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SCIENCE DIRECT®
LWT 38 (2005) 323–329
LWT
www.elsevier.com/locate/lwt

Improved keeping quality of minimally fresh processed celery sticks by modified atmosphere packaging

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Received 6 April 2004; received in revised form 25 June 2004; accepted 30 June 2004

Abstract

Recommended storage conditions of green celery sticks are 4 °C for 10 days, but there are no reports about optimal modified atmosphere packaging (MAP) conditions to preserve them longer. The objective of this research was to describe the gas composition of MAP generated by two polymeric films and its effects on chemical, sensorial and microbial quality, and physiological disorders of celery sticks stored at 4 °C for 15 days. Green sticks of 15-cm length of 'Trinova' cv. were placed in hermetically sealed plastic bags: low-density polyethylene, oriented polypropylene (OPP) and polyethylene-perforated bags as control (air). The O_2 and CO_2 concentrations, soluble solid content, pH, titratable acidity, colour, sensorial quality and sugar and organic acids contents were monitored. Compared to the control, both MAP treatments improved the sensory quality, avoided the loss of green colour, decreased the development of pithiness and retarded the growth of microorganisms. In any treatment neither off-odours nor off-flavours were detected. After 15 days at 4 °C within the OPP bags a steady-state atmosphere of 6 kPa O_2 + 7 kPa CO_2 was reached and celery sticks stored under these bags showed the best quality.

Keywords: *Apium graveolens* L. var. dulce (Mill.); Minimally fresh processed; Overall quality attributes; Shelf-life

1. Introduction

Minimal processing of celery provides convenience for consumers and many economic benefits for producers. However, little information has been published about this product. Petioles are generally freshly processed by cutting them as sticks and they are used as snacks for appetisers. Celery sticks are very susceptible to decay, to loss of green colour and to development of pithiness, where parenchyma is transformed into aerenchyma. Pithiness is characterised by the appearance of whitish regions and air spaces within the tissue, and is a major source of quality loss and decreased shelf-life in celery (Saltveit & Mangrich, 1996). Extension of the shelf-life of sticks is of great interest for the industry of minimal processing.

The use of modified atmosphere packaging (MAP) keeps the postharvest quality and the shelf-life of a wide range of products. MAP implies the use of polymeric films of different permeabilities to O_2, CO_2, C_2H_4 and water vapour. Atmospheric modification generates within the package as a result of the respiration rate of the plant tissue and the gas diffusion characteristics of the film (Kader, 1992). Film selection and temperature are very important for obtaining the passive evolution of an appropriate atmosphere within the package.

Among the favourable effects of MAP on commodities are decreased respiratory activity, reduced weight loss mainly by improved moisture retention, protection from mechanical damage and minimisation of the

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0023-6438/$30.00
doi:10.1016/j.lwt.2004.06.014

incidence of decay and physiological disorders (Kader, 1986; Church, 1994; Artés, Castañer, & Gil, 1998; Beaudry, 1999; Artés, 2000).

Shelf-life of celery stalks can benefit from 2 to 5 kPa O_2 and 5 to 10 kPa CO_2 atmospheres at 2–4 °C (Saltveit, 1997; CSIRO, 1998; Suslow & Cantwell, 2000). It could be assumed that MAP of celery sticks should be designed to maintain both O_2 and CO_2 as close as possible to these levels.

The objective of this research was to characterise how MAP generated by two different films affects the overall quality of celery sticks in terms of colour, chemical properties (soluble solids content, titratable acidity (TA), pH, sugars and organic acids content), pithiness and decay development, as well as sensory parameters and microbial growth.

