Postharvest Biology and Technology 136 (2018) 57–65

Contents lists available at ScienceDirect

Postharvest Biology and Technology

journal homepage: www.elsevier.com/locate/postharvbio

Influence of 1-MCP and modified atmosphere packaging in the quality and preservation of fresh basil

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ARTICLE INFO

Keywords:
Shelf life
Polyethylene bag
1-Methylcyclopropene
Quality
Edible herbs

ABSTRACT

A study was conducted to assess the individual and combined effect of 1-methylcyclopropene (1-MCP) and modified atmospheres packaging (MAP) in preserving basil (*Ocimum basilicum* L.) leaves. Fresh samples were stored at 11 °C and 85% RH, by packing them in sealed LDPE bags and in open macro-perforated LDPE bags with and without previous exposition to 1-MCP. Preliminary evaluations were performed to define a suitable 1-MCP dose in solution and exposure time being these, 0.3 $cm^3\ m^{-3}$ and 24 h, respectively, and to preconfigure the MAP system with satisfactory gas levels, obtaining steady concentrations inside the packaging of ca. 10.5% of O_2 and 4.2% of CO_2. The combined treatment of MAP and 1-MCP increased the storage life of the basil leaves up to 18 days, compared to 9 days in the control samples (stored at 11 °C in open bags without 1-MCP exposure), delaying changes in the evaluated quality properties.

1. Introduction

Basil (*Ocimum basilicum* Linn.) is an edible herb with a high demand at the global level due to its organoleptic characteristics and its nutraceutical, antibacterial, anticarcinogenic and antioxidant properties (Bernhardt et al., 2014; Bušić et al., 2014; Hussain et al., 2008; Pandey et al., 2016). Despite these qualities, its supply and marketing is limited by its short shelf life, which is between one and two weeks, depending on the storage temperature (Cantwell and Reid, 2001; Hassan and Mahfouz, 2010). This short shelf life is the result of stress caused by high or low temperatures, mechanical damage such as detachment from the plant, excessive handling and change in the light intensity, which leads to an increase in respiration and transpiration rates, ethylene production and action, and accelerate the process of senescence (Berry et al., 2010). These processes must be adequately controlled in the postharvest handling and storage to avoid inducing weight loss, chlorophylls and protein degradation and decay on the leaves that result in the overall loss of the produce quality (Hassan and Mahfouz, 2010; Sudheer and Indira, 2007).

To increase the shelf life of basil is possible to use various storage methods such as low temperatures, 1-methylcyclopropene (1-MCP) to control the ethylene action and modified atmosphere packaging. At 10 °C, basil shelf life can be extended up to 8–12 days (Da Silva et al., 2005) whereas at 20 °C, its shelf life is ca. 4 days respectively (Berry et al., 2010). However, temperatures below 10 °C could lead to chilling injury with appearance of darkened pitted lesions on the leaves and decay (Hassan and Mahfouz, 2010; Lang and Cameron, 1994).

The 1-MCP is an ethylene action inhibitor that occupies the membrane receptors irreversibly blocking the signal transduction that lead to the gene transcription related to ripening and senescence (Jiang et al., 1999). The 1-MCP has ten times higher receptor affinity compared to ethylene and is active at lower concentrations (Blankenship and Dole, 2003). This compound has been used in several studies as an ethylene antagonist to slow down the degradation of chlorophylls and senescence of basil leaves as well as maintain the antioxidant capacity of coriander leaves (Hassan and Mahfouz, 2010, 2012). In studies in broccoli, it was found that 1-MCP decreased the degradation of chlorophylls, respiration rate and increased its postharvest life (Gang et al., 2009).

