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Effects of heat treatment on atmospheric composition and color of peeled white asparagus in modified atmosphere packaging

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ABSTRACT

Freshly harvested spears of white asparagus were subjected or not to heat treatment by immersion in a hot water bath at 55 °C for 3 min, then left unpeeled or were peeled before wrapping in 16 μm stretch film and stored at 3 °C for 6 days. During storage, the atmosphere within the packages was sampled for O_2, CO_2 and C_2H_4 determination, while spear fresh weight, color and anthocyanin content at the 3 cm apical peel segments were determined before and after storage. The results showed that CO_2 concentration in packages of white asparagus spears was not greatly influenced by peeling or heat treatment. On the other hand, a higher package O_2 depletion of treated (peeled or heated) spears was observed. Peeling also resulted in an increase of ethylene peak concentration, indicating wound-induced ethylene production, which was suppressed by heat treatment. The initial color of the whole spear was retained, while the appearance of a violet coloration on the spear tip was prevented by heat treatment in both unpeeled and peeled spears.
Industrial relevance: Peeled white asparagus has drawn the attention of industry as a novel lightly processed product. The combination of heat treatment with modified atmosphere packaging (MAP) could be used to improve the storage life of this product. Moreover, both peeling and heat treatment cause changes in ethylene production and respiration rate of asparagus spears and this information could be useful for development of novel application to MAP design for lightly processed (peeled) white asparagus.

1. Introduction

Modern consumption trends for convenient and fresh food have led the horticultural industry towards production of lightly processed, ready-to-use products. Among many vegetables, peeled white asparagus (*Asparagus officinalis* L.) has drawn the attention of industry and research as a novel lightly processed product.

The texture is probably the most important factor in determining eating and cooking quality of fresh asparagus and excessive fiber is an undesirable textural quality characteristic. Toughening of asparagus is mainly due to spear lignification in both the fiber ring and the vascular bundles (Chang, 1987) and there is a basipetal increase in toughness (Siomos, Sfakiotakis, & Dogras, 1994; Brovelli, Cuppett, & Uhlinger, 1998; Papadopoulou, Siomos, & Dogras, 2003). Thus, peeling is essential for good ready-to-eat quality.

The physiology of the lightly processed fruits and vegetables is essentially one of the wounded tissues and is characterized by increased respiration and ethylene production. Other consequences of wounding are chemical or physical in nature, such as oxidative browning reactions or enhanced rate of water loss (Brecht, 1995). Moreover, in response to tissue wounding, many secondary compounds are synthesized, many of which may affect the product's color. For example, wounded lettuce had higher phenolic content and antioxidant capacity compared to non-wounded tissue, while phenol oxidation resulted in the so called browning complex (Kang & Saltveit, 2002). Therefore, some color changes could be expected as a result of the wound-induced response caused by spear peeling.

The color of the whole spears as well as of the tips is used to evaluate white asparagus spears in relation to specifications for grades and standards imposed by the Commission Regulation (EEC) No 454/92 (1992) and its amendments. Color of the tips is the basis for sorting white asparagus into commercial grades and spears with a purple color in the tip are judged to be of a lower quality (Siomos, 2003). Violet coloration of the tip is due to anthocyanin synthesis in the epidermal tissues. Our results (Siomos et al., 1994; Siomos, Dogras, & Sfakiotakis, 1995; Siomos, Sfakiotakis, Dogras, & Vlachonasios, 1995; Siomos, Sfakiotakis, & Dogras, 2000; Siomos, Dogras, & Sfakiotakis, 2001) indicate that postharvest anthocyanin synthesis in white asparagus spears progresses, after an initial stimulation by light, irrespective of temperature and light conditions during storage, resulting in the appearance of purple color in the apical segment of the spears. Discoloration of the whole spear (loss of the initial white color) is due to the yellowing or browning induced by oxidative processes and enzyme activities, which are also initiated by high temperature (Lipton, 1990).

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Modified atmosphere packaging (MAP) (Siomos et al., 2000) and heat treatment (HT) by immersion in water at 55 °C for 2–3 min (Siomos, Gerasopoulos, & Tsouvaltzis, 2005) have been found to be the most effective treatments to retain the initial color of unpeeled spears. However, the effect of these treatments on the color of peeled spears is unknown. Moreover, the combination of HT with MAP could be used to improve the storage life of peeled asparagus, since it has been reported to result in beneficial effects on the quality of many fruits and vegetables (Fan, Toivonen, Rajkowski, & Sokorai, 2003; Suparlan & Itoh, 2003; Ali, Nakano, & Maezawa, 2004; Malakou & Nanos, 2005).

It should be mentioned that HT causes changes in ethylene production and respiration rate of fruit and vegetables, which varies considerably and depends largely on treatment temperature and length of exposure (Lurie, 1998). However, the effect of HT on the respiration rate and ethylene production of peeled asparagus is still unresolved and this information could be useful for application to MAP design for this product, since it has been found that high CO_2 has a beneficial effect on the initial white color retention (Siomos et al., 2000, 2001), while ethylene has a detrimental effect on toughening by enhancing it (Lipton, 1990).

Therefore, this work investigates the effect of the combination of HT and MAP on the color of peeled white asparagus spears as well as the effect of HT on atmosphere composition of peeled white asparagus during storage at 3 °C for 6 days under MAP.

