LWT - Food Science and Technology 79 (2017) 554–560

Contents lists available at ScienceDirect

LWT - Food Science and Technology

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

Quality traits of ready-to-use globe artichoke slices as affected by genotype, harvest time and storage time. Part II: Physiological, microbiological and sensory aspects

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ARTICLE INFO

Article history:
Received 23 May 2016
Received in revised form
17 October 2016
Accepted 3 November 2016
Available online 5 November 2016

Keywords:
Minimally processed globe artichoke
Genotype
Physiological response
Microbial count
Sensory evaluation

ABSTRACT

The microbiological, physiological and sensory characteristics of ready-to-use globe artichoke slices subjected to a shelf life study are reported. The traits of three genotypes ('Apollo', 'Exploter' and 'Spinoso di Palermo'), grown in an experimental field, were monitored for 11 d at 4 °C. Significant variations due to genotype, harvest time, storage time and their interactions were found. The selected packaging system allowed the generation of a passive atmosphere, which did not affect the produce metabolism. Microbial populations, with the exception of yeasts and moulds, did not exceed the limits suggested for minimally processed vegetables. Sliced artichoke heads from early and late harvests showed a shelf life of 11 and 7 d, respectively. The 'Exploter' proved to be the most suitable genotype for minimal processing as it received the highest overall sensory score at the end of the storage period.

1. Introduction

Minimal processing of fruits and vegetables undoubtedly represents a paradox in food science, since the aim of making available fresh, ready-to-use produces is achieved by operations (washing, peeling, cutting and slicing) that give rise to microbiological and enzymatic changes and determine a metabolic response of the vegetable, with increased respiration and transpiration (Ahrenainen, 1996): the combination of both factors is responsible for the rapid loss in quality (Nguyen-the & Carlin, 1994). It also represents a challenge for scientists and for food companies, continuously seeking for solutions meant to slow down the quality decay, to offer consumers nutritive and appealing products with the longest shelf life possible. The spoilage kinetics can be slowed down through the use of sanitizing and antioxidant washing solutions and by applying suitable packaging technologies and materials. Low O_2 and elevated CO_2 atmospheres combined with refrigerated storage temperature are well known strategies to reduce the product respiration rate (Watada, Ko, & Minott, 1996; Del Nobile, Licciardello, Scrocco, Muratore, & Zappa, 2007) and the microbial growth (Giménez et al., 2003). Packaging films with controlled permeability, appropriate packaging size and produce weight, are all key parameters to achieve optimum equilibrium gas concentrations in the package. Suitable headspace packaging atmospheres can be the result of the balance between produce respiration and gas permeation through the film (Licciardello et al., 2013; Muratore et al., 2015). Globe artichoke heads are characterized by a high respiratory activity (Muratore et al., 2015; Restuccia et al., 2014), which requires the use of films with high permeability to O_2 and CO_2 to ensure sufficient residual O_2 levels to avoid the onset of anerobic metabolism. The respiratory activity of vegetables is an indirect measure of tissue metabolism and is inversely correlated with postharvest durability of products (Böttcher, Günther, & Kabelitz, 2003; Del Nobile et al., 2009): hence, the reduction of respiration through suitable packaging technologies is essential to extend the produce shelf life.

The preservation of the sensory characteristics of food is often perceived as a guarantee of its microbiological quality, as an excessive microbial growth is associated, together with the biochemical processes, to changes in food color, odor and/or

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http://dx.doi.org/10.1016/j.lwt.2016.11.003
0023-6438/

texture.

Among vegetable crops, globe artichoke [*Cynara cardunculus* var. *scolymus* (L.) Fiori] has been attracting great scientific interest because due to its appealing nutritional and antioxidant properties (Lattanzio, Kroon, Linsalata, & Cardinali, 2009; Lombardo et al., 2012). The nutritional importance of globe artichoke heads (immature inflorescences) is mainly connected to its high polyphenol content (Brat et al., 2006; Pandino, Lombardo, Williamson, & Mauromicale, 2012a), which, at the same time, makes it very susceptible to browning. Most studies on minimally processed globe artichoke heads have been focused on efficient ways to reduce such phenomenon and the growth of microrganisms, as well as on the use of innovative packaging (Amodio, Cabezas-Serrano, Peri, & Colelli, 2011; Restuccia et al., 2014; Sanz, Giménez, Olarte, Lomas, & Portu, 2002; Del Nobile et al., 2009), but, to the best of our knowledge, none has studied ready-to-use globe artichoke head slices. Such product could be used directly as an ingredient in fresh salads, boiled, fried, and could be exploited to increase the consumption of globe artichoke over the Mediterranean basin. The genotype selection and choice is one of the most important pre-harvest factors determining the suitability of globe artichoke for fresh cut processing (Cefola et al., 2012). Other factors, such as harvest time, environmental conditions and agronomic management (Lombardo, Pandino, Mauro, & Mauromicale, 2009; Pandino, Lombardo, Mauro, & Mauromicale, 2012b; Pandino, Lombardo, Lo Monaco, & Mauromicale, 2013; Pandino, Lombardo, Mauromicale, & Williamson, 2011; Pandino et al., 2015) determine the level of phytochemicals, which contribute to the overall nutritional quality of this crop. The activity of polyphenoloxidase is one of the main factors determining the enzymatic browning and reducing the overall quality of minimally processed artichoke slices (Giménez et al., 2003; Del Nobile et al., 2009; Ricceri & Barbagallo, 2016), which has been addressed in Pandino et al. (2016).

