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Quality traits of ready-to-use globe artichoke slices as affected by genotype, harvest time and storage time. Part I: Biochemical and physical aspects

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ABSTRACT

Minimally processed globe artichoke products are not widespread due to rapid biochemical and enzymatic damage. This article reports a study concerning the shelf life of ready-to-use globe artichoke slices based on principal traits, including phytochemicals content, polyphenol oxidase activity, antioxidant activity and colour parameters. These traits were monitored, during 11 days of storage at 4 °C, for globe artichoke slices of three genotypes ('Apollo', 'Exploter' and 'Spinoso di Palermo'). Significant variations due to genotype, harvest time, storage time and their interactions were found. For example, harvest time markedly affected the level of considered biochemical parameters. Results demonstrate that genotype and harvest time are key factors for the extension of the shelf life of globe artichoke slices, but a compromise among nutritional values can be achieved for 'Apollo' and 'Spinoso di Palermo'. The comparison among the three genotypes analyzed support the conclusion that 'Exploter' presents the best properties for a commercial use as "minimally processed vegetable" (MPV). Furthermore, these results suggest that ready-to-use globe artichoke slices maintained high nutritional quality and colour parameters for at least 7 days of storage.

1. Introduction

Many epidemiologic studies provide evidence on the health-promoting activity of fresh vegetables and fruits and on the correlation between their consumption with a reduced risk of some types of cancers (William & Hord 2005; Tyrovolas & Panagiotakos, 2009). These properties have been associated with phytochemical compounds, such as micronutrient, vitamins and polyphenols, whose content is affected by several pre- and post-harvest factors (genotype, environmental and agronomic conditions, harvest time, food processing). Nowadays, there is a continuous increase in the demand for fresh, ready-to-use products, such as minimally processed vegetables (MPV). Minimal processing operations can cause undesirable changes in the sensory, nutritional and health-promoting properties by loss of soluble compounds or the formation of unstable components (Shahidi, 1997). The main enzyme involved in the browning reaction is polyphenol oxidase (PPO; EC 1.14.18.1), which produces dark pigments (melanoidins), unacceptable in terms of sensory and nutritional quality, which have also safety implications since they would provide an excellent substrate for microbial spoilage (Barbagallo, Chisari, & Spagna, 2009; Lattanzio, Cardinali, Di Venere, Linsalata, & Palmieri, 1994). These negative effects have led, over the last twenty years, to focusing research on the shelf life extension of fresh-cut fruits and vegetables. Globe artichoke [*Cynara cardunculus* var. *scolymus* (L.) Fiori] draws wide scientific interest due to its established nutritional and antioxidant properties (Di Venere et al., 2004; Lattanzio, Kroon, Linsalata, & Cardinali, 2009; Lombardo et al., 2012a; Sergio et al., 2016). The nutritional relevance of globe artichoke is mainly due to its high polyphenol content (Lombardo, Pandino, Mauro, & Mauromicale, 2009) which, on the other hand, makes it very susceptible to browning. Many studies on minimally processed globe artichokes have been focused on efficient ways to reduce this reaction and the growth of microorganisms, as well as on the use of innovative packaging (Amodio, Cabezas-Serrano, Peri, & Colelli,

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2011; Del Nobile et al., 2009; Restuccia et al., 2014), but, to our knowledge, very few were focused on ready-to-use globe artichoke slices. These products might be used directly for salad or cooked, and could represent a new product with the potential to increase globe artichoke consumption over the Mediterranean Basin. In a previous research, Cefola et al. (2012) regarded selection of globe artichoke genotypes as fundamental pre-harvest step for the improvement of the fresh-cut vegetable processing. Obviously, the level of biochemical compounds is also influenced by other factors, such as harvest time, environmental conditions and agronomic management (Pandino, Lombardo, Lo Monaco, & Mauromicale, 2013). On the basis of previous researches, the aim of this paper was to study the influence of genotype, harvest time, storage time and their interactions on the quality maintenance of ready-to-use globe artichoke slices by measuring their phytochemicals content, polyphenol oxidase activity, antioxidant activity and colour changes.

2. Materials and methods

2.1. Experimental field, plant material 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. The soil type is vertic xerochrepts (USDA, Soil Taxonomy) and the local climate is semiarid-Mediterranean, with mild winters and hot, rainless summers. The mean 30-year maximum monthly temperature ranges between 14.8 °C (January) and 30.6 °C (July) and minimum temperature between 7.8 °C (January) and 22.3 °C (August).

