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Effect of plastic permeability and exposure to light during storage on the quality of minimally processed broccoli and cauliflower

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ABSTRACT

The impact of lighting on minimally processed broccoli and cauliflower packaged in four different film types (PVC and three P-Plus) has been measured and compared. The effect on the sensory quality of storage at 4 °C in darkness and under lighting was evaluated. The gas concentration in the packages, pH, mesophilic counts and weight loss was also determined.

Neither the type of film used for packaging nor the storage conditions led to changes in the evolution of pH or the microorganism count in broccoli and cauliflower. However, exposure to light stimulated stomatic opening facilitate the exchange of gases between the plant tissue and the atmosphere within the packaging. Thus, a considerable loss of water vapor was observed in the packages of both vegetables stored in the presence of illumination. Moreover, exposure to light stimulated respiratory activity so that for the cauliflower, the composition of the atmosphere within the packages varied depending on the permeability of the packaging film used and the storage conditions. However, in the case of the broccoli, the increase in respiratory activity due to the lighting was compensated by the photosynthetic activity which took place in these conditions, in such a way that the composition of the atmosphere inside the packs solely depended on the permeability of the film.

This difference in the physiological response conditioned the most suitable kind of packaging film in each case. For cauliflower, in conditions of darkness, P-Plus 120 film proved the most suitable for preserving its sensory qualities, while under conditions of lighting, this film did not prove suitable due to its low permeability. However, in broccoli the different packaging films tested behaved in a very similar way whether stored under lighting or in the dark.

1. Introduction

The shelf life of minimally processed vegetables (MPV) is usually extended by means of a combination of appropriate refrigerated storage throughout the entire cold chain, modified atmosphere packaging (MAP) and, of course, good manufacturing and handling practices. However, several factors affect the physiological response of vegetables to minimal processing and these must be controlled in order to extend the shelf life of MPV products.

Numerous reports have been published on the use of permeable polymeric films to extend the shelf life of minimally processed vegetables through the modification of the atmospheric conditions of packaging (MAP) (Singh & Goswami, 2006).

The effect of the interruption of the cold chain on the physiological behavior of MPV products has also been studied by numerous authors (García, Medina, & Olias, 1998; Jacxsens, Devlieghere, & Debevere, 2002). Other factors such as calcium content (Conway & Sams, 1987; Dong, Wrolstad, & Sugar, 2000; Soliva-Fortuny, Oms-Oliu, & Martín-Belloso, 2002) and the presence of ascorbic acid compounds or other additives (Artés, Escalona, & Artés-Fernández, 2002; Lamikanra & Watson, 2001; Piagentini, Güemes, & Pirovani, 2002) have also been studied.

However, only a very small number of studies in the bibliography make reference to the effect of exposure to light during storage on the physiological response of MPV products. Nevertheless, the few studies that have examined this effect highlight the importance of this factor in terms of preserving the sensory and nutritional quality of such products (Paradis, Castaigne, Desrosiers, & Willmot, 1995; Sanz, Olarte, Echavarri, & Ayala, 2007).

Color is one of the most important sensory attributes that determine food quality which is highly affected by light (Hutchings, 1999). Changes in color during the processing and storage of food products need to be measured and controlled. The most evident symptom of senescence in harvested vegetables is the loss of the green color due to degradation of chlorophyll. The presence of light

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normally delays the loss of chlorophyll in detached leaves (Okada, Inoue, Satoh, & Katoh, 1992), but most vegetables are stored in darkness. However, it is important to bear in mind that the commercialization of MPV products normally involves the exposure of these products to light for prolonged periods. However, few, if any, research studies have described the influence of light on color retention during vegetable handling and retailing (Nilsson, 2000).

Earlier studies by our research team allowed us to prove the marked influence of exposure to light on the sensory quality of minimally processed cauliflower (Sanz et al., 2007). Broccoli is a vegetable with very similar characteristics to cauliflower, since they are two varieties of the same species, and in both cases, the edible part is the immature inflorescence. The most notable difference is the presence of pigmentation in broccoli as opposed to the total absence of any in cauliflower. The aim of the study is to evaluate the impact of light exposure on the physiological response and quality in a vegetable like broccoli (pigmented) and in cauliflower (unpigmented), packaged in different films, and to compare their response to light.

2. Materials and methods

2.1. Preparation of samples

Cauliflowers of the Beluga variety (commercialized by Clause Tezier, Oxnard, USA) were grown in Calahorra (La Rioja, Spain). Broccolis of the Olimpia variety (commercialized by Sakata Seed Iberica, Valencia, Spain) were grown in Sartaguda (Navarra, Spain). In both cases, the vegetables were harvested and transported directly from the fields to the laboratory. All the plants were of high quality and free from defects.

In the case of the cauliflower, around 50 kg were processed (approximately 50–60 cauliflowers), while for broccoli, the amount processed was 40 kg (around 40–50 units).

