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Effect of packaging film and antibrowning solution on quality maintenance of minimally processed globe artichoke heads

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ABSTRACT

The effects of three different packaging materials (macroperforated, microperforated and non-perforated films) in combination with an antibrowning solution (containing 1.0% ascorbic acid and 0.2% citric acid) on the qualitative traits of minimally processed globe artichoke heads (cvs. 'Violet de Provence' and 'Tema 2000') were studied during refrigerated storage for 16 days. Results highlighted that the heads treated with the antibrowning solution and packaged in the microperforated and non-perforated films maintained better qualitative attributes (*i.e.*, lower microbial growth, moderate respiration rate and browning degree, higher total polyphenol content and antioxidant activity) than those not treated with the antibrowning solution and packaged in the macroperforated film. 'Tema 2000' displayed better performances in terms of browning degree and antioxidant activity, as well as lower bacterial count values, than 'Violet de Provence'. However, the choice of a proper packaging film is crucial for extending the shelf life of minimally processed globe artichoke heads.

Industrial relevance: The fresh heads of globe artichoke are a well-known source of healthy compounds (mainly polyphenols), but the tedious culinary preparation limits their fresh consumption to the original area of cultivation (*i.e.*, Mediterranean basin). Minimal processing could, therefore, ease its consumption on a wider scale, but may also result in a more perishable product. Hence, with the aim to improve the current knowledge on the qualitative maintenance of minimally processed globe artichoke heads, we examined the effects of three packaging films in combination with an antibrowning solution on physical, physiological, chemical and microbiological traits of two cultivars during refrigerated storage. Our results demonstrated the effectiveness of the microperforated and non-perforated films to reduce microbial growth and enhance the total polyphenol content, especially for the heads treated with the antibrowning solution. It was also shown that the cultivar choice should be considered as crucial in order to preserve the overall quality of the product. Finally, from an industrial standpoint, this study provides relevant data for extending product shelf life through a proper packaging procedure and, hence, promoting the exportation of minimally processed globe artichoke heads on a wider scale.

1. Introduction

In recent years the fresh-cut industry has rapidly grown worldwide into a multi-billion dollars sector, largely driven by increasing consumer demand for healthy, freshly prepared and convenient fruits and vegetables (Francis et al., 2012). By contrast, processing operations, such as cutting, may accelerate qualitative deterioration depending on the commodity.

Globe artichoke [*Cynara cardunculus* L. var. *scolymus* (L.) Fiori = *C. scolymus* L.] is a herbaceous C_3 plant native to the Mediterranean Basin, belonging to the Asteraceae family. The main product is the immature inflorescence (head or *capitulum*), which consists of a receptacle protected by bracts and usually consumed either fresh or processed. Nowadays, this crop is widely distributed all over the world, even though it is mainly concentrated in the Mediterranean regions, where it contributes to the agricultural economy (Pandino, Lombardo, & Mauromicale, 2013). In recent years, an increasing demand for functional foods with added value has led to a renewed interest for this crop (Lombardo, Pandino, Mauro, & Mauromicale, 2009; Pandino, Lombardo, & Mauromicale, 2011; Pandino, Lombardo, Mauromicale, & Williamson, 2012a; Pandino, Lombardo, Williamson, & Mauromicale, 2012b). In this sense, globe artichoke has shown to possess 'in vitro' hepatoprotective, anticarcinogenic, antioxidative, antibacterial, anti-HIV, bile-expelling, and diuretic properties as well as the ability to inhibit cholesterol biosynthesis and low density lipoprotein (LDL) oxidation (Lattanzio, Kroon, Linsalata, & Cardinali, 2009). Although such health-promoting characteristics make globe artichoke an important ingredient in human diet, the complex trimming operations limit its fresh consumption (Cabezas-Serrano, Amodio, Cornacchia, Rinaldi, & Colelli, 2009). This boasts the development of new products, such as minimally processed ones, which could increase the level of globe artichoke consumption thanks to their ease of preparation and convenience. However, both fresh and minimally processed globe artichoke heads may undergo negative qualitative

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changes related to microbial growth and physiological activity which lead to the degradation of some biocompounds, among which polyphenols (Lombardo, Pandino, Mauromicale, et al., 2012a). Hence, some strategies are available in order to slow down the postharvest quality loss of globe artichoke heads, among which the washing with ozonized water may represent a promising technique (Lombardo et al., 2015; Restuccia et al., 2014).

The main physiological and biochemical parameters affecting globe artichoke suitability for storage and processing are the respiration rate and the activity of the key enzymes catalyzing the oxidation of polyphenols, respectively responsible for senescence and browning processes (Cefola et al., 2012; Ghidelli, Mateos, Rojas-Argudoa, & Pérez-Gago, 2015). Moisture loss and microbial growth are also two main spoilage mechanisms affecting minimally processed globe artichoke heads (Del Nobile et al., 2009; Giménez et al., 2003).

Globe artichoke is characterized by a high postharvest metabolic activity, which is demonstrated by its high respiration rate (Campus, Porcu, Cappuccinelli, Scano, & Roggio, 2007). The high browning rate of the edible portion, mainly after cutting, restricts the shelf life of fresh-cut heads due to a loss in visual quality (Cabezas-Serrano et al., 2009). Such phenomenon may be prevented by inhibiting the activity of polyphenol oxidase (PPO) enzyme through a proper antibrowning agent (Amodio, Cabezas-Serrano, Peri, & Colelli, 2011). In this view, ascorbic and citric acids have been shown to avoid browning in fresh-cut globe artichoke heads (Lattanzio, Linsalata, Palmeri, & Van Sumere, 1989). Along with anti-browning agent, packaging may preserve the shelf life of minimally processed products (Del Nobile, Licciardello, Scrocco, Muratore, & Zappa, 2007). Due to the high O_2 consumption rate of vegetables, in particular, packaging is crucial to determine equilibrium headspace gas composition which may slow down respiration, though maintaining an aerobic metabolism (Böttcher, Günther, & Kabelitz, 2003; Del Nobile et al., 2007).

