Food Control 31 (2013) 302–313

Contents lists available at SciVerse ScienceDirect

Food Control

journal homepage: www.elsevier.com/locate/foodcont

Retention of quality and functional values of broccoli 'Parthenon' stored in modified atmosphere packaging

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ARTICLE INFO

Article history:
Received 18 June 2012
Received in revised form
28 September 2012
Accepted 9 October 2012

Keywords:
Respiration rate
Health promoting compounds
Antioxidant activity
Quality parameters

ABSTRACT

The aim of this research was to identify, quantify and compare the main quality parameters and functional compounds of 'Parthenon' broccoli florets stored at two different conditions. The first condition consisted in a modified atmosphere packaging (MAP) using microperforated polypropylene plastic. Then, the second one was in an unpackaged storage (Control). The main quality parameters assessed in this research were the overall appearance, odour, weight loss and colour. While, the functional compounds evaluated in this study were the chlorophyll and carotenoid pigments, vitamin C, total phenol content and intact glucosinolates, as well as the *in vitro* antioxidant activity. The results indicated that the loss of quality was lower in MAP than in Control samples when comparing with Fresh sample. In addition, the weight loss in MAP samples was 0.75% while in the Control samples was 3.36% at the end of storage. Besides, the losses of external attributes were also more pronounced in Control than in the MAP samples. Moreover, this degradation tendency was also observed for bioactive compounds, where their retention in the MAP was higher than in Control samples. In fact, the loss of total phenol content and intact glucosinolates content in MAP samples was about 20 and 23%, respectively, while in Control samples was about 48% and 57% correspondingly. This was also observed in the antioxidant activity (AA) values, since AA is correlated with these functional compounds.

1. Introduction

Currently the interest in healthier diets has increased notoriously, consumers demand easy-to-cook and easy-to-eat products not only with relevant nutritious but also with healthy properties. In that sense, the demand on broccoli has increased particularly, and broad types of broccoli products are now available in the market: from fresh broccoli heads to new formats such as salads ready to eat or vegetable mixtures ready to cook (Schreiner, Peters, & Krumbein, 2007). From an economical point of view, Spain and Italy are the largest producers of broccoli and cauliflower in Europe. According to data from the Statistics Division of the Organization for Food and Agriculture of the United Nations (FAOSTAT, 2010), the broccoli production has risen steadily since 1997, peaking in 2010, when 511,100 t and 427,407 t were harvested in Spain and Italy, respectively.

A key factor of the increase of broccoli consumption is the abundance of health-promoting compounds observed in these cruciferous plants. Precisely, important amounts of glucosinolates, flavonoids and vitamins, together with antioxidant and free-radical scavenging properties were quantified in broccoli plants (Kris-Etherton et al., 2002; Page, Griffiths, & Buchanan-Wollaston, 2001; Vallejo, García-Viguera, & Tomás-Barberán, 2003). Different studies have demonstrated that these bioactive compounds have an important role in the prevention of different human diseases (Traka & Mithen, 2009). However, the abundance of these compounds decreases after harvest, together with a deterioration of the organoleptic quality attributes (Howard, Jeffery, Wallig, & Klein, 1997; Vallejo, García-Viguera et al., 2003).

A limiting factor that reduce broccoli consume is its perishable nature, characterized by its reduced shelf life after harvest. The main symptoms of quality loss are surface dehydration and loss of green colour, with floret yellowing as consequence of chlorophyll degradation together with a fastening of plant metabolism (Eason,

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http://dx.doi.org/10.1016/j.foodcont.2012.10.012

Ryan, Page, Watson, & Coupe, 2007; Eason et al., 2005; Hansen, Sorensen, & Cantwell, 2001; Izumi, Watada, & Douglas, 1996; King & Morris, 1994; Zhuang, Hidebrand, & Barth, 1995), though this pattern may differ among cultivars (Toivonen & Sweeney, 1998). The quality decline is also affected by the postharvest processing, and this decline is higher in fresh-cut broccoli than in the intact heads.

Considering the above-mentioned factors, it is necessary to design appropriate postharvest procedures aiming to preserve the relevant bioactive, nutritional and organoleptic qualities of broccoli plants. A convenience product must also be provided to consumers. In that way, in this research, MAP has been studied in order to assess whether this postharvest storage condition is an appropriate alternative to maintain broccoli quality and bioactive compounds.

Polypropylene microperforated films are commonly used in the MAP of high respiration fresh food products; for example minimally processed fruits and vegetables. These microperforations can regulate the gas exchange in the polymeric film (Oliveira, Fonseca, Oliveira, Brecht, & Chau, 1998).