After manual removal of the outer leaves and cutting into pieces (50–60 g each), a random sample of 4–6 pieces was taken until a weight of approximately 300 g per sample was obtained. The samples were quickly and separately washed by immersion for 5 min in water (containing 50 ppm free chlorine) at 4 ± 2 °C (10 l/kg). Washing conditions were established according to the results obtained in previous experiments. The inflorescences were then rinsed until the free chlorine levels were below 0.3 ppm and the excess water was removed by centrifugation.

The broccoli and the cauliflower were each separately packaged using four types of films. One was a microperforated PVC (polyvinylchloride) film (13 μm thickness) supplied by FEISA (Madrid, Spain), totally permeable to O_2, CO_2 and steam (control batch). The other three films were 35 μm P-Plus films (made of polypropylene) supplied by Danisco (Bristol, UK) in 20×25 cm bags: P-Plus 240, P-Plus 160 and P-Plus 120 film, with O_2 permeabilities of 36,000, 15,000 and 8000 $cm^3\ m^{-2}\ 24\ h^{-1}\ atm^{-1}$ at 25 °C, respectively.

The films used in this study performed identically when exposed to light, as we observed when we compared the respective absorption spectra in the range 300–1200 nm (Spectroradiometer PR-714, Photo Research Division of Kollmorgen Instruments Corporation, Chatsworth, California, USA).

For each vegetable, two batches – D (darkness) and L (light) – of 24 samples each of 300 g (8 days of sampling by three repetitions) were packaged with each of the four film types used (a total of 96 samples per batch). When PVC film was used, the pieces of the florets were placed by hand on 140 mm wide by 230 mm long polystyrene trays which were covered and sealed using a Hand Wrapper hot plate, model WS500E (Barcelona, Spain). In the case of P-Plus films, the pieces were placed by hand into 20×25 cm bags sealed by using a Vaessen-Schoemaker machine (Barcelona, Spain). The cauliflower and broccoli pieces of each sample were in a single layer. The packaged vegetables were stored in the same cold store at the same temperature (4 °C) for more than 25 days under two different conditions: batch D in complete darkness and batch L under lighting. The packs were placed just below the lamps, 30 cm away and in a single layer, with the light shining down on them perpendicularly. The storage conditions under light were controlled in such a way that the angle and the intensity of the light received were identical for all the packs.

Fluorescent light was used for batch L (Cool white fluorescence lamps, 36 W, FSL, YZ36RR26 Foshan Electrical and Light Co. Ltd, China). This type of light is similar to that used in retail outlets. In each package, each piece received a comparable level of light exposure.

Three samples of each condition tested (type of vegetable, lighting conditions and packaging film) were taken on day 0 and after 1, 3, 7, 11, 15, 21 and 25 days of storage. The following determinations were made for each sample: atmosphere composition within the package, pH, mesophilic counts, weight loss, color and sensory evaluation of the product.

All of the analyses were performed in duplicate, taking the average of the measurements obtained as the reading.

2.2. Gas determination

Carbon dioxide and oxygen were measured using an O_2 and CO_2 head space gas analyzer – Checkmate model 9900 (PBI-Dansensor, Ringsted, Denmark).

2.3. Mesophilic counts

Broccoli or cauliflower pieces were chopped under sterile conditions and 25 g were aseptically weighed and homogenized for 2 min with 225 ml of sterile soy peptone water (0.1% soy peptone plus 0.5% sodium chloride) using a Stomacher™ (IUL, Barcelona, Spain). Further decimal dilutions were made with the same diluent. Mesophilic microorganisms were enumerated on Plate Count Agar (Difco, Detroit, MI) following the pour plate method and incubated at 31 ± 1 °C for 72 h (ICMSF, 1978).

2.4. Color determination

For each sample, the reflectance spectra were measured at six different points on the surface of the piece and at six different points in the cut zones, after which the mean reflectance spectrum was obtained separately for each surface and cut zone. These measurements were taken with a Minolta CM 2600d spectrophotometer with *d*/8 geometry and a xenon lamp with 8 mm aperture size, manufactured by Minolta Co. Ltd. (Osaka, Japan). The mean spectrum allowed the color coordinates L^*, a^*, b^*, and c^* and h^* indexes within the CIELAB space to be calculated for each sample, using illuminant D65 (CIE, 1991a) and standard observer CIE64 (CIE, 1991b), in accordance with CIE specifications (CIE, 1986).

2.5. Other determinations

Free chlorine was determined by colorimetric reaction with DPD (*N*,*N*-diethyl-1,4-phenylenediamine) (Merck, Darmstadt, Germany). To measure the pH of the product, 25 g of broccoli or cauliflower were blended for 2 min with 25 ml of distilled and deionized water (pH 7.0). The pH of the macerate was determined using a Crison model 2002 pH meter (Crison Instruments, Barcelona, Spain). Weight samples were measured with a Sorvall Balance (B410-model scales, Sartorius, Barcelona, Spain).