraints of diffusion tube dimensions, which

* *Corresponding author*. Tel.: +82 55 249 2687; fax: +82 505 999 2171.
E-mail address: dongsun@kyungnam.ac.kr (D.S. Lee).
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depend on the produce respiration activity in the container (Jo, An, & Lee, 2013b). Using a single O_2 sensor rather than both an O_2 and a CO_2 sensor as part of the control system allows for the miniaturisation of the module and reduces the construction cost without sacrificing the beneficial effects of an MA preservation system (Jo, An, & Lee, 2013a).

A proper air feed rate should be achieved by adjusting the area of the diffusion tube or membrane to balance the respiration of the produce as part of the perforation-mediated container (Paul & Clarke, 2002). While a given perforation dimension for the sensor-controlled MA container works well at a certain temperature, it may have problems with regards to CO_2 accumulation or anaerobic atmosphere build-up when subjected to temperature abuse storage, which can lead to an unbalanced high respiration activity relative to the gas transfer across the structure of the package. As a way to facilitate air feeding to the produce, containers that are able to match the high respiration by providing intermittent air flushing with a programmed time and cycle have been proposed (Berrios, 2002). To overcome the limitations and obstacles observed for these sensor-controlled MA containers, an active flushing system with a small pump was designed in the present study to control the container's atmosphere, thus allowing prompt responses in high temperature conditions. This study therefore aims to test and compare the active flushing system of the sensor-controlled MA container to an O_2 switched passive diffusion tube system in its ability to maintain the desired MA. If this system, with its delicate and costly accessories, works well, it may be better accepted for a large storage container.

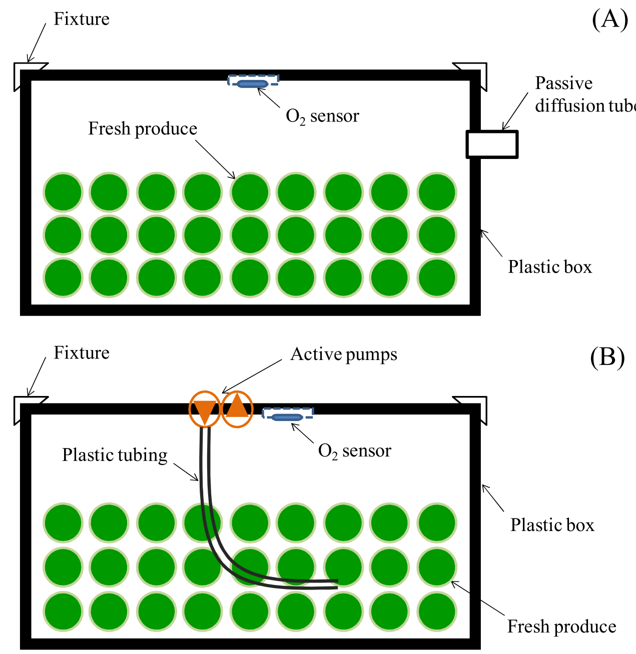

Fig. 1 – Schematic diagram of an O_2 sensor-controlled container system equipped with either (A) an O_2 switched passive diffusion tube or (B) an active flushing pump to obtain MA benefits for storing fresh produce.

2. Materials and methods

2.1. *Modified atmosphere container with a gas diffusion tube or an active flushing mechanism*

The prototype container was equipped with a perforation-mediated gas transfer system responding to an O_2 sensor, as shown in Fig. 1, and was modified from that of Jo et al. (2013). A 2-mm-thick polypropylene container with dimensions 32 × 23 × 18 cm was attached to an O_2 gas sensor (SS2118, Senko, Ansan, Gyeonggi, Korea) below its cover. The O_2 switched passive diffusion tube system was equipped with a metal tube (1 cm diameter and 5.5 cm length) that can be opened or closed in response to the measured O_2 concentration (Fig. 1(A)). In the active flushing system, a circular inlet and exit measuring 3 mm in diameter can be opened and operated in synchronisation by two mini-motors (6 V) responding to the O_2 concentration ($[O_2]$), and these were installed as part of a module on the cover to give a flow rate of approximately 2.5 l min^{-1} through the perforation at their opening (Fig. 1(B)). To effectively flush air into the container, a 20-cm-long plastic tube was connected to the inlet and hung in the container. The O_2 concentration was measured by the sensor and provided the information that the control system used to regulate the opening/closing action for the perforation-mediated gas transfer, gas diffusion tube or active flushing pump. A non-dispersive infrared type CO_2 sensor, K33 (SenseAir, Delsbo, Sweden), was placed inside the container to measure the CO_2 concentration ($[CO_2]$). The container was used to store 350 g of spinach, which was within the container's capacity.

2.2. *Control regimes responding to real-time O_2 concentration variations*

A simplified version of the control logic was devised to control the container's atmosphere in response to its O_2 concentration. Spinach was assumed to have an optimal MA window of 7–10% O_2 and 5–10% CO_2 (Kader, 2001). Attempts at controlling the O_2 concentration were executed using a decision rule to open or close the perforation according to the on-line measured O_2 concentration. In a simplest version, the perforation or gas exchange device (i.e., the diffusion channel or active flushing pump) was opened or turned on when the $[O_2]$ decreased to a set value, and returned to the closed position when the $[O_2]$ reached a value higher than the setting. To avoid an increase in the $[CO_2]$ to a level above its upper tolerance limit for spinach ($[CO_2]_H$), the criterion $[O_2]$ value of this on-off control was set by subtracting the $[CO_2]_H$ from 21% (Jo et al., 2013a; Jo et al., 2013). This approach is based on the assumed relationship of $[O_2] + [CO_2] = 21\%$ for typical perforated packages (Mannapperuma & Singh, 1994; Paul & Clarke, 2002); the $[O_2]$ control point for spinach with a $[CO_2]_H$ of 10% was thus set to 11%.

A relaxed version of the control system was also designed with a buffer range in the O_2 concentration based on the opening and closing of the perforations. The perforation starts to open at a set $[O_2]$ value on the lower end of the target range and remains open until the $[O_2]$ increases to a set value at