The modified atmosphere packaging (MAP) have been used in turn to delay senescence by balancing the produce respiration, transpiration and ethylene production with the gas exchange through the packaging system used. (Castellanos et al., 2016b; Domínguez et al., 2016). This leads to low O_2 levels and moderate CO_2 levels in the packaging headspace which are favorable to preserve the quality properties in the packed produce (Mendoza et al., 2016). In studies conducted for basil, it was possible to extend its shelf life up to 15 days by using an atmosphere of 5% of O_2 and 5% of CO_2 with low density polyethylene (LDPE) bags and at 10 °C (Camargo, 2008). In other studies with 'Holy' basil, it was possible to preserve the produce up to 9 days using

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http://dx.doi.org/10.1016/j.postharvbio.2017.10.010
Received 12 August 2017; Received in revised form 22 October 2017; Accepted 22 October 2017

different macro-perforated polypropylene bags with O_2 concentrations between 11 and 18% and CO_2 between 0.7 and 1.8% at 10 °C (Niamthong et al., 2007). However, in the available literature have not been found so far, studies combining the use of 1-MCP and MAP systems at low temperatures to preserve edible herbs and specifically basil.

Considering the above, the aim of this study was to evaluate the individual and combined effect of 1-MCP and modified atmosphere packaging in the postharvest quality and storage life of fresh basil at a suitable storage temperature. For this, an appropriate concentration and exposure time of 1-MCP and through the simulation of the evolution of gases in the packaging system, a suitable MAP configuration were predetermined in order to obtain the best preservation of the basil samples.

2. Materials and methods

2.1. Fresh basil leaves

Basil samples (*Ocimum basilicum* L. v. nufar) were kindly provided by the company Morenos Ltd. (Bogota, Colombia) from a plantation located in Espinal, Department of Tolima, Colombia. Basil plants were harvested 3 months after seeding by cutting samples (stem with leaves) of 15–20 cm long. After the harvest, cut samples were placed in baskets with water and stored at 12 °C for 8 h to preserve their freshness until packaging and storage. Then, the samples were left to dry (only removing the excess surface water) in air at the same temperature and then were packed in macro-perforated low-density polyethylene (LDPE) bags; bunches of 500 g per bag. The packed samples were finally transported to the Postharvest Laboratory, Faculty of Agricultural Sciences, Universidad Nacional de Colombia (Bogotá, Colombia) in the following day, for the different storage tests. Samples with symptoms of disease, insect spoilage, wounding and yellowing were discarded before the experiments. In the basil samples was not made any disinfection treatment because their sensitivity to excessive or improper handling (DAFF, 2012), which could have resulted in quality deterioration and alteration of the results obtained.

Before the main storage experiments (see below), tests were conducted to define on the one hand, the most appropriate dose of 1-MCP and exposure time and on the other hand, to establish a suitable modified atmosphere packaging. All tests were performed at 11 °C to do not induce chilling injury (Niamthong et al., 2007).

2.2. Packages

For the tests in MAP, low density polyethylene (LDPE) bags with a thickness of 0.051 mm and a size of 38 × 40 cm were used. The bags were provided by Diplast Ltd. (Bogotá, Colombia) with a moderate permeability to O_2 and high permeability to CO_2 and water vapor compared to other polymeric films. For the tests without MAP, macro-perforated low-density polyethylene (LDPE) bags with a thickness of 0.020 mm and a size of 23 × 36 cm were used to pack the samples but were left unsealed. The bags had 18 perforations of 5 mm in diameter and were also provided by the manufacturer described above.

2.3. Determination of an appropriate exposure time and 1-MCP dose

The 1-MCP used for the treatments was released from a commercial powdered formulation (EthylBloc® Floralife Inc., Walterboro, SC, USA) with an original content of 0.43% (w/w) 1-MCP. To prepare the concentrations in solution, the powder formulation was completely dissolved in distilled water at 40 °C in a beaker and then the 1-MCP was left to volatilize within hermetic chambers of 30 l containing ca. 1250 g of basil during different exposure times. Basil bunches were treated by exposing them at four different 1-MCP concentrations in solution, 0, 0.3, 0.6 and 0.9 $cm^3\ m^{-3}$ (µl l^{-1}; microliter per liter) and three different exposure times, 12, 16 and 24 h respectively. Exposure to 1-MCP was conducted in the dark at 15 °C for all treatments. After this, bunches of 50 ± 5 g were packed in the macro-perforated LDPE bags and were left at 11 ± 2 °C until deterioration was evidenced. For each treatment, the evolution in weight loss, respiratory intensity (r_{CO2}), chlorophyll content, electrolyte leakage, color and shelf-life was evaluated in the basil bunches.