In this work the influence of genotype, harvest and storage time on the shelf life of ready-to-use globe artichoke slices has been analyzed, with a special focus on the physiological, microbiological and sensory changes.

2. Materials and methods

2.1. Experimental field and management practices

The experimental field was conducted at the farm of the University of Catania located in the Plain of Catania (Sicily, Italy), which is a vocated area for globe artichoke cultivation in the Mediterranean Basin. Globe artichoke genotypes studied were: 'Apollo' (Patent EU n° 13,972 Vitroplant Italia Srl), 'Exploter' (Patent EU n° 13,972 Vitroplant Italia Srl), 'Spinoso di Palermo'. A detailed description of the genotypes' characteristics, type of soil and climate, as well as management practices and head harvest have been reported in Pandino et al. (2016).

2.2. Post-harvest treatments and sampling

Approximately 100 heads for each genotype and replicate were harvested in early March and early April at marketable stage (Mauromicale & Ierna, 2000) and transported to the laboratories of the University of Catania under refrigerated conditions to be processed. All the inedible parts (leaves, floral stem and outer bracts) and the heads' tips (about 2 cm) were first removed. The globe artichoke heads were cut into 5 mm thick slices by using a manual cutting machine. The slices were then immersed in a sanitizing sodium hypochlorite solution (active chlorine 0.23 g/L) for 5 min, rinsed with tap water at 12 °C for 1 min and immersed for 5 min in an acidic solution containing 2 g ascorbic acid and 5 g citric acid in 100 mL of water. The excess solution was then eliminated by manual centrifuging.

Twelve slices (10 ± 1 g for each one) were put into PET trays (23 × 17.5 × 2 cm) and packaged into a semi-permeable polyolefine film (SP/BY - System Packaging s.r.l., Siracusa, Italy; thickness: 19 μm; oxygen permeability: 3700 cm^3/m^2/24 h; carbon dioxide permeability:11100 cm^3/m^2/24 h). The bags were hermetically sealed by a sealing bar. All samples were stored at 4 ± 0.5 °C and 90–95% relative humidity (RH) up to 12 d and analyzed after 0 (processing day), 4, 7 and 11 d of storage. At each storage time, the following determinations were conducted: fresh weight loss, packaging headspace composition, microbiological and sensory parameters.

2.3. Headspace gas composition and fresh weight loss determination

The quantification of carbon dioxide and oxygen in the package headspace was performed by using a CheckPoint portable gas analyser (PBI Dansensor, Denmark) and in accordance to the manufacturer's instructions. The headspace gas composition was analyzed on three replicate packages at each sampling time. For the determination of fresh weight loss, each package was labeled and weighed at the beginning of the storage period. Then, three replicate packages for each cultivar and treatment were selected at each sampling time (after 4, 7, 11 d of storage) and weighed before opening the container for further analytical determinations. Fresh weight loss was expressed as % of the initial sample weight at the moment of packaging.

2.4. Microbiological analyses

An aliquot (10 g) of globe artichoke slices was sterilely sampled from each package and homogenized with 90 mL of sterile quarter-strength Ringer Solution (BR0052, Oxoid, Basingstoke, UK) in a Stomacher (Lab-Blender 400, Brinkmann, Westbury, NY, USA) for 2 min. The same diluent was used for subsequent decimal dilutions. The total mesophilic bacteria (TMB) count was performed on Plate Count Agar (PCA, CM325 Oxoid Ltd., Basingstoke, UK) with cycloheximide 0.1% solution (OXOID, SR0222), incubated at 32 °C for 24–48 h; the total psychrotrophic bacteria (TPB) count was performed on PCA with cycloheximide 0.1% solution (OXOID, SR0222), incubated at 22 °C for 5 d; the total enterobacteria (TEB) were determined on Violet Red Bile Glucose Agar (VRBGA, CM0485, Oxoid) incubated at 32 °C for 24–48 h; yeast and mold (YM) count was carried out on Sabouraud Dextrose Agar supplemented with chloramphenicol (0.1 g/L) (SDA, CM0041, Oxoid) incubated at 25 °C for 48–72 h; *Pseudomonas* spp. (Ps) were determined on *Pseudomonas* Agar Base (CM0559, Oxoid), supplemented with Pseudomonas CFC selective agar supplement (SR0103, Oxoid) and incubated at 25 °C for 48 h.

The microbiological counts, performed in triplicate, were expressed as $\log_{10}$ CFU/g of globe artichoke slices.

2.5. Sensory analysis

The UNI 10957 (2003) sensory profile method was used to measure any change in sensory characters of the three artichoke genotypes over the cold storage period. Eleven panelists (six females and five males) were trained in 4 sessions using both commercial and experimental samples (fresh artichokes and artichokes subjected to 11 d of cold storage) to develop a common vocabulary for the description of sensory attributes and to familiarize with scales and procedures. All panelists had a wide expertise in sensory evaluation of foods and, in particular, of fruits and vegetables. Four