Innovative Food Science and Emerging Technologies 39 (2017) 148–155

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Study on the quality and stability of minimally processed apples impregnated with green tea polyphenols during storage

Silvia Tappi [a,*], Urszula Tylewicz [a], Santina Romani [a,b], Marco Dalla Rosa [a,b], Federica Rizzi [c], Pietro Rocculi [a,b]

[a] Department of Agricultural and Food Sciences, University of Bologna, Cesena, Italy
[b] Interdepartmental Centre for Agri-Food Industrial Research, University of Bologna, Cesena, Italy
[c] Department of Biomedical, Biotechnological and Translational Sciences, University of Parma, Italy

ARTICLE INFO

Article history:
Received 8 June 2016
Received in revised form 5 December 2016
Accepted 7 December 2016
Available online 9 December 2016

Keywords:
Minimally processed apples
Vacuum impregnation
Green tea catechins
Quality
Antioxidant activity

ABSTRACT

In the present study, a green tea extract (GTE) was used to enrich minimally processed apples by vacuum impregnation VI in order to obtain a nutritionally fortified product.
Apples were impregnated with isotonic sucrose solutions containing 1% GTE and/or 1% ascorbic acid (AA). The impact of GTE enrichment on quality characteristics of the product, stability of the antioxidant compounds and activity during refrigerated storage were assessed.
Results showed that a satisfactory impregnation of minimally processed apples was achieved and resulted in a strong increase of the antioxidant compounds content and activity. While other qualitative parameters were only slightly affected, colour of samples was influenced just after the VI treatment with an increase of the yellow/orange colour components but also during storage with a higher degree of browning development. However, the addition of 1% of AA allowed to better preserve colour and antioxidant properties during storage limiting oxidative phenomena.
Industrial relevance: The demand for functional foods characterized by a high nutritional value is constantly increasing. Vacuum impregnation (VI) is a technology that allows the replacement of the gas into the porous food structure with an aqueous solution, promoting compositional changes in short treatment times thus permitting the direct formulation of a porous food matrix, hence representing a promising technology for product innovation for the fruit and vegetable industry.
Green tea (GT) is a high source of flavanoids, known to have strong antioxidant properties which has been widely studied both in *in-vitro* and *in-vivo* trials. According to the results obtained in this study, the enrichment of apples with GT catechins and AA seemed to be promising in order to obtain a nutritionally fortified fruit product.

1. Introduction

Vacuum impregnation (VI) is a technology that allows the replacement of the gas into the porous food structure with an aqueous solution. This occurs through the application of vacuum pressure exploiting a mass transfer, known as hydrodynamic mechanism (HDM) as described and modelled by Fito, Andrés, Chiralt, and Pardo (1996).

VI has been recognised as an effective non-thermal technology that allows the direct formulation of porous foods promoting compositional changes in short treatment times; thus it can be exploited for functional products development. Various literature studies report impregnation of fruit or vegetables with both isotonic or hypertonic solutions or juices containing one or more bioactive substances, mainly probiotics or minerals with the aim of increasing the daily intake to meet nutritional recommendation or health benefits (Betoret et al., 2003; Gras, Vidal, Betoret, Chiralt, & Fito, 2003; Xie & Zhao, 2003; Alzamora et al., 2005). More recently, fruit juices with a high content in bioactive compounds have been used for fruit enrichment (Betoret et al., 2012; Diamante, Hironaka, Yamaguchi, & Nademude, 2014; Castagnini, Betoret, Betoret, & Fito, 2015).

Green tea (GT) is a high source of flavanoids, in particular catechins that include mainly epicatechin (EC), epigallocatechin (EGC), epicatechin-gallate (ECG) and epigallocatechin gallate (EGCG). These compounds are known to have strong antioxidant properties which has been widely studied both in *in-vitro* and *in-vivo* trials. A large number of studies have demonstrated the link between green tea catechins consumption and the prevention of different kinds of cancer such as skin, lung, liver, pancreatic, gastrointestinal, breast, and prostate cancers (Wheeler & Wheeler, 2004; Bettuzzi et al., 2006; Khan & Mukhtar, 2007; Davalli et al., 2012) and the prevention of cardiovascular diseases (CVD), microbial diseases, diabetes, and obesity (Zaveri, 2006). Moreover, other properties of GT catechins such as antihypertensive and hypolipidemic were observed (Henry & Stephens-Larson, 1984).

* Corresponding author.
E-mail address: silvia.tappi2@unibo.it (S. Tappi).

http://dx.doi.org/10.1016/j.ifset.2016.12.007
1466-8564/

However, the amount of GT that needs to be consumed daily in order to obtain the mentioned health benefits is rather large and difficult to reach (Vuong, Stathopoulos, Nguyen, Golding, & Roach, 2011). In this direction, the fortification of food products with GT could help to reach the right amounts of catechins able to exert beneficial effects on human health.

Nevertheless, researches about its potential use for food fortification are still quite limited. Some studied investigated the addition of GTE as a natural antioxidant compound in order to improve the shelf-life of products susceptible to fat oxidation such as sausages (Bozkurt, 2006; Martínez, Cilla, Beltrán, & Roncalés, 2006; Siripatrawan & Noipha, 2012) and surimi (Pérez-Mateos, Lanier, & Boyd, 2006).

