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Application of humidity-regulating tray for packaging of mushrooms

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ABSTRACT

Major postharvest challenge of mushroom includes high transpiration rate resulting in rapid weight loss and the risk of water vapour condensation inside the package, which results in accelerated deterioration in quality and decay. Thus, this study investigated the transpiration behaviour of mushroom under various combinations of storage temperature (4, 12 and 20 °C) and relative humidity (RH) (76, 86, 96 and 100%) and assessed the impact of salt embedded humidity-regulating tray on humidity and condensation behaviour in mushroom package at 7 °C and 85% RH. The impact of humidity-regulating and control-polypropylene (control-PP) trays on condensation and quality of mushroom was evaluated after 6 days. Despite the saturated RH condition, across all temperatures studied, mushrooms stored at 100% RH lost moisture at the rate of 0.03–0.22 mg kg^{-1} s^{-1}. Humidity-regulating tray maintained a stable RH (93%) inside the package and it absorbed 4.1 g of water vapour within 6 days at 7 °C and 85% RH storage condition. Humidity-regulating tray better maintained the quality of mushrooms compared to control-PP tray, but it absorbed only 4.1 g of water vapour in 6 days which was not enough to prevent water condensation in the package headspace for mushrooms.

1. Introduction

Mushrooms are highly transpiring and respiring fresh commodities. They are sensitive to surrounding humidity levels; low relative humidity (RH) results in excessive loss of weight and firmness, while very high RH favours water vapour condensation on mushroom surface, which accelerates microbial growth and discolouration (Mahajan et al., 2008a). Thus, their postharvest life is shortened as consequence of these processes. Appropriate packaging is one of the essential methods for protecting and maintaining the quality, and prolonging the shelf life of produce from growers to consumers. It is well established that package gas composition in modified atmosphere packaging (MAP) is influenced by respiration rate of the product and the gas permeability of the packaging film (Song et al., 2002; Caleb et al., 2013a). Current MAP design considers the respiration rate of product as the only important parameter for deciding target gas barrier properties required to achieve an equilibrium modified atmospheres. However, besides in-package gas composition it is also important to control the in-package level of relative humidity, in order to avoid condensation and/or mould and bacterial development in MAP systems.

Most polymeric materials (polyethylene, polypropylene or polyvinyl chloride) used in fresh produce packaging have lower water vapour transmission rate relative to the transpiration rates of fresh produce. Therefore, most water molecules evaporated from the produce do not escape through the film and remain within the package, enhancing the water vapour pressure in the package microenvironment. Under these near-saturation conditions, even minor temperature fluctuation may result in condensation inside the package resulting in sliminess, decay, enhancement of microbial growth, and browning of produce surface (Ayala-Zavala et al., 2008; Linke and Geyer, 2013). Micro-perforated packaging films are commonly used in fresh produce packaging to enhance O_2 and CO_2 gas permeability and achieve equilibrium MAP. But generally such films do not allow the diffusion of sufficient amounts of water vapour into the environment leading to high humidity levels and condensation of water vapour in the package. A possible solution to control humidity is to use of moisture absorbers to remove excess moisture from the packaging headspace (Mahajan et al., 2008b). These moisture absorbers have beneficial effect on the shelf life by lowering the surface moisture content, reducing microbial growth and better colour preservation (Shirazi and Cameron, 1992). However, the moisture absorber should be used carefully for high water activity

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products like fresh fruit and vegetables since excessive weight loss of food must be avoided.

Recently, Singh et al. (2010) and Saengerlaub et al. (2011) developed humidity regulating package system by directly incorporating the active substance (NaCl) in the packaging material. It consists of 3-layer structure: barrier layer, active layer with NaCl and sealing layer. The active layer consisted of polypropylene with different percentage of NaCl (6, 12 and 18%) and it was foamed and stretched in order to form cavities around salt particles. The authors evaluated the impact of humidity regulating trays on the quality of fresh mushrooms. Based on both sensory and biochemical analysis, it was reported that the shelf life of fresh mushrooms was significantly increased by 6 days (d) in trays with 18% NaCl on a weight basis in the active layer as compared to conventional pack at 5 °C. However, limited information is available on the transpiration and condensation behaviour of mushroom and the package, respectively. The objectives of this study were (i) to investigate the transpiration behaviour of mushroom under different storage conditions, and (ii) to assess humidity regulation and condensation behaviour in humidity-regulating tray containing mushrooms.

