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Combination of fogging and refrigeration for white asparagus preservation on vegetable stalls

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A B S T R A C T

The aim of this study was to assess the combined effect of fogging and cold plate refrigeration on white asparagus quality during storage on a vegetable stall. Of the three storage conditions (Control, C; Fog, F; and Fog-Cold plate, FC), FC ensured that white asparagus retained a fresher appearance and had a longer shelf life (at least 5 d). Weight loss was reduced in products stored under FC conditions; meanwhile, weight loss was up to 14% when asparagus were stored under C conditions for 3 d. In the case of asparagus stored under F and C, browning was observed and the visual appearance of the product deteriorated obviously after 1 d, whereas for products stored under FC, such deterioration occurred only after 3 d or more. The results demonstrated that FC could be a promising technique for white asparagus storage on vegetable stalls.

1. Introduction

White asparagus (*Asparagus officinalis* var. white) is a popular fresh vegetable with a high economic value because of its delicious taste and nutritional value, given that it contains vitamins, amino acids and trace elements (Eichholz et al., 2012; Huyskens-Keil and Herppich, 2013). Storage of white asparagus at ambient temperature and exposed to light, such as in a retail store, leads to rapid product quality deterioration: water loss, toughening and tip purple or green color changes caused by anthocyanin or chlorophyll synthesis (Chang, 1987; Simón and Gonzalez-Fando, 2011; Siomos et al., 2000). Weight loss is an important indicator of the quality of fresh produce. If the weight loss is around 3–10%, the produce begins to wilt or shrivel, and cannot be restored to its original condition (Harris, 1988), so becomes unsellable as fresh produce (Ben-Yehoshua and Rodov, 2003).

Temperature and humidity are factors that greatly influence product quality (Ndukwu, 2011) and should be controlled (Kader et al., 2001). Cold storage ensuring a low product temperature is a primary factor in shelf-life extension since it reduces water loss, physiological activity, respiration rate and the consumption of soluble sugars (Chang, 1983; Huyskens-Keil and Herppich, 2013; Lallu et al., 2000). Because of the loss of fresh appearance, the shelf life of asparagus is about 11–14 d at a storage temperature of 5 °C, 6 d at 10 °C and 1–2 d at room temperature (Chang, 1983; Simón and Gonzalez-Fando, 2011). On the other hand, humidity is critical because it can influence the maintenance of acceptable visual quality and the microbiological quality (Fallik, 2014). Optimum relative humidity for the storage of most fresh fruits and vegetables is 85–95% (Hung et al., 2011; Maguire et al., 2004; Paull, 1999; Rennie et al., 2003) and suitable storage conditions for fresh asparagus storage are: 0–2 °C and 95–100% humidity (Paull, 1999). High ambient humidity combined with low temperature is thus necessary for product quality preservation.

Fogging is a technology that has been applied in order to preserve the shelf life of fresh produce on stalls at retail outlets for two decades. In the USA, about 90% of the major retail supermarkets mist vegetables (Barth et al., 1992). Fogging is used to raise the humidity in order to prevent dehydration, to improve the appearance of the produce and to extend the shelf life of fresh produce such as fresh fruit and vegetables, and recently fresh meat also (Brown et al., 2004, 2007). Fogging is also used to enhance heat transfer during post-harvest cooling. Heat transfer can be two point eight times higher with fog than with dry air alone (Allais and Alvarez, 2001). Fogging also helps maintain good fresh produce appearance. Besides reducing weight loss, fogging can maintain other quality attributes (Brown et al., 2004; Hung et al., 2011; Saenmuang et al., 2012). Moreover, fogging decreases the

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Nomenclature

D_d Droplets diameter, m
k Mass transfer coefficient between water droplets on product surface and air, m s^{-1}
k' Mass transfer coefficient for condensation, m s^{-1}
m Mass, kg
$\dot{m}$ Mass variation, kg s^{-1}
P Pressure, Pa
T Temperature, K
V_a Air velocity, m s^{-1}
W_d Mass fraction of droplet in air, kg droplet/kg air
α % of opening stomatal pores, dimensionless
β % of wet surface on the product, dimensionless

Subscript
a Air
cond Water condensation on the product surface
d Droplet
d dep Droplet deposition on product surface
d evap Droplet evaporation from product
infl Water infiltration from droplets to product
opt Optimal
p Product
p evap Water evaporation from product to air
sat Saturation
w prod Water on product

populations of microorganisms on the fresh produce surface, especially in the case of fresh fruit and vegetables (Brown et al., 2004; Mohdsom et al., 1995). Inversely, intense fogging can wet the surface of produce and cause the stomata to open, which consequently resulting in water loss (Lange et al., 1971).

