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Packaging and storage conditions to extend the shelf life of semi-dried artichoke hearts

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ABSTRACT

Consumer interest in quick yet healthy food is increasing and the "ready-to-use" artichoke is a tasty, easy, food to prepare with excellent nutraceutical qualities. This study evaluated the postharvest performance of semi-dried artichoke (SDA) hearts. The product was packaged in air, in modified atmosphere (MA), and in vacuum and stored at 4 °C for 40 days. Sensorial, physical, biochemical, and microbiological parameters were evaluated during that period. The results show that storage in the absence of O_2 and in the presence of a high CO_2 percentage (30%) was the most effective method for preserving phytochemical content, antioxidant capacity, and hygienic traits and that SDA packaged in MA could be stored for more than 30 days. To our knowledge, this is the first time that the postharvest performance of SDA has been studied. The results indicate that this innovative product could have great market value due to the possibility of preserving its qualitative and sensorial proprieties in refrigerated conditions for long periods of time.

1. Introduction

Over the past years, the busy lifestyles of modern consumers together with their desire for healthy food choices has led to a rise in consumption of "ready-to-use" fruits and vegetables. Among vegetables, artichoke (*Cynara cardunculus* L. subsp. *Scolymus* (L.) Hayek) is gaining consumer interest due to its therapeutic characteristics, such as hepatoprotective, antioxidative, antimicrobial, diuretic, anticholesterol, antiglycemic, and anticarcinogenic (Mileo, Di Venere, Abbruzzese, & Miccadei, 2015; Rondanelli, Giacosa, Orsini, Opizzi, & Villani, 2011; Saénz Rodriguez, García Giménez, & De la Puerta, 2002). The nutraceutical properties of artichokes are mainly due to its high polyphenolic content (Azzini et al., 2007), which can be up to 2% of the fresh weight (Mileo, Di Venere, Linsalata, Fraioli, & Miccadei, 2012), and the presence of fructan inulin that has been reported to have a prebiotic function that stimulates the growth of intestinal bifidobacteria (Lavermicocca et al., 2016; Salazar et al., 2015).

Artichoke is a herbaceous perennial plant native to the Mediterranean area and is traditionally grown for its immature inflorescences (heads) that are used in many Mediterranean dishes. The flower heads are either sold in fresh markets or sent off to be industrially processed and sold as frozen, cooked, canned, and preserved in oil products. Processed artichoke hearts are popular among consumers since preparation of the fresh product is inconvenient and time consuming (Del Nobile et al., 2009; Muratore et al., 2015). Furthermore, peeling a fresh artichoke is quite difficult, and the heart requires blanching soon after peeling to inactivate its endogenous enzymes (mainly peroxidase (POD) and poliphenoloxidase (PPO)) that can cause off-flavour and off-colour (Sergio, Cardinali, De Paola, & Di Venere, 2009).

The semi-dried food is a "ready-to-use" product with characteristics very similar to fresh products, but with a longer shelf life. It is characterized by a residual water content higher than traditional dry products, moreover it has some of its water "bound" by glycerol, sorbitol, salt, or certain organic acids that prevent the growth of many microorganisms. However, the presence of some "free" water can negatively affect the shelf life of this product and further measures are necessary to prolong its shelf life (Giovanelli & Paradiso, 2002). Important factors affecting shelf life are the type of cultivar, the drying method, the use of modified atmospheres, the application of anti-browning agents, and the selection of innovative coating and packaging (Muratore, Rizzo, Licciardello, & Maccarone, 2008; Mohseni & Ghavidel, 2011; Yang & Atallah,

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1985). To our knowledge, the current literature has not addressed the effects of different storage conditions on the quality parameters of semi-dried artichoke (SDA).

In this study, the artichoke cv "Locale di Brindisi" was used for trials as it is widely grown in southern Italy and known for the tenderness, flavour, and compact meatiness of its head. The post-harvest performance of SDA heart slices packaged in air, in modified atmosphere, and in vacuum and then refrigerated for 40 days was evaluated through an assessment of changes in sensorial quality, physical (colour, water activity, firmness) and biochemical (POD and PPO enzymatic activity, sugars, inulin, total phenols, phenolic composition, antioxidant activity) parameters, and microbiological (bacteria and fungi) contaminations during the shelf life of the product.

2. Materials and methods

Samples of artichokes (*C. cardunculus* L. subsp. *Scolymus* (L.) Hayek) cv "Locale di Brindisi" were collected from a farm located near Brindisi (Apulia Region, southern Italy) and transported to the laboratory under refrigerated conditions. The procedure to prepare the SDA product used standard industry conditions with some modification. The artichoke heads, selected within a weight range of 125–135 g, were treated as follows: removal of external bracts, washed in tap water, cut into quarters, dipped in an acid solution (0.5% citric acid and 0.05% ascorbic acid) for 30 min, blanched in a 1% citric acid and 1% wine vinegar water solution at 95 °C for 8 min, and finally cooled in a 0.05% citric acid water solution for about 20 min. After this pre-treatment, the artichoke heart pieces were dried with heat pump technology equipment (Heat Pump Dryer, STC s.r.l., Italy) at 60 °C, for 3 h (air flow rate = 4 m s^{-1}) until they reached a weight loss of about 45%.