Given the available literature data (Amodio et al., 2011; Cabezas-Serrano et al., 2009; Del Nobile et al., 2009), the aim of this work was to evaluate the influence of three packaging materials combined with two antibrowning solutions on the quality maintenance of minimally processed globe artichoke heads of two cultivars, grown in a typical Italian environment for this crop. The effectiveness of the adopted processing procedure was assessed by monitoring both physical (product browning and colour, weight loss), physiological (headspace gas composition), chemical (total polyphenol content and antioxidant activity) and microbiological (total mesophilic bacteria, yeasts and moulds, *Enterobacteriaceae*) parameters during refrigerated storage. The integrated approach (proper management practices, adapted cultivars and harvest time) may allow to define a proper packaging procedure for minimally processed globe artichoke heads with high qualitative standards.

2. Materials and methods

2.1. Experimental field, plant material and management practices

Experimental field trial was conducted during the 2012–2013 growing season in a farm located in Ramacca (37° 23′ N, 14° 41′ E, 200 m a.s.l.) in the Catania Plain (Sicily, Italy), which is a specific area for the globe artichoke cultivation in Italy. The local climate is semiarid-Mediterranean, with mild winters and hot-rainless summers. The mean 30-year maximum monthly temperature ranges between 14.5 °C (January) and 30.3 °C (August). The soil type is vertic xerochrepts (USDA; Soil Taxonomy) and soil texture is clay.

Two cultivars of globe artichoke were studied: 'Violet de Provence' and 'Tema 2000'. The former is an early reflowering multiclone cultivar from France actually widespread in all the Mediterranean Basin and produces green heads with purple shades; the latter is an early clone cultivar, recently developed in Italy from 'Violetto di Toscana', which produces intensely violet-coloured heads with conical shape (Ierna, Pandino, Spagna, & Mauromicale, 2013).

The two cultivars were arranged in a randomized complete block design with four replicates, consisting of 100 plants per plot. Semi-dormant offshoots ('ovoli') were manually planted in August, adopting a planting density of 1.0 plant/m^2. A typical fertilization programme (200 kg N, 80 kg P_2O_5 and 120 kg K_2O per ha) was applied. Drip irrigation was carried out during the summer, when the accumulated daily evaporation reached 35 mm. Weed and pest control followed standard commercial practice. Lateral offshoots were removed twice in November and mid-February, having only one offshoot per plant.

2.2. Head harvest, post-harvest treatments and sampling

About 500 (main and secondary) heads for each cultivar were harvested during spring 2013 at marketable stage (Mauromicale & Ierna, 2000) and transferred to the laboratories of Catania University, where they were treated as follows: a) washing and immersion in 2% sodium hypochlorite solution for 5 min; b) rinsing with tap water at 12 °C for 1 min; c) cutting of the floral stems at 5 cm length; d) elimination of about 10 outer bracts; e) trimming (about 2 cm) of head tips; f) immersion for 5 min in an ascorbic acid + citric acid (1,0 + 0.2%) solution (treatment A) or in distilled water (treatment W) followed by centrifugation.

Four heads treated as abovementioned were used for pre-storage evaluations, while the others were packaged in polypropylene trays and sealed in ordinary atmosphere into bags made with one of the following materials: non-perforated film, OTR 3700 cc/m^2/24 h (SP/BY 19 micron — System Packaging s.r.l., Siracusa, Italy); microperforated film, OTR 19,000 cc/m^2/24 h (Coralife SW AF N MY 30 — Corapack s.r.l., Como, Italy); macroperforated film (Corapan AL400, Corapack s.r.l., Como, Italy). Then, the 18 packages (2 washing solutions × 3 packaging films × 3 replicates) per each cultivar and sampling time (3, 6, 9, 13 and 16 days of cold storage) were stored under refrigerated conditions (+4 °C; 90–95% RH) until analyses.

2.3. Assessment of head fresh weight losses

To establish the effect of packaging on the head fresh weight loss during cold storage, just before packaging each package was labelled and weighed (time 0). Then, three replicate packages for each cultivar and treatment were selected at each sampling time and weighed before opening for further analytical determinations. Fresh weight loss after 3, 6, 9, 13 and 16 days of storage was expressed as % of the sample weight at the moment of packaging (time 0).

2.4. Headspace gas composition analysis

At each storage time, the headspace O_2 and CO_2 levels were determined by a portable gas analyzer (Dansensor CheckPoint, PBI, Ringsted, Denmark) on three replicate packages for each cultivar and treatment.

2.5. Colour and browning assessment by image analysis

Immediately after the package opening and the sampling for microbiological analyses, minimally processed globe artichoke heads were transferred into a black room with standardized light conditions, and images were acquired with a digital camera. The determination of the RGB (R = red; G = green; B = blue) colour parameters and browning degree of cut areas was carried out by quantification of black spots area through image analysis using the software Image-Pro® Plus (Media Cybernetics Inc., Rockville, USA). Three replicate packages for each cultivar and treatment were used for such evaluations.