Therefore, the determination of the influence of combined fogging and refrigeration on white asparagus quality during sale in stores at ambient temperature was the objective of this study. In stores, fogging is sometimes used, but the choices of operating conditions have non-empirical evidences. Moreover, no studies related to the use of fogging combined with cold plate refrigeration for extending the shelf life of fresh produce during display on vegetable stalls have been reported in spite of the beneficial effects of high humidity and low temperature on vegetable quality preservation.

2. Materials and methods

2.1. Fogging system

The fogging system consists of two elements: a device for producing fine water droplets (manufactured by Areco, reference OD V7) and a control box (Fig. 1). In the fog production device, water is sent to the tank in which two piezoelectric ceramic devices are installed. The application of alternating electrical voltage to the piezoelectric ceramics generates oscillation of the devices and water agitation, and fine water droplets are produced in this manner. The water droplets are transported to the outlet (a cylinder with orifices of a diameter of 0.01 m) using a fan. The intensity of piezoelectric vibration and the air flow rate can be varied using the control box.

Measurement of the water droplet size distribution was carried out with a Spraytec device (Malvern Instruments Ltd., UK, range of particle size 1×10^{-7}–9×10^{-4} m diameter) (Fig. 2).

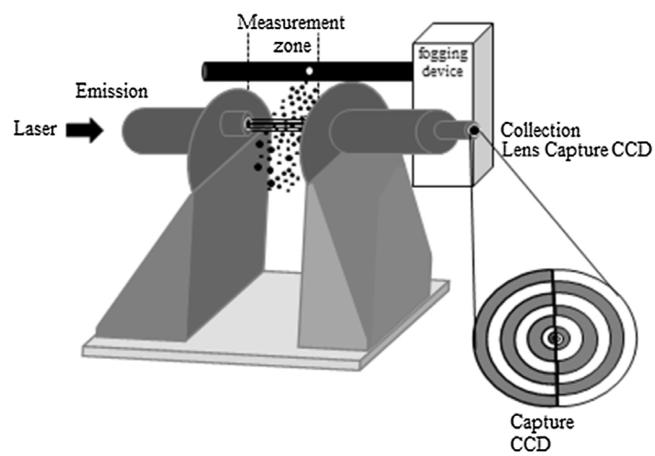

Fig. 2. Device for measurement of the water droplet size distribution (Spraytech).

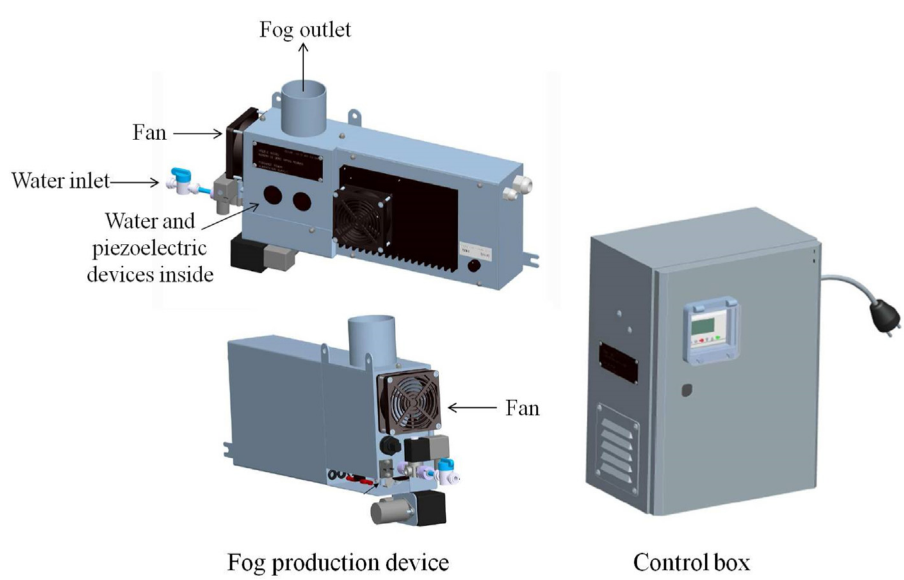

Fig. 1. Fogging system used in this study.