Innovative Food Science and Emerging Technologies 10 (2009) 128–133

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

New packaging strategies to preserve fresh-cut artichoke quality during refrigerated storage

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ARTICLE INFO

Article history:
Received 14 March 2008
Accepted 22 June 2008

Keywords:
Artichoke
Biodegradable packaging
Microbial characteristics
Pre-treatments
Sensory characteristics
Shelf life

ABSTRACT

The influence of both post-harvest treatments and film permeability on the quality loss kinetic of minimally processed artichokes is assessed in this study. In particular, fresh-cut artichoke heads were subjected to dipping in citric acid/calcium chloride water solution, and coating with citric acid loaded sodium alginate, respectively. Three different packaging materials were used: a polyester-based biodegradable film, an aluminum-based multilayer film, and a commercially available oriented polypropylene film. Artichokes quality loss kinetic during storage was determined by monitoring produce appearance, weight loss, pH, and viable cell load of the main spoilage microorganisms. Results suggest that among the selected treatments, coating shows the best performance in terms of artichokes shelf life. As far as the packaging material is concerned, the biodegradable film tested in this work seems to be the most suitable packaging to preserve the quality of the coated fresh-cut produce.

Industrial relevance: Fresh-cut vegetables market has grown rapidly in recent years as a result of changes in consumer attitudes. There is a real need to find methods for preservation of minimally processed food products that can gain widespread acceptance by the industry. This paper suggests effective packaging solutions to delay the quality decay kinetic of fresh-cut artichokes. Moreover, the present study proposes a new "green packaging system" that could emphasize the relevance of the obtained results due to the increased attention to the environmental impact.

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1. Introduction

The artichoke (*Cynara cardunculus* L. subsp. *scolymus* (L.) Hayek) is a perennial rosette plant grown throughout the world for its large, fleshy heads (Conti, Abbate, Alessandrini & Blasi, 2005). Most of its culture (about 90%) is concentrated in the countries bordering the Mediterranean Basin mainly in Italy (50 000 ha), Spain (17 000 ha) and France (10 000 ha) (FAO, 2008). The edible portions are the fleshy bases of the bracts, the thick, fleshy receptacle on which the bracts are borne, and the flower primordia. It is reputed that this vegetable has a marked anti-oxidative and health protective potential (Adzet, Camarasa & Laguna, 1987; Jimenez-Escrig, Gragsted, Daneshvar, Pulido & Saura-Calixto, 2003; Perez-Garcia, Adzet & Canigueral, 2000; Wang et al., 2003).

To make artichokes as minimally processed products would be very convenient for its commercialization, reducing transport costs, storage space and preparation time (Yommi, Giletto, Horvitz & Lòpez-Camelo, 2001). However, very few works are reported in the literature on fresh-cut heads, because the technologies successfully applied for other fresh-cut vegetables cannot be entirely used for artichokes, due to rapid enzymatic browning occurring after cutting (Giménez, Olarte et al., 2003). The most successful strategies aimed to prevent browning occurring on fresh-cut fruit and vegetables are based on treatments with reducing agents, acidifying agents, chelating substances and calcium solutions (Martin-Diana et al., 2007; Ragaert, Devlieghere & Debevere, 2007; Rico, Martín-Diana, Barat & Barry-Ryan, 2007).

In addition to enzymatic browning, artichokes weight loss is another phenomenon that negatively influences its marketability. The dehydration depends on many factors including the temperature and relative humidity of the storage room, the air movement and the packaging material. The weight loss is a natural consequence of the catabolism of horticultural products, catalysed by enzymes and accelerated by cutting and slicing. The decrease in weight may be attributed to respiration and other senescence-related metabolic processes during storage (Watada & Qi, 1999). There are studies that propose edible coatings, in combination with active compounds, to

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doi:10.1016/j.ifset.2008.06.005

delay browning and water loss (Park, 1999). Among the renewable sources to produce edible coating the polysaccharides-based materials are the most diffused because they are abundant, cheap and easy to use (Devlieghere, Vermeulen & Debevere, 2004; Lee, Park, Lee & Choi, 2003).

In Apulia, the most important Italian region for artichoke production, there are widely cropped early cultivars such as 'Violetto di Sicilia' or 'Brindisino', a "Catanese type"; the autumn–winter production is normally destined to the fresh consumption, while that harvested during the spring period is used by the processing industry. The industrial preparation of artichoke heads is done by eliminating the inedible fibermost parts (external bracts and the apex of inner ones) resulting in 20% of product-useful. Recently a new "seed" propagated cultivar ('Madrigal') has been launched for processing purposes, which is characterized by more tender, less fibrous and greener bracts compared with the traditional cultivars.

There is growing pressure in the fresh fruit and vegetables packaging sector to replace the petrochemical based packaging films with more environmentally-friendly biodegradable materials (Tharanathan, 2003). Biologically-based packaging contains raw materials originated from agricultural sources, produced from renewable raw materials such as starch and bio-derived monomers (Koide & Shi, 2007). Although biodegradable and renewable films are more expensive than the petrochemical films, they have the advantage to be biopolymers (Avella et al., 2005). Among the biopolymers, films made from starch are the most developed. The interest in this kind of new materials is linked to the usefulness and suitability in many applications (Bastioli, 1997); however, due to their low barrier proprieties to low molecular weight compounds, the application in food packaging is still limited. In fact, the permeability coefficient of a polymeric matrix intended for food packaging applications is strictly related to the shelf life of packed food (Del Nobile, Licciardello, Scrocco, Muratore & Zappa, 2007; Muratore, Del Nobile, Buonocore, Lanza & Nicolosi, 2005).