2. Materials and methods

2.1. Plant material and handling

White asparagus (*A. officinalis* L.) spears of the cultivar 'Dariana' were morning harvested from ridged plants of a commercial plantation near Giannitsa, Macedonia, Greece and immediately placed into lidded styrofoam containers to avoid light exposure. After 3 h transportation in darkness at ambient temperature (ca. 20 °C), the spears were immersed in cool water (1–2 °C) for 10 min, trimmed to 23 cm in length and washed thoroughly. Straight and undamaged spears, 16–24 mm in diameter (measured at the middle of the spear) with closed bracts were selected for the experiments.

2.2. Treatments

The spears were divided in two groups. Spears of the one group were immersed in a hot water bath held at 55 °C for 3 min (Siomos et al., 2005). After hot water treatment, spears were cooled in water containing 150 μL L^{-1} chlorine at ambient temperature for 10 min and then placed on absorbent paper to remove excess surface water. Spears of the other group were treated as above without immersion in a hot water bath. In each group, half of the spears were peeled with a sharp vegetable peeler starting 3 cm below the tip, while the rest remained unpeeled.

2.3. Packaging and storage

Spears of each replication were weighed, their color was measured and they were placed in polystyrene trays of 26 × 18 × 2.5 cm. The trays were hand wrapped with a 16 μm stretch film (Fabbri Arti Grafiche S.R.L-Vignola, Modena, Italy). The film surface area of each package was 468 cm^2. The film had O_2 and CO_2 transmission rates of 583 and 1750 mL $m^{-1} h^{-1} atm^{-1}$, respectively, and a moisture vapor transmission rate of 14.6 g $m^{-1} h^{-1} atm^{-1}$ at 39 °C and 90% RH (film permeability measured by the manufacturer). The trays were kept in a refrigerator at 3 °C for 6 days. For each treatment three replications were used; each replication consisting of ten spears.

During the whole handling operations, the spears were exposed to ambient light for about 3 h.

2.4. Package atmosphere analysis

The atmosphere within the packages was sampled at 1, 3, 6, 16, 26, 39, 49, 66, 80 and 110 h after wrapping. At each sampling time, three 1 mL samples from each package were taken using an insulin-type syringe through a rubber septum glued on the surface of the package for O_2, CO_2 and C_2H_4 determination in separation.

Oxygen and CO_2 were measured according to Saltveit and Strike (1989) by injecting the gas samples into a stream of N_2 carrier gas flowing through a CO_2 and O_2 analyzer (model Compo 280, David Bishop Instruments, UK).

Ethylene was measured by injecting the gas sample into a Varian 3300 gas chromatograph (Varian Instruments, Walnut Creek, CA) equipped with a 60/80 porapak N column and a flame ionization detector. Operating conditions were: detector at 120 °C, injector at 80 °C and column at 50 °C. The flow rate of the Argon carrier gas was 30 mL min^{-1}.

2.5. Color and anthocyanin determination

At the end of storage, spears of each replication were weighed, their color was measured and the peel of the 3 cm apical segments was used for anthocyanin content determination. Three replications of both unpeeled and peeled spears were also used for the day zero evaluation of anthocyanin content.

Color measurements were made using a chromameter (Minolta CR-200, Minolta, Osaka, Japan), equipped with an 8-mm measuring head and a C illuminant (6774 K). The meter was calibrated using the manufacturer's standard white plate. Color changes were quantified in the L^*, a^*, and b^* color space. Hue angle [$(h^0 = 180 + \tan^{-1}(b^*/a^*)$] and chroma values [$C^* = (a^{*2} + b^{*2})^{1/2}$] were calculated from a^* and b^* values. L^* refers to the lightness, ranging from 0 = black to 100 = white; h^0 value is defined as a color wheel, with red-purple at an angle of 0°, yellow at 90°, bluish-green at 180°, and blue at 270° and C^* represents color saturation, which varies from dull (low value) to vivid (high value). On each spear, two color measurements were made at two opposite sites at 2 and 11.5 cm from the tip.

Anthocyanins were extracted with 7 mL acidified ethanol (85:15 v/v of 100% EtOH:0.5 M HCl) per g peel f.w. overnight at 4 °C in darkness. The supernatant phase was filtered through a Whatman No. 1 filter and then was centrifuged at 12,000*g* for 20 min at 4 °C. Spectrophotometric measurement at 532 nm was performed, using extraction solvent as the blank. Peak absorbance occurred at 532 nm, as determined by scanning. For calculation of anthocyanin content, the anthocyanin extinction coefficient of 984 (g per 100 mL) cm^{-1} was used (Fuleki & Francis, 1968).

2.6. Statistical analysis

Data for color, anthocyanins and fresh weight loss were analyzed by analysis of variance (ANOVA) using a completely randomized design with three replications and the means were compared by the LSD test at the 0.05 level with the MSTAT version 4.00/EM (Michigan State University), while for package atmosphere (O_2, CO_2 and C_2H_4 concentration) means ± SE are presented.

3. Results and discussion

3.1. Package atmosphere composition

Atmosphere modification occurred rapidly within 1 h after wrapping spears with stretch film, when CO_2 content in the packages reached a maximum of 3.5–3.0% and decreased thereafter to equilibration levels of 1.5–2.0% by day 3 (Fig. 1). Rapid atmosphere modification was the result of high respiration rate of packaged spears (Papadopoulou, Siomos, & Dogras, 2001), but the degree of modification was not greatly influenced