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Controlled atmosphere preserves quality and phytonutrients in wild rocket (*Diplotaxis tenuifolia*)

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Abstract

Leaves of wild rocket (*Diplotaxis tenuifolia* (L.) DC.) are increasingly eaten alone or as part of mixed salads. This species contains a wide range of health-promoting phytonutrients including vitamin C and flavonoids. The effect of controlled atmosphere (CA) containing low oxygen and high carbon dioxide on the sensory and microbiological quality, flavonoids, vitamin C (ascorbic acid + dehydroascorbic acid; AA + DHAA) and antioxidant capacity evaluated by ABTS, DPPH and FRAP assays was studied. Rocket leaves stored in air were compared with those kept in 5 kPa O_2 + 5 kPa CO_2, 5 kPa O_2 + 10 kPa CO_2 and enriched air with 10 kPa CO_2 for up to 14 days at 4 °C. After 10 days, the sensory and microbiological quality of samples stored in air were not commercially acceptable. On the contrary, CA of 5 kPa O_2 + 10 kPa CO_2 maintained visual quality and controlled aerobic mesophilic and psychrotropic microorganisms as well as coliforms. The total flavonoid content of wild rocket was approximately 100 mg 100 g^{-1} fresh weight and remained constant during storage or even increased at the end of the shelf-life in CA, but it was degraded in those samples kept in air. In addition, AA was transformed into DHAA during storage, and the total content of vitamin C was higher in CA-stored samples than those kept in air. A decrease in the total antioxidant capacity was observed during storage and it was particularly marked in samples stored in air. A positive correlation was demonstrated between antioxidant capacity and vitamin C content, whereas a poor correlation was observed with total phenolics. Our data indicate that wild rocket leaves has potential as a good dietary source of phytonutrients when stored under optimal conditions.

Keywords: Antioxidant capacity; *Brassicaceae*; Flavonoids; Fresh-cut; Minimally processed; Phenolics; Storage; Vitamin C

1. Introduction

During the past 10 years there has been a growing interest by consumers in fresh-cut fruit and vegetables because of their freshness and convenience. In addition to extending shelf-life periods, food safety, high nutrient content and excellent sensory quality are also required. However, physical damage during preparation causes an increase in respiration rates, biochemical changes and microbial spoilage, which may result in degradation of color, texture and flavor of the produce (Cantwell, 1996). In other reports, minimal processing increases phenolic metabolism and therefore, the accumulation of phenolic metabolites in many fruit and vegetables (Tomás-Barberán et al., 2000). Generally, low O_2 or high CO_2 concentrations decrease respiration, reduce the number of postharvest pathogens, and the rate of deterioration (Kader et al., 1989). Nevertheless, the beneficial effects of CA can be reversed by too low O_2 or too high CO_2 concentrations. Therefore, fresh-cut products should always be stored under low temperature in addition to controlled or modified atmosphere (CA or MA) when showing a beneficial effect in maintaining quality, avoiding decay and inhibiting aerobic spoilage microorganisms and consequently extending shelf-life (Gorny, 1997).

Recently, new vegetable species have been introduced in the fresh-cut market due to an increasing interest in new special salads, which include baby lettuce and other greens.

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Wild rocket (*Diplotaxis tenuifolia*) is a member of the family *Brassicaceae* found wild in most Mediterranean countries. Like other cruciferous vegetables, rocket contains a range of health-promoting phytonutrients including vitamin C, fiber, flavonoids and glucosinolates (Crozier et al., 1997; Barillari et al., 2005). There is a great interest in knowing the nutritional value of foods to know the contribution of an individual food product to daily nutritional requirements and how storage affects quality and nutritive composition. As part of our studies on the nutritional role of fruit and vegetables, we have investigated the flavonoids and vitamin C contents of fresh-cut products as well as their changes due to different postharvest conditions (Gil et al., 1998a,b, 1999). Previous studies on wild rocket provide relevant information about the identification of glucosinolates (Bennett et al., 2002, 2004). However, little information is still available concerning the influence of storage conditions on the preservation of phytonutrients. The aim of this work was to determine the influence of CA on the sensory and microbiological quality as well as phytonutrients of wild rocket leaves.

