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Modelling the influence of time, temperature and relative humidity conditions on the mass loss rate of fresh oyster mushrooms

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ABSTRACT

The use of poorly designed packaging for high metabolic fresh produce like oyster mushrooms may lead to condensation inside the package and to shelf-life shortening. In order to quantify transpiration rate (TR) of oyster mushrooms and to develop an empirical predictive model that will allow to design an effective packaging system, fresh mushrooms were stored at 2, 6, 10, 14 and 18 °C and at 86, 96 and 100% relative humidity (RH) under an ambient atmosphere. Periodically, mushroom mass was recorded over 248 h of storage. TR of mushrooms ranged between 0.52 (±0.04), at 2 °C and 100% RH, and 3.88 (±0.41) $g.kg^{-1}.h^{-1}$ for mushrooms stored at 18 °C and 86% RH. An empirical mathematical model considering the effect of temperature and RH was developed. Temperature effect was explained using an Arrhenius model and the constants of the model were fitted into linear equations to explain the effect of RH on TR.

1. Introduction

Fresh fruits and vegetables continue their active metabolism after harvest, which drives severe losses of produce quality and shelf-life. Respiration and transpiration are the main physiological factors affecting postharvest quality retention (Kader, 2002). Harvested horticultural products release water vapour into the surrounding atmosphere through the process of transpiration, whereas the respiration process uses reserves of organic materials and also releases water vapour.

Modified atmosphere packaging (MAP) is a technique widely used to extend the shelf-life of fresh produce by slowing down respiration. Nevertheless, its use can become a problem due to water accumulation as condensation inside the package and at the surface of the product promoting microbial growth and sliminess (Linke and Geyer, 2013; Song et al., 2001, 2002; Sousa-Gallagher et al., 2013).

This problem occurs because the choice of the packaging film used in a MAP system is usually based on O_2 and CO_2 permeability rates and not on water vapour permeability rate. The in-package humidity is influenced directly by transpiration and indirectly by respiration of the fresh produce, as well as the water vapour permeability of the packaging material, the fluctuation of storage temperatures and the package size (Linke and Geyer, 2013; Mahajan et al., 2016; Rux et al., 2016). Therefore, knowledge of water loss rate, usually described in the literature as transpiration rate (TR), and the development of reliable TR models could improve the selection of packaging materials for fresh produce.

Among mushrooms available in the market, *Pleurotus* are one of the most consumed around the world due to its unique flavour, gastronomic versatility and nutritional and health benefits (Jedinak and Sliva, 2008; Manzi et al., 2001; Roy and Prasad, 2013). Despite this increasing consumption, mushrooms in general, present very short shelf-lives, as a result of their high metabolism and lack of cuticle, leading to high superficial dehydration (Ares et al., 2007;

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Bano and Rajarathnam, 1988; Villaescusa and Gil, 2003). No previous studies on the transpiration rate modelling of oyster mushrooms have been found in the literature.

The objectives of this work were to determine the transpiration rate using a gravimetric approach (mass loss rate), under controlled environmental conditions (temperature and RH) and to model the effect of these variables on the TR of fresh *Pleurotus ostreatus* mushrooms.

2. Materials and methods

2.1. Mushrooms sample

Oyster mushrooms (*Pleurotus ostreatus*) grown in Wexford, Ireland were bought and transported to the laboratory. Mushrooms were immediately sorted by appearance, and prepared for mass loss measurements, according to Leonardi et al. (2000) by placing them in 6.5 L plastic containers.

2.2. Measurement of mass loss during storage

Mushrooms were stored at 2, 6, 10, 14 and 18 °C and 86, 96 and 100% of RH. In each container, RH was controlled by using saturated salt solutions of potassium chloride and potassium nitrate (providing 86 and 96% RH, respectively) and distilled water (to create the saturated atmosphere of 100%), placed at the bottom of the container (Patel et al., 1988). Lids were placed and the container was sealed with petroleum jelly.

Temperature and RH inside the container were monitored using a data logger (HMP50, Campbell Scientific Inc., Utah). Furthermore, a gas analyser (Checkmate, 9900, PBI Dansensor, Denmark) was used to measure possible changes in the atmosphere inside each container. It was confirmed that the experimental setup provided a constant temperature, RH and gas composition throughout the experimental run.