2. Materials and methods

2.1. Plant material and packaging tray

White button mushrooms (*Agaricus bisporus*) were obtained at commercial maturity from Frucht Express GmbH, Groß Kreutz, Germany and transported in chilled conditions to the Department of Horticultural Engineering Laboratory, Leibniz Institute for Agricultural Engineering, Potsdam, Germany. On arrival, the mushrooms were carefully sorted into uniform sizes and stored at the study temperatures (4, 12 and 20 °C) for thermal equilibrium. Initial average weight, density and moisture content of mushroom were found to be 14.4 g, 619 kg/m^3, and 92.3%, respectively.

The humidity-regulating tray used in this study was incorporated with NaCl (18% on a weight basis) between the outer barrier layer (polypropylene) and the inner sealing layer (polypropylene/EVOH/polyethylene). The sealing layer (inside) guarantees the tray in total is sealed and prevents the migration of salt into the food whereas the barrier layer (outside) protects the product against gas exchange with the surrounding atmosphere. The annotated diagram of the humidity-regulating tray is presented in Fig. 1. The multilayer film was extruded and the trays ($178 \times 225 \times 50\,mm^3$) were thermo-formed as reported by Singh et al. (2010).

2.2. Transpiration behaviour

To evaluate the transpiration rate (TR) of mushrooms, a mass loss technique as reported by Mahajan et al. (2008b) was followed. Mushrooms of an average initial mass of 14.4 g were stored in modified atmosphere storage chambers (200 L) maintained at different temperatures (4, 12 and 20 °C) and relative humidity (RH) (76, 86, 96 and 100%). Air humidity sensor FHA 646R (Ahlborn, Holzkirchen, Germany) was used to monitor air temperature and RH with an accuracy of ±0.1 °C and ±2%, respectively. The humidity sensor was calibrated in the high humidity range. Inside each chamber the RH was controlled by using saturated salts solutions of sodium chloride, potassium chloride, potassium nitrate and distilled water for maintaining 76, 86, 96 and 100% RH. At regular intervals, the chamber was opened and mushrooms were weighed using an electronic balance. Transpiration rate was expressed as change in mass of mushroom per unit initial mass per unit time, using Eq. (1):

$$TR = \frac{M_i - M}{t \times M_i} \quad (1)$$

where TR is the transpiration rate in mg kg^{-1} s^{-1}, M_i is the initial mass of mushroom in kg and M is the mass of mushroom in mg at weighed time t in seconds.

A separate study was conducted to monitor the surface temperature of a single mushroom at 100% RH and 13 °C. Mushroom and evaporation sphere, having volume-surface ratio of 0.60 and 0.75, respectively, were hung separately to the bottom of electronic weighing scales using a fishing string. Surface temperature of mushroom was measured using the infrared temperature sensor (AMIR 7842, Ahlborn, Holzkirchen, Germany) shown in Fig 2. The evaporation sphere consisted of a hollow perforated plastic sphere (diameter 45 mm) filled with water storing granulate material (polyacrylamide) (Linke et al., 2008). Mass loss of both objects was monitored continuously using electronic balance connected to the data logger (ALMEMO 2490, Ahlborn, Holzkirchen, Germany). At the end of 100 h of storage, the chamber was opened to allow the RH to decrease to the surrounding level (65%). Measurements were further continued for 20 h.

2.3. Packaging and performance evaluation

Mushrooms (250 g) were packed in the humidity-regulating trays and in control-polypropylene trays (control-PP) without salt.

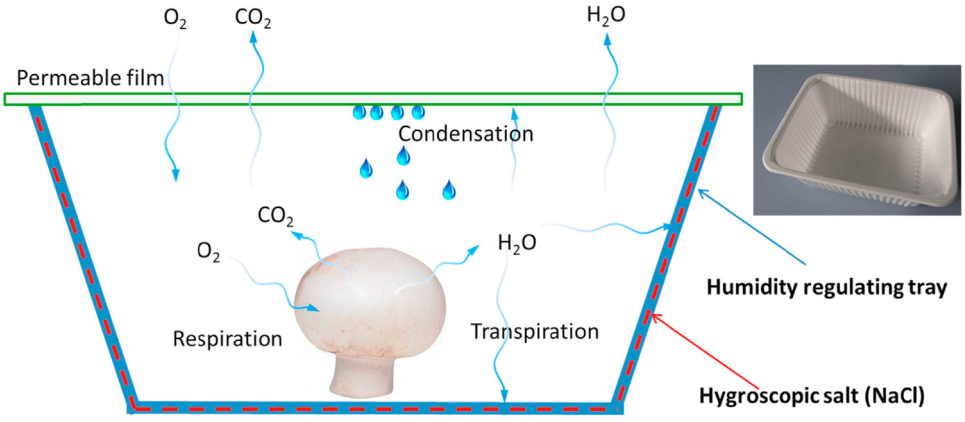

Fig. 1. Concept of humidity-regulating tray. Insert on right: a tray containing 18% NaCl on a weight basis in its active layer.