On the other hand, Cantwell and Suslow (1999) reported that broccoli can be benefitted by 1–2% O_2 with 5–10% CO_2 atmospheres at a temperature range of 0–5 °C, extending its shelf-life. However, temperature fluctuations during commercial handling could induce unpleasant sulphur-containing volatiles at these low O_2 levels. For this reason, most modified atmospheres packaging are designed to maintain O_2 at 3–10% and CO_2 at about 5–10% to avoid the development of these undesirable off-odour volatiles from stored broccoli plants (Cantwell & Suslow, 1999).

Thus, this research work is aimed to evaluate the retention of quality and functional values of broccoli 'Parthenon' stored under modified atmosphere packaging conditions at 5 °C. For this storage, microperforated polypropylene bags were employed. The applicability of these storage conditions was assessed by evaluating the organoleptic quality parameters (overall appearance, odour, weight loss and colour) and the composition in functional compounds such as chlorophyll and carotenoids pigments, vitamin C, total phenol and glucosinolate content, and antioxidant activity.

2. Materials and methods

2.1. Plant material

Broccoli (*Brassica oleraceae* L. var. *italica* cv. Parthenon) heads were grown in a commercial farm in Foggia, Italy, according to standard cultural practices. Plants were harvested during the last week of November 2010, at commercial maturity stage. The samples were rapidly transported to the Postharvest Laboratory of University of Foggia and selected, discarding damaged plants. Broccoli heads were cut into florets and prepared according to the experimental design.

2.2. Experimental design

Approximately 250 g of broccoli florets were packed in microperforated polypropylene bags of 25 cm × 25 cm with a thickness of 30 μm making a total of 54 bags of ready-to-use product. From them, 24 bags were sealed (Tecnovac T720, Tecnovac, Srl, Grassobbio, Italy) and placed at 5 °C in an active modified atmosphere (MAP). The MAP conditions were established according to our previous study (Fernández-León, Lozano, Ayuso, & González-Gómez, 2011). Thus, the experimental design was established in order to reach a final atmosphere composition of 5% of CO_2 and 10% of O_2 in each sealed sample bag. Thus, to get this final atmosphere composition, the equation proposed by Massey (2003) and González, Ferrer, Oria, and Salvador (2008) were applied:

$$\mathrm{GTR} = \frac{\mathrm{RR} \times t \times W}{A \times (\mathrm{Gi} - \mathrm{Gf})}$$

where:

GTR = Gas transmission rate (Film Permeability)
RR = Respiration rate
t = Film thickness
W = Product weight
A = Film surface area
Gi = Initial gas composition
Gf = Final gas composition.

Therefore, considering the entire experimental factor, the proposed MAP was obtained by injecting 10% of CO_2 and 5% of O_2 (MAP samples).

The 30 remaining bags were not sealed and were divided into two groups: 6 bags were analysed on the same day of the experiment (Fresh samples) and the other 24 remaining bags were stored at 5 °C (Control samples). Both Control and MAP samples were analysed in each sampling day (3, 6, 9 and 12), so that 6 bags were available for each sampling date and treatment. When it was necessary samples were frozen at −80 °C until analysis. In all cases $N = 6$.

In order to know the permeability of microperforated polypropylene film, it was evaluated at 5 °C (1250 mL CO_2/m^2 × day) by a Lissy L100-5000 manometric gas permeability tester (M.Penati Strumenti, Srl, Pioltello, Italy).

2.3. Respiration rate

Respiration rate (mL CO_2/kg × h) was measured in triplicate using a dynamic system (Kader, 2002). Briefly, 0.1 mL of gas was collected from the inlet and from the outlet flows of each jar and injected into a gas chromatograph (model 17A; Shimadzu, Kyoto, Japan) equipped with a thermal conductivity detector (230 °C). Separation of carbon dioxide was achieved on a capillary column 19091J-413, HP-5 (30 m × 0.32 mm; 0.25 μm) from Agilent Technologies (Waldbronn, Germany), with a column flow of 7 mL/min, and oven temperature of 180 °C; the difference in concentration was then referred to the sample weight and to the air flow rate.

2.4. Gas analysis

The CO_2 and O_2 concentrations inside the packages were measured in triplicate by a gas analyzer MAPY 4.0 (Witt Italia Srl, Solza, Italy). A silicone septum was provided on the bag surface for sampling gas inside the package. Results were expressed as % of O_2 and CO_2 inside the bags.

2.5. Overall appearance and odour

In order to evaluate the effect of modified atmosphere packaging on fresh-cut broccoli, appearance and odour of broccoli florets were individually scored using a subjective scale of 5 to 1 as also described by Winkler, Faragher, Franz, Imsic, and Jones (2007) at each sampling day. In the case of appearance, a scale composed of pictures and a brief description for each score value was used, with 5 = excellent, no defects; 4 = very good, minor defects; 3 = fair, moderate defects; 2 = poor, major defects; and 1 = inedible. In the case of odour: 5 = typical odour, 4 = slightly off-odour, 3 = moderate off-odour, 2 = strong off-odour, 1 = odour of mouldiness. A score of 3 was considered as the limit of