Three globe artichoke genotypes were studied: 'Apollo', 'Exploter' and 'Spinoso di Palermo'. 'Apollo' a Romanesco-type genotype, features spherical-shaped heads with deep bracts that are harvested from the end of February until May; 'Exploter' has been recently cropped in Sicily and is characterized by deep violet bracts and ovoid shaped heads with harvest time in March-May; 'Spinoso di Palermo' is an early reflowering multiclone genotype actually widespread in Sicily, producing ovoidal, green heads with purple shades and yellow spines, which produces from November to April. They were planted in the form of either semi-dormant offshoots ('*ovoli*') or seedling with 3–4 leaves in August 2013. The plant material was arranged in a randomized block experimental design with four replicates, consisting of twenty plants per each plot. Plants were planted 0.8 m apart within a row and 1.2 m apart among close rows, adopting a plant density of 1.0 plant m^{-2}. Crop management (fertilization, irrigation, weed and pest control) was performed according to the standard commercial practice. Giberellic acid was not supplied to the plants during the crop cycle.

2.2. Head harvest, post-harvest treatments and sampling

About 100 heads for each genotype and replicate were harvested in early March and early April at marketable stage, when the length of central flower ranged from 2.0 to 3.0 mm, and transported to the laboratories of the University of Catania under refrigerated conditions for the processing as ready-to-use vegetable. Three weeks before harvest, the maximum temperatures were 16 and 17 °C, while minimum ones were 4 and 8.5 °C, respectively for the first and second harvest. After manual removal of the inedible parts (leaves, floral stem and outer bracts) and trimming (about 2 cm) of heads tips, the globe artichoke heads were sliced by a manual slicing machine at 5 mm thickness. The slices were then immersed in sanitizing solution (0.23 g L^{-1} active chlorine) for 5 min, rinsed with tap water at 12 °C for 1 min and immersed for 5 min in a solution of 2% ascorbic acid and 5% citric acid. The excess aqueous solution was then eliminated by manual centrifugation.

A number of 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., SR, Italy; thickness: 19 μm; oxygen permeability: 3700 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% RH and analyzed after 0 (production day), 4, 7 and 11 days of storage, respectively. At each storage time, the following physical, chemical and enzymatic determinations were performed.

2.3. Biochemical parameters analysis

The colour parameters and polyphenol oxidase activity were assessed on the fresh tissues, immediately after sampling for microbiological analyses (Licciardello et al., 2016). The other tissue portion (about 1 kg) was freeze-dried (Christ freeze drier, Osterode am Harz, Germany) at the following conditions: vacuum level, 15 atm; time, 4 days; shelf temperature, −50 °C, and then stored at −20 °C until the determination of sugars, ascorbic acid, total polyphenol content and antioxidant activity. All the reagents and solvents for the chemical determinations were purchased from Sigma-Aldrich (Milan, Italy) and were of analytical or HPLC grade. Bi-distilled water was used throughout this analytical trial.

2.3.1. Soluble sugars and inulin

Soluble sugars (glucose, fructose and sucrose) and inulin content was determined following the method by Lombardo et al. (2016). Briefly, 1 g of freeze–dried sample was added to 40 mL of boiling water and the pH was adjusted to 7.0 with 50 mM KOH. The solution was kept at 85 ± 2 °C for 15 min. After cooling at room temperature, the volume was made up to 100 mL with deionized water. One aliquot of this extract was used for the direct analysis of free glucose/fructose, another was incubated for 30 min at 40 ± 2 °C with sucrase to determine the fructose from sucrose and a third aliquot was incubated for 60 min at 60 ± 2 °C with fructanase for the determination of total fructose. Absorbance was measured at 340 nm using a Shimadzu 1601 UV-Visible spectrophotometer (Shimadzu Corp., Tokyo, Japan). All data presented were expressed as g kg^{-1} of dry weight (DW).

2.3.2. Ascorbic acid, total polyphenols and antioxidant activity

The ascorbic acid determination was carried out as previously described by Lombardo, Pandino, and Mauromicale (2015a). Quantification was performed at 245 nm by the external standard method, comparing the sample chromatographic areas with a calibration curve obtained with suitable standard dilutions. The ascorbic acid content was expressed as g kg^{-1} of DW.

Total polyphenol content was quantified using a modified Folin-Ciocalteu method (Cicco, Lanorte, Paraggio, & Viaggiano, 2009). About 0.1 g of freeze-dried material was diluted in 1 mL ethanol 70% and stirred at room temperature for 1 h. The mixture was centrifuged at 5000*g* for 5 min at 25 °C; then, a suitably diluted aliquot was purified with a C-18 end-capped cartridge Phenomenex-Strata (Castel Maggiore, Bologna, Italy) in order to avoid interference by other reducing substances in the assay, and then mixed with Folin-Ciocalteu reagent at room temperature for 2 min. Sodium carbonate (5% w/v) was added and the mixture was allowed to rest at 40 °C for 20 min in thermostatic bath. The absorbance was read at 760 nm. The content was determined on the basis of a standard calibration curve generated with increasing concentrations of chlorogenic acid and expressed as g of chlorogenic acid equivalent kg^{-1} of DW.

The antioxidant activity of the extracts was evaluated as percentage inhibition of DPPH radical (Brand-Williams, Cuvelier, &