2. Materials and methods

2.1. Plant material

Horticulturally mature celery stalks cv. 'Trinova' were harvested from a greenhouse and transported to the laboratory where they were precooled at 4 °C by forced air. The next day the plants were carefully inspected, selecting those with similar visual appearance and free from defects. The minimal fresh processing was as follows. First, to avoid risk of microbial development, the stalks were immersed for 1 min into a 100 mg l^{-1} NaOCl water solution at 4 °C (pH 7.5) and bottled dry. Petioles were then cut to a length of 15 cm. Immediately after cutting they were immersed into 100 mg l^{-1} NaOCl water for 1 min at 4 °C. Then, they were rinsed, drained and packed in plastic bags (20 cm length × 20 cm width, 400 cm^3 volume) of either oriented polypropylene (OPP, 35 μm thick, permeability to O_2 5500 ml m^{-2} d^{-1} atm^{-1} and permeability to CO_2 10,000 ml m^{-2} d^{-1} atm^{-1} at 23 °C), low-density polyethylene (LDPE, 25 μm thick, permeability to O_2 7000 ml m^{-2} d^{-1} atm^{-1} and permeability to CO_2 35,000 ml m^{-2} d^{-1} atm^{-1} at 23 °C) or macroperforated polypropylene (four holes of 6 mm ∅ by dm^2) as a control (air). Bags were hermetically heat-sealed on the edges. A total of 10 sticks per bag were packaged (≈200 g bag^{-1}) and stored up to 15 days at 4 °C. Seven bags per treatment were used where each bag represented a replicate.

2.2. Atmosphere composition

Concentration of O_2 and CO_2 within the packages was periodically monitored. Gas samples were taken through a silicone septum with a plastic syringe from the headspace. O_2 and CO_2 were measured by injecting samples into a Thermofinnigan gas chromatograph (Trace GC, Milan, Italy) equipped with a thermal conductivity detector (temperatures for oven, injector and detector were 110, 150 and 150 °C, respectively) and provided with a Chromosorb 102 80/100 column (1.2 m × 2.0 mm ∅, Supelco Inc., Bellefonte, PA, USA).

2.3. Chemical quality

Each sample was blended with a standard blender (Solac 850, Vitoria, Spain) and the obtained juice was used for chemical analysis. Initially and at the end of cold storage, TA was quantified by titrating 10 ml of celery juice with NaOH 0.1 N to an endpoint of pH 8.1 (Metrohm 716 DMS titrator, Swiss) and expressed as g of citric acid 100 ml^{-1} (AOAC, 1984). The total soluble solids (TSS) content was measured with a digital refractometer (Abbe 1S, Barcelona, Spain) and expressed as °Brix. The pH was measured with the same equipment used for measuring TA.

For sugars and organic acid content, samples of juice that had been frozen (−70 °C) at the end of the experiment were then thawed and centrifuged (Sigma, 1–13 model, Germany) at 10,000*g* for 10 min. The supernatant was filtered twice, first by using a 0.45 μm pore size filter (Nylon filter media, Whatman, Clifton, NJ, USA) and then with a Sep-Pack Cartridge (Waters, Ireland). To determine the sugar composition a high-performance liquid chromatograph (HPLC), equipped with a refractive index detector (Hitachi, L-7490 model, Tokyo, Japan) and a LiChrospher 250-4 NH2 (5 mm) column (Merck, Germany), was used. Samples of 20 μl were injected using 85:15 acetonitrile:water (Merck, Germany) as mobile phase (1.5 ml min^{-1} of flow rate, ambient temperature).

To determine the organic acids composition the same HPLC was used but provided with a UV detector (wavelength 210 nm) and a LiChrospher 60 RP-select B (5 μm, Merck, Germany) column. Samples of 0.3 μl were injected using 99:1 potassium dihydrogen phosphate buffer:methanol (Merck, Germany) at a pH of 3 (adjusted with SO_4H_2) as mobile phase (0.7 ml min^{-1}, ambient temperature), adapted from Melgarejo, Salazar, and Artés (2000).

Standards were chromatographed for quantification and determination of retention times and were also (in some cases) co-chromatographed with the sample for identification. Standard calibration curves were obtained and used to estimate the sample contents. The sum of the sugars and the main organic acids detected was considered as the amount of total sugars and total organic acids, respectively.

2.4. Colour

At harvest and after cold storage the surface colour was determined on three spots along five randomly chosen sticks per bag. A compact tristimulus chroma-