The experiments were conducted using a completely randomized factorial design, being the factors the different treatments with 1-MCP (dose and exposure time before the storage), in addition to the control samples (without 1-MCP) with four replicates for each treatment. An analysis of variance (ANOVA) was performed for the properties of the basil samples that fulfilled the assumptions of normality and homoscedasticity (weight loss, CO_2 production rate, chlorophyll content, electrolyte leakage and color) and the significant differences between mean of the measured properties were determined by using a Tukey's Test ($p < 0.05$). The Kruskal-Wallis test was performed to analyze the properties of the basil samples that did not meet the normality assumptions (overall visual quality and storage life) and then, the Wilcoxon test ($p < 0.05$) was made to compare the mean values. The statistical software used was RStudio® (version 1.0.44).

Once the suitable treatment with 1-MCP (dose and exposure time) was determined, this was used in the main storage tests.

2.4. Definition of the MAP system

Before the storage tests in MAP, it was assessed whether the LDPE bags to use were suitable for preserving the basil samples through a previous simulation of the change in concentration of gases in the packaging headspace. The respiration and the transfer of gases through the package were considered according with the model proposed in Castellanos et al. (2016a). The basis of this assessment was to ensure that the O_2 and CO_2 concentrations inside LDPE bags were steady and within the recommended limits for storage in MAP; 2–10% of O_2 and 1–10% of CO_2 (Mangaraj and Goswami, 2009; Sandhya, 2010).

To perform the simulation, the O_2 consumption and CO_2 production rates of the basil leaves were determined experimentally using a closed system method at 11 °C as described in Mendoza et al. (2016). 55 ± 3 g of basil were placed in open glass container of 2000 cm^3 during an hour of acclimatization at the experiment temperature and then hermetically sealed. The O_2 and CO_2 concentrations in the headspace were measured by taking a gas sample of 5 cm^3 through a rubber seal on the top of the container, which was analyzed with an electronic analyzer Oxybaby® 6i (Witt-Gasetechnik GmbH & Co. KG, Witten, Germany). Five cm^3 of air were introduced into the container to replace the withdrawn sample. The tests were performed in temperature-controlled cabinets setting temperature in 11 ± 0.2 °C and taking measurements (four replicates) at regular intervals for up to 1.5 days, avoiding reaching the phase of anaerobic respiration. From the change in the level of gases, the experimental rates of O_2 consumption (r_{O2}) and CO_2 production (r_{CO2}) were estimated over time. A Michaelis-Menten enzyme kinetics with uncompetitive inhibition (MMU) was fitted to the experimental data obtained in the closed system to represent the r_{O2} and r_{CO2} for the basil samples considering the MMU kinetics has been successfully used for representing the respiration rates of many products (Mangaraj et al., 2015; Mendoza et al., 2016). The O_2 consumption (and the CO_2 generation) rate was expressed as:

$$r_{O_2} = \frac{r_{O_{2max}} y_{O_2}}{K_{m_{O_2}} + y_{O_2}\left(1 + \frac{y_{CO_2}}{K_{mu_{CO_2}}}\right)} \quad (1)$$

Where r_{O2} (here in mmol $kg^{-1}\ d^{-1}$) is the O_2 consumption rate (or r_{CO2} the CO_2 generation rate); r_{O2max} is the maximum O_2 consumption rate (or r_{CO2max} the maximum CO_2 generation rate), K_{mO2} and is the Michaelis constant, and K_{muCO2} is the inhibition constant due to CO_2 (Mangaraj et al., 2015; Mendoza et al., 2016). The experimental r_{O2}, r_{CO2}, y_{O2} and y_{CO2} data measured at 11 °C were fitted to Eq. 1 and the