On the other hand, nutritional fortification with GT extracts has been studied in bakery products such as bread (Wang & Zhou, 2004; Wang, Zhou, Yu, & Chow, 2006; Wang, Zhou, & Isabelle, 2007; Bajerska, Mildner-Szkudlarz, Jeszka, & Szwengiel, 2010), biscuits (Sharma & Zhou, 2011), noodles (Li et al., 2012), in an apple product at intermediate moisture (Lavelli, Corey, Kerr, & Vantaggi, 2011; Lavelli, Vantaggi, Corey, & Kerr, 2010) and in probiotic yogurt (Muniandy, Shori, & Baba, 2016) monitoring the evolution of the catechins and of the antioxidant activity during processing and storage. Tea catechins are in fact very reactive compounds and can undergo degradations, enzymatic or chemical, leading to a variation of the antioxidant activity. Thus, it is fundamental to assess the stability of the compounds used for fortification within the matrix in which they are included during product shelf-life. Moreover, the addition of GT to a product's formulation may lead to variations of quality parameters such as colour and texture and impact on the product sensorial profile. While Li et al. (2012) found that overall acceptability of fresh noodles was not affected by the addition of three different quantity of GTE in the dough, Bajerska et al. (2010) identified a good compromise to combine technological properties and sensory characteristics of GT enriched rye breads.

Minimally processed fruits are one of the major growing segments in food retail establishments, playing an important role on the antioxidant intake of an increasing number of consumers. The production of minimally processed apple enriched with GT catechins could allow one to combine the health properties of both components, in order to obtain an innovative foodstuff. Nevertheless various aspects have to be taken in consideration. For this product it is crucial to understand not only the direct effect of VI enrichment on the content and the antioxidant properties of their bioactive components, but also their behaviour during storage. In fact, the endogenous metabolic activity of the tissue promotes a response to the processing stress and to the passive atmosphere modification of the package headspace that can influence antioxidant stability during the shelf-life period.

In the present study, a GT extract was used to enrich minimally processed apples by vacuum impregnation in order to obtain a nutritionally fortified product. The impact of GTE enrichment on quality characteristics of the product and the stability of the antioxidant compounds and their *in-vitro* activity during refrigerated storage were assessed.

2. Materials and methods

2.1. Raw materials

Apples (*Malus domestica* Borkh) of the Cripps Pink variety harvested one week before were purchased at the local market and stored at 5 ± 1 °C for two weeks, during which the experimental research was carried out. Apples were characterized by a soluble solids content of 13.7 ± 0.3 g/100 g, dry matter of 12.5 ± 0.5 g/100 g (AOAC International, 2002) and porosity of 25.34 ± 1.36% (determined according to Gras et al., 2003). Cylindrical samples (20-mm diameter, 20-mm length) were cut with a manual cork borer and a manual cutter designed for the purpose.

2.2. Solutions for impregnation

Impregnating solutions were prepared at isotonic concentration (characterized by water activity of 0.993 ± 0.002) compared to apples with sucrose, ascorbic acid and green tea extract (GTE) (Polyphenon 60-Sigma Aldrich) in different combinations as reported in Table 1. Isotonic was considered a solution having the same osmotic potential as the sample, measured by water activity measurement, in order to avoid any osmotic phenomena during the treatment. The amount of GTE was chosen in order to obtain, after impregnation, a concentration of catechins in the final product equal to the quantity found in a cup of tea (50–110 mg), according to Lavelli et al. (2011), considering a 50 g apple portion. The addition of 1% (w/v) of ascorbic acid (AA) to the sucrose solution was chosen on the basis of previous reports of literary in which it was observed a preservation of phenolic compounds, thanks to this antioxidant power when applied by dipping (Cocci, Rocculi, Romani, & Dalla Rosa, 2006) or by VI (Blanda et al., 2008) in apples. Solutions were characterized for pH, viscosity and colour parameters.

2.3. Vacuum impregnation treatment

An automatic vacuum controller system (AVCS, S.I.A., Bologna, Italy) connected to a closed chamber and a vacuum pump was used for the impregnation process. Impregnation was carried out at ambient temperature at the pressure of 200 mbar for 5 min, before restoring atmospheric pressure. A relaxation time of 5 min was applied. Pressure value and processing times were chosen after preliminary tests as the minimum values that allowed one to obtain a level of impregnation corresponding to the product real porosity, as too long exposure to high vacuum levels can cause tissue deformation (Mújica-Paz, Valdez-Fragoso, López-Malo, Palou, & Welti-Chanes, 2003).

Samples were immersed in the solutions in a ratio of 1:4 (w/v). At the end of the relaxation time, samples were removed from the solution, blotted with absorbing paper, and weighed. At least three independent impregnation cycles were carried out for each sample. Obtained cylinders were then randomly divided into packages for storage.

2.4. Packaging and storage

VI samples and a fresh, untreated ones (F) were packed in polypropylene (PP) trays and hermetically sealed with a high permeability PP micro-perforated film. The content of each package (about 50 g) was weighed before sealing. Packages were stored in thermostatic chambers at 10 °C. Although 10 °C can be considered an abuse temperature, as reported by Saftner, Bai, Abbott, and Lee (2003), it is the actual temperature recorded in retail for fresh cut fruit storage. It was chosen in order to simulate as close as possible real storage conditions.

For each group of samples, three packages were removed after two, five and seven days in order to carry out the analytical determinations.

The shelf-life period has been chosen on the basis of preliminary test aimed at evaluating the browning kinetics of untreated apples at the chosen storage temperatures (10 °C). According to various authors (Rocha & Morais, 2003; Lee, Park, Lee, & Choi, 2003) a decrease of >20 units in the L* parameter determines the non-acceptance of the product evaluated by sensory analysis. In our experiment this values was reached after 7 days.

Table 1
Composition of the solutions used for VI of apples.

Coded name	Composition
S	Sucrose (13,7%)
SG	Sucrose (13,7%) + GTE (1%)
SA	Sucrose (13,7%) + AA (1%)
SAG	Sucrose (13,7%) + AA (1%) + GTE (1%)