At regular intervals, mushrooms were weighed using an analytical balance (Precisa 1000C-3000 D). The plastic containers were opened momentarily (less than 1 min) to take out the samples for weighing. After weighing, the plastic containers were opened to bring the samples back and then closed for 12 h until next measurement. Transpiration rate (TR, $g.kg^{-1}.h^{-1}$) was determined based on the slope (dM/dt) of the graph of changes in mass of oyster mushrooms over time (h), where M (kg) is the mushroom mass at any time and M_0 (kg) is the initial mushroom mass (Eq. (1)).

$$TR = \frac{dM}{dt} \times \frac{1000}{M_0} \tag{1}$$

For each temperature and RH conditions, two sampling times were performed daily (approximately 12 h between each measurement) over a maximum 248 h period. Four replicates were used for each storage condition, and the entire set of experiments was replicated twice.

2.3. Data analysis

Effect of temperature and RH on TR of oyster mushrooms was evaluated through the use of a two-way analysis of variance (ANOVA), using IBM SPSS Statistics Version 23.0 (IBM, 2015). Multiple comparisons were performed using the Tukey's test. All tests were applied at a 95% confidence interval. The constants of the model developed to describe the influence of temperature and RH on TR of oyster mushrooms were estimated by nonlinear regression using SPSS.

3. Results and discussion

3.1. Transpiration rate of oyster mushrooms

Normalized mass loss (M/M_0) of oyster mushrooms is shown in Fig. 1, at the specific temperature of 2 °C, as an example of the conditions tested. There was a linear decrease in mass over time. Therefore TR was obtained though the slope of mass loss against time for all the storage conditions tested. A linear decrease in mass with time has been previously observed for button mushrooms (Burton and Noble, 1993; Guillaume et al., 2010; Mahajan et al., 2008; Varoquaux et al., 1999), although different rates of mass loss were found. A similar trend was also found for other commodities, e.g. tomatoes and pomegranate (Caleb et al., 2013; Shirazi and Cameron, 1993).

Over a 248 h period, oyster mushrooms stored at 2 °C, lost significant amounts of mass for all RH conditions (Fig. 1). Mushrooms, stored at 2 °C and under saturated condition, had the least

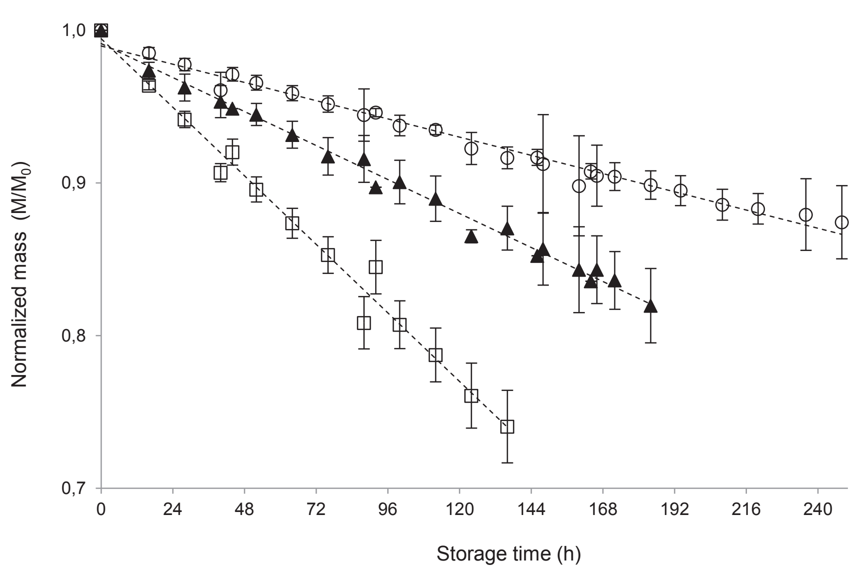

Fig. 1. Changes in normalized mass (M/M_0) of oyster mushrooms stored at 2 °C over time. Each point represents the mean of eight replicates, vertical bars represent the SE of the mean and lines represent the linear data fit. □ 86% RH; ▲ 96% RH; ○ 100% RH.