2. Material and methods

2.1. Plant material

Fresh wild rocket leaves, *D. tenuifolia* (L.) DC., were supplied by Agrolito (Torre Pacheco, Murcia, Spain). Samples were transported 35 km under refrigerated conditions to the laboratory where they were stored at 4 °C for 24 h, prior to processing. A voucher specimen was deposited in the Herbarium of the Department of Botany of the University of Murcia.

2.2. Processing and storage conditions

Samples consisted of detached leaves with some stem. Leaves with defects such as yellowing, decay and bruising were discarded. Then, the leaves were washed with 100 mg l^{-1} total chlorine prepared from sodium hypochlorite (10%, w/v) (Panreac, Monacad i Reixac, Barcelona, Spain) adjusted to pH 6.5 with citric acid for 1 min at 4 °C. Excess surface water was removed by a handheld salad spinner (Dynamic model E-20, Vence, France) for 30 s. Approximately 100 g of leaves were placed in 1 l glass jars connected to a flow-through system providing humidified air or atmospheres of 5 kPa O_2 plus 5 kPa CO_2 (5 + 5), 5 kPa O_2 plus 10 kPa CO_2 (5 + 10) and air plus 10 kPa CO_2 (air + 10) for 14 days at 4 °C. Three replicates were used for each treatment at day 0, 6, 10 and 14 after storage.

2.3. Gas analysis

The rate of CO_2 production was measured using the above mentioned samples stored in air where a flow of 10 ml min^{-1} of humidified air was pumped into the jars to avoid dehydration and excessive CO_2 accumulation for 14 days. The increase in CO_2 content in the headspace was determined using a gas chromatograph (Shimadzu GC-14, Kyoto, Japan) equipped with a thermal conductivity detector (TCD). Samples were analyzed in triplicate and monitored during 14 days.

2.4. Sensory evaluation

The organoleptic characteristics including visual quality, stem browning, decay, texture and aroma of wild rocket were evaluated on day 0 and after 6, 10 and 14 days of storage by a five-member expert panel. For the sensory evaluation, panelists evaluated all 12 samples according to a completely randomized design. The expert panel was trained for their ability to discriminate between small variations in the sensory characteristics. Visual quality as gloss, freshness, color uniformity and intensity was evaluated and scored on a 9–1 scale, where 9 = excellent, 7 = very good, 5 = good, limit of marketability, 3 = fair, limit of usability and 1 = poor, inedible. Stem browning and decay were evaluated on a 5–1 scale, where 5 = severe, 3 = moderate and 1 = not affected. The weight loss was determined after each sampling date and expressed as percentage of the initial fresh weight (fw).

2.5. Microbial analysis

The growth of mesophilic, psychrophilic and coliforms bacteria in the leaves was followed during the experiment. Twenty-five grams of leaves were homogenized in 125 ml sterile 1% peptone buffered water (AES Laboratoire, Combourg, France) in sterile 400 Lab stomacher bags (Seeward Medical, London, UK) by using a stomacher (IUL Instrument, Barcelona, Spain) during 90 s. All culture media were purchased from Scharlau Chemie (Barcelona, Spain). Total aerobic mesophilic and psychrophilic bacteria were enumerated by the standard plate count method using plate count agar (PCA) at 30 ± 1 °C for 48 h and at 4 ± 1 °C for 7 days, respectively. Total coliforms were isolated using endo agar at 37 ± 0.5 °C for 24 h. Microbiological analyses were achieved on day 0 and after 6, 10 and 14 days of storage. All samples were analyzed in duplicate and each microbial count is the mean of three samples from three different packages. Microbial counts were expressed as log cfu g^{-1} of tissue.

2.6. Extraction and phenolic compound analyses

The quantitative analysis of phenolic compounds in wild rocket leaves was carried out comparing three extraction solvents which include water and two hydro-alcoholic mixtures of MeOH/H_2O (4:1 and 1:1, v/v). For tissue preparation, approximately 75 g of leaves were frozen at −70 °C and then lyophilized. Freeze–dried samples (0.5 g) were homogenized with 16 ml of either H_2O, MeOH/H_2O (1:1) or MeOH/H_2O (4:1). The homogenates were filtered through cheesecloth, and then through a 0.45 μm pore filter (Millex HV13, Millipore, Bedford, MA). Samples of 20 μl were analyzed using