The purpose of this study is to evaluate industrial yield performance and the influence of post-harvest treatments and film permeability on the quality loss of minimally processed artichokes of cv. Madrigal during storage at 4 °C. Sensorial, microbial and physico-chemical parameters were monitored to assess the best packaging conditions to preserve the fresh-cut artichokes quality.

2. Experimental

2.1. Raw material

'Madrigal' (Nunhems) artichokes were collected in an experimental field of Nunhems in the area of Foggia from plants raised by "seeds" transplanted the preceding summer. 'Madrigal' artichokes are a new "seed" propagated cultivar characterized by a pale green color of the external bracts, with a good yield of uniform heads concentrated exclusively in the spring period. After harvesting, the fresh produce was directly transported from the field to the laboratory.

2.2. Artichokes morphological characterization

A number of 30 heads, uniform in size and weight, at the optimal stage for processing were selected. Heads were deprived of the floral stalk and the equatorial diameter and the height were measured. Heads were further processed by applying a cut to the top part at 60% and at 70% of its total height for removing the inedible leathery apex of the bracts, and by eliminating the outermost and the hardest bracts (15–20). In order to achieve the optimal degree of tenderness, starting from the subsequent bract, every single bract was subjected to the measure of the cutting force, until reaching the cutting force of 35 N, which was previously set as optimal tenderness threshold value. A penetrometer with a prismatic body (3 mm width and 10 mm length) was used and the force was measured 5 mm below the transversal point of cut of the bract (60 or 70% of the height of the head), in parallel to this and in middle position with respect to the breadth of the bract.

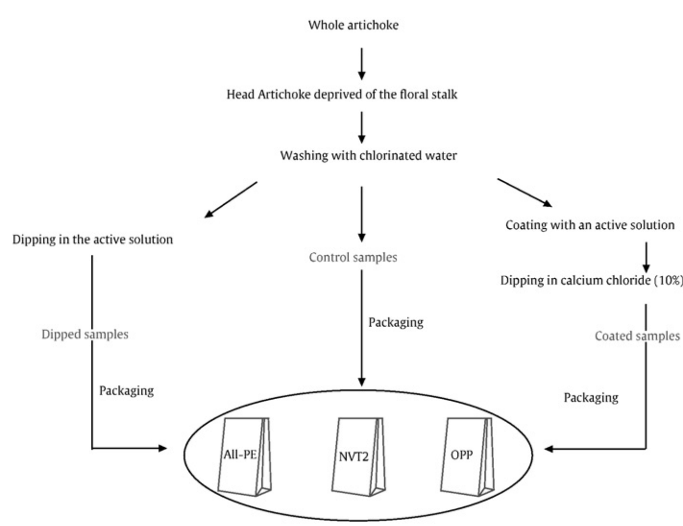
2.3. Samples packaging

From the heads the inedible parts (leaves, stalks and outer bracts) were removed according to the procedure reported above. The artichoke heads were washed with tap water and treated for 30 s with chlorinated water (20 mL/L) (pH = 9.06). The excess water was then eliminated by manual centrifugation. Before packaging, the fresh-cut artichokes were subjected to two different treatments:

a) Dipping (Dip): fresh-cut artichokes were dipped for 1 min into a solution containing citric acid (1%, w/v) and calcium chloride ($CaCl_2$) (10%, w/v) (pH = 0.10).
b) Coating (Coat): fresh-cut artichokes were dipped into sodium alginate solution (5%, w/v) to obtain a coating of about 100 µm. The sodium alginate solution was prepared by dissolving sodium alginic acid in distilled water at 100 °C for 2 h. A 1% (w/v) of citric acid solution was added to the above alginic solution (pH = 9.27). The coated fresh-cut samples were immersed into a 10% (w/v) calcium chloride ($CaCl_2$) solution for 1 min (pH = 9.33). Sodium alginic acid and $CaCl_2$ were provided by Sigma-Aldrich Co. Inc. (USA), Citric Acid Anhydrous by Baker (Holland).

After dipping or coating treatment, 50 g of cut artichokes were packaged in different bags with a surface area of 396 cm^2: a multilayer film obtained by laminating an aluminum foil with a polyethylene film (All-PE, thickness 133 µm), kindly supplied by Goglio (Daverio, Varese, Italy); a biodegradable monolayer film based on a blend of biodegradable polyesters (NVT2, thickness 25 µm) kindly provided by Novamont (Novara, Italy), and an Oriented Polypropylene film (OPP thickness 20 µm) kindly provided by Metalvuoto (Milano, Italy). Bags were hermetically sealed. Samples simply washed in chlorinated water were also packaged in the three different bags, to be used as control (Cntr). All bags were stored at 4 °C for 6 days.

To better explain the adopted experimental method, a flow chart of the samples preparation procedure is reported in the following.



2.4. Weight loss

The percentage weight loss was determined according to the following Eq. (1):

$$\%WL(t) = \frac{W_0 - W_{(t)}}{W_0} \cdot 100 \quad (1)$$

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