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Effect of MAP with argon and nitrous oxide on quality maintenance of minimally processed kiwifruit

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Abstract

The shelf-life of minimally processed (MP) kiwifruit is principally limited by softening and colour degradation, caused by increased enzymatic activities as a consequence of wounding. Modified atmosphere packaging (MAP) with non-conventional gas mixtures was tested on the maintenance of some physico-chemical characteristics of MP kiwifruit slices, during refrigerated storage. Kiwifruit slices were sealed in polypropylene boxes that were stored in air (control) and in three different modified atmospheres: N_2 (90%), O_2 (5%), CO_2 (5%); Ar (90%), O_2 (5%), CO_2 (5%) and N_2O (90%), O_2 (5%), CO_2 (5%). The packed kiwifruit samples were stored at 4 °C for 12 days and the following quality parameters were monitored during storage: soluble solids content, weight loss, carbon dioxide and oxygen levels in the package headspace, texture changes and surface colour by a reflectance colorimeter (lightness, hue angle and chroma) and by image analysis (percentage of browning area). MA with 90% of N_2O was the best mixture of tested gases in order to maintain the quality of kiwifruit slices. The initial firmness value of kiwifruit slices (about 13 N) decreased only by 10% after 8 days in the sample packed in N_2O, while about 70% firmness loss was detected in the control sample after just 4 days of refrigerated storage. Kiwifruit slices in N_2O also maintained a better initial colour, in particular in terms of L^* and hue. Moreover, the use of image analysis showed less browning in both the pericarp and core surfaces of the samples in N_2O, compared to the control. Correlation analysis between texture and all colour results showed that the application of an image analysis technique allowed a good recognition of chromatic changes related to fruit softening. Score plots of principal component analysis (PCA) showed slight modifications in the most important discriminated quality factors for the sample in N_2O, a rapid quality loss for samples in air and in N_2 and an acceptable quality maintenance until the 8th day of storage for the sample in Ar.

Keywords: Kiwifruit; Minimally processing; MAP; Nitrous oxide; Argon; Image analysis

1. Introduction

Minimally processed (MP) fruit are products that maintain their attributes and quality similar to those

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of fresh products (Alzamora et al., 2000). However, the loss of cellular compartmentation, due to peeling and cutting, causes mixing of previously sequestered metabolites of the ethylene generating system stimulating ethylene production (Mazliak, 1983; Watada et al., 1990). Enzymatic activities, softening and ripening of kiwifruit are promoted by ethylene (Arpaia et al., 1985; Wegrzyn and MacRae, 1992). Therefore, it is difficult to maintain the quality of kiwifruit slices once they have been cut (Chien and Buta, 2003).

Abe and Watada (1991) found that the use of an ethylene absorbent prevented the accumulation of ethylene and was effective in reducing the rate of softening in packed kiwifruit slices. A sensory evaluation of kiwifruit cubes stored at 4 °C in closed circular polypropylene containers showed a decrease in texture properties after 2 days, and the appearance of a bitter flavour after just 4 days (O'Connor-Shaw et al., 1994). An extension of MP kiwifruit shelf-life from 3 days (control sample) to 10 days using a combination of $CaCl_2$ dips, and storage at 1 °C under an atmosphere of 2% O_2 and 5% CO_2 with an ethylene scrubber, was obtained by Massantini and Kader (1995). Agar et al. (1999) showed that fresh-cut kiwifruit had a shelf-life of 9–12 days if treated with 1% of $CaCl_2$ or 2% of calcium lactate, and stored at 0–2 °C in an ethylene-free atmosphere of 2–4 kPa of O_2 and/or 5–10 kPa of CO_2. The introduction of volatile compounds, in particular methyl jasmonate, inside polystyrene trays was effective in good quality maintenance of kiwifruit slices, up to 3 weeks of storage at 10 °C, compared to the control sample, but did not cause any differences in terms of respiration rate (Chien and Buta, 2003).

Most studies have been based on the effects of different CO_2 and O_2 levels on fruit metabolism to extend the shelf-life of whole and MP vegetables, packed in modified atmospheres (Lee et al., 1991; Mathooko, 1996; Watada et al., 1996; Gil et al., 1998; Beaudry, 2000). Recently, there has been a great interest in the potential benefits of argon (Ar) and other noble gases in MAP applications (Spencer, 1995; Mostardini and Piergiovanni, 2002).

In some studies, argon is reported to be biochemically active, probably due to its enhanced solubility in water compared to nitrogen and it seems to interfere with enzymatic oxygen receptor sites (Spencer, 1995). However, inconsistent results have been presented on the effect of Ar on inhibition and control of the growth of certain micro-organisms, on the activity of quality-related enzymes and on degradative chemical reactions in selected perishable food products, such as MP fruit (Powrie et al., 1990; Spencer, 1995; Day, 1996, 1998; Kader and Watkins, 2000; Jamie and Saltveit, 2001; Mostardini and Piergiovanni, 2002).

Another "new" packaging gas, nitrous oxide (N_2O), has been allowed for food use in the EU; however, little is known about its effects on MAP fruit. It seems that N_2O binds lipids and also proteins, such as cytochrome c oxidase (Gouble et al., 1995; Day, 1996). Sowa and Towill (1991) reported the action of N_2O on partial and reversible inhibition of respiration and cytochrome c activity in mitochondria isolated from seeds, leaves or cellular suspensions.

Moreover, Sowa et al. (1993) found that an exposure to 80% N_2O atmosphere reduced seedling respiration and root length of germinating *Phaseoulus vulgaris* L. seeds. Leshem and Wills (1998) showed that N_2O inhibits ethylene action and synthesis in higher plants. Furthermore, continuous N_2O gas treatment had a significant effect on inhibiting ripening by extending the lag phase which precedes the ethylene rise, delaying colour change in pre-climateric fruit of tomatoes and avocados (Gouble et al., 1995). Benkeblia and Varoquaux (2003) found that an exposure of onion bulbs to N_2O at different concentrations reduced the incidence of rots, especially in bulbs pre-treated with 100% N_2O for 4 days.

In previous research, we found that a non-conventional atmosphere (65% N_2O, 25% Ar, 5% CO_2, 5% O_2), combined with a dipping treatment in an aqueous solution of 0.5% of ascorbic acid, 0.5% of citric acid and 0.5% of calcium chloride for 3 min, maintained the fresh quality of MP apples for 12 days (Rocculi et al., 2004). However, to our knowledge, little data are available on the influence of Ar and N_2O on the shelf-life of MP fruit.

The aim of this investigation was to study the effect of the use of non-conventional gas mixtures of Ar and N_2O on the maintenance of high quality characteristics of minimally processed kiwifruit slices during refrigerated storage.