The SDA packaging was performed in air (control), in partial vacuum (P ≈ 450 mm Hg), and in modified atmosphere (MA) (30% CO_2 + 70% N_2) in polypropylene (PP) trays and multilayer cover film in OPA + PP/EVOH/PA/PP (Oriented Polyamid and Polypropylene externally, Etilvinilalcool and Polyamid internally, Alpak s.r.l., Italy) with low gas permeability (at 23 °C oxygen transmission <2 cm^3/(m^2 days atm), a water vapour transmission rate < 2 g/(m^2 days atm)), and a thickness of 85 μm. Preliminary tests were performed to choose the best performing gas mixture for the MA and the partial vacuum value that minimized the air content without damaging the product's appearance. In order to test postharvest performance, the SDA packaged in air, in MA, and in vacuum were stored at 4 ± 1 °C for 40 days. Sensorial, physical, biochemical, and microbiological parameters were evaluated every 10 days. For each packaging condition (air, MA, or vacuum) and each sampling time during storage (0, 10, 20, 30, or 40 days) three packages, each containing 23–25 SDA slices (about 200 g), were prepared. All analyses were performed in triplicate.

2.1. Sensory evaluation

To evaluate the general acceptability of the SDA, a sensorial test was performed to determine appearance, texture, odour, and mould presence following the procedure reported by Giménez et al. (2003). A panel of 10 judges assessed the sensory characteristics of the investigated product samples. The judges were selected on the basis of their interest, liking of vegetables, and sensory evaluation experience. The panellists are all members of the CNR-Institute of Sciences of Food Production (Bari, Italy) where the test sessions were performed. The judges were trained in the discriminative evaluation of SDA. The products used in the training sessions had been subjected to various storage times and treatments. Just processed SDA was used as the control (score = 5, see below). The training panel observed the effect of storage over the 40-day period. The intensity of the evaluated attributes was quantified on a 5 to 1 scale, where 5 = excellent, no defects; 4 = very good, slight defects; 3 = fair, moderate defects; 2 = poor, serious defects; and 1 = inedible. To score products, judges relied on their own training experience. The sensory evaluation was used to determine the shelf life of the product. A score of 3 was considered the limit of marketability and a score of 2 was the limit of edibility. Selecting from each storage condition, storage duration, and replication, 5 slices were presented to the panellists on coded plastic dishes at room temperature under normal lighting conditions (ISO/DIS 8589). During the test sessions, the samples were randomized. The evaluation of samples was carried out under the same conditions as the training sessions.

2.2. Physical traits

Colour parameters L^* (brightness), a^* (redness), and b^* (yellowness) were measured on three randomly chosen points of 5 SDA heart slices for each replication with a colorimeter (CR-400, Konica Minolta, Osaka, Japan).

Water activity (a_w) was measured on 5 SDA heart slices for each replication with an "AQUA LAB" (Decagon Device Inc., Pullman, WA, USA) apparatus. Measurements were performed at 25 ± 1 °C.

The firmness of the SDA was measured by means of a manual penetrometer Fruit Pressure Tester mod. FT327 (Facchini s.r.l., Alfonsine, RA, Italy) equipped with a plunger having an 8 mm diameter (0.5 cm^2 area). The measurements were performed on the midpoint of the external surface of 10 SDA slices for each replication in correspondence with the upper limit of the receptacle.

2.3. Dry matter determination

To calculate the dry matter (DM) percentage, about 50 g of each replication was weighed individually and maintained in a forced ventilation oven at 65 °C until a constant weight was achieved. DM results are expressed as a percentage.

2.4. Enzymatic activity assays

For the extraction of POD and PPO enzymes, 25 g of SDA hearts were homogenized with a 50 mL of 50 mM sodium phosphate buffer pH 7.2% polyvinylpyrrolidone (PVP) using a Waring Blendor (15000 rpm). The homogenate was centrifuged (17400 g, 30 min, 4 °C) and the supernatant separated.

On recovered supernatant, POD (EC 1.11.1.7) activity was determined using a spectrophotometer Varian Cary 50 as reported by Sergio et al. (2009). The POD activity unit (U) was defined as the absorbance change at 470 nm per minute under the reported conditions. On the same extract, PPO (EC 1.14.18.1) activity was determined polarographically by measuring the oxygen uptake at 37 °C with a Clark electrode connected to a Gilson K-IC Oxygraph (Medical Electronics, Middleton, Wisc., USA). The reaction mixture consisted of a 0.01 M chlorogenic acid in a 0.15 M potassium phosphate buffer pH 6 and a suitable amount of extract. The PPO activity unit (U) was defined as the decrease of 1 mmol/L in O_2 concentration per minute.

2.5. Sugars

To determine sugar content, 20 g of SDA tissue from each replication were homogenized and refluxed with 200 mL of boiling deionized water. After filtration through a Whatman 1 filter paper, the solution was diluted and analysed for glucose, fructose, and sucrose content as previously reported by Cefola et al. (2014).