Journal of Food Engineering 116 (2013) 689–694

Contents lists available at SciVerse ScienceDirect

Journal of Food Engineering

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

Microstructure and olfactory quality of apples de-hydrated by innovative technologies

P. Laurienzo [b,*], G. Cammarota [a], M. Di Stasio [a], G. Gentile [b], C. Laurino [a], M.G. Volpe [a,*]

[a] *Istituto di Scienze dell'Alimentazione, CNR, Via Roma, 64, 83100 Avellino, Italy*
[b] *Istituto di Chimica e Tecnologia dei Polimeri, CNR, Via Campi Flegrei 34, 80078 Pozzuoli, Naples, Italy*

ARTICLE INFO

Article history:
Received 5 November 2012
Received in revised form 19 December 2012
Accepted 3 January 2013
Available online 11 January 2013

Keywords:
Apple texture
Food packaging
Environmental scanning electron microscopy
Electronic nose

ABSTRACT

The purpose of this study was to investigate of structural changes induced in apple texture upon dehydration with classical methods, as freeze-drying and convective-air drying, compared to apples dried by packaging in innovative films based on natural polysaccharides. ESEM microscopy was used to detect structural changes. Our studies has shown that apples obtained by freeze-drying had a more broken tissue texture, and that the composition of the films has an effect both on structure and re-hydration kinetics. Olfactory characteristics of the different dried apples were also investigated by using an electronic nose device and compared with tissue texture properties. Apples that have shown the most intact cell walls are those that better retain olfactory properties.

1. Introduction

De-hydration is the oldest and more natural way to preserve fruits, and it can be realised by several ways, as sun exposition or accelerated solar drying techniques, freeze-drying, air convective drying. All these techniques lead to high degree of de-hydration, but the quality and olfactory characteristics are only partially preserved (Burdon and Clark, 2001). Also the microstructure of the fruits is affected by the process conditions.

Apple texture is one of the critical quality features for the consumer, as it is strictly correlated to the firmness of the fruit. Texture of fruits is determined by physical characteristics that arise from structural organization of cells and tissue. Cell integrity strongly impacts textural quality. Microscopy techniques are required to investigate structural modifications. Scanning electron microscopy (SEM) without (Sousa et al., 2006; Alonso et al., 2006) or with a cryo-system (cryo-SEM) (Chassagne-Berces et al., 2009) have been used to investigate the effects of pre-treatments and freezing methods on textural properties of fruits.

Moreover, the microstructure differences influence the retention of flavours. The electronic nose offers a fast and non-destructive alternative to detect aromas differences, some authors reported of positive applications of electronic nose technology to the discrimination of different quality apples (Young et al., 1999; Brezmes et al., 2000).

In a previous study an alternative methodology for apple drying consisting in packaging with biofilms as reported by (Laurienzo et al., 2010). Apple slices were packed into biodegradable films based on natural polysaccharides, which had the double function of packaging and contemporary dehydration. Films made of blends of agar (Ag) and alginate (AA), well known polysaccharides obtained from natural source, already approved for use in agro-food industry, were used to pack apple slices. Blends with two different compositions of the components were utilized and compared. During storage, apples slowly dehydrate, as the film gradually absorbs water from the fruit. Free sugar content and loss of volatile components (flavours) of de-hydrated apples were determined. The apples dried through the different biofilms were compared to commercial products obtained by classical technologies, i.e., freeze-drying and air convective drying. In that work, we concluded that this “mild” technology is able to preserve volatile components, free sugar content and pH stability even better than freeze-drying and with a low cost treatment. Moreover the use of biofilms, that have the function of packaging as well, eliminates the high cost related to special packing, needed for fruits de-hydrated by freeze-drying or air convective drying in order to avoid oxidation and moisture gain.

The objective of the present work was to assess the changes induced on apple tissue structure by dehydration with the different biofilms compared to apples de-hydrated by conventional methods, and verify how they are related to re-hydration kinetics and

---

* Corresponding authors. Tel.: +39 081 867 5111; fax: +39 081 867 5230 (P. Laurienzo), tel.: +39 0825 299513; fax: +39 0825 781585 (M.G. Volpe).

E-mail addresses: paola.laurienzo@ictp.cnr.it (P. Laurienzo), mgvolpe@isa.cnr.it (M.G. Volpe).

0260-8774/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jfoodeng.2013.01.002

olfactory characteristics. Structural modifications were investigated by SEM operating in low vacuum and environmental mode (ESEM) that is a useful tool to visualize fruit structure at the tissular and cellular scales, without need of time consuming sample preparations.

Moreover we verified if the different biofilms affected the volatile components loss during de-hydration by using a specific electronic nose device, based on a chemical sensors array and suitable pattern recognition techniques.

2. Materials and methods

2.1. Materials

AA, (viscosity: 20–40 cps %1 (w/v) in water) and Ag (fine powder, viscosity range: 5–50 cps %1 (w/v) in water) were the same as reported by Laurienzo et al. (2010).

Melinda "Golden Delicious" variety apples and commercial dried apples came from local supermarkets. The processing conditions of commercial dried apple were not reported on the label.

2.2. Preparation of films

Sodium alginate and agar, alone or in the chosen blend composition, were dissolved in distilled water, at an overall concentration of 1.5% by wt. The solution was cast onto a casting surface and the water was let to evaporate at room temperature (25 °C) for 48 h. Films of plain Ag and of Ag/AA 70/30 and 30/70 blends were prepared. The procedure used for film sterilisation and apple packaging was the same as reported in previous work (Laurienzo et al., 2010). Apple slices packed in the different films were stored at 4 °C for a maximum duration of 1 month. Commercial fresh and dehydrated and freeze-dried apples samples were also analysed.

2.3. Scanning electronic microscopy

SEM analysis was performed with a FEI Quanta 200 FEG scanning electron microscope operating in low vacuum mode ($PH_2O = 0.1–1.0$ torr) using a large field detector (LFD) and in environmental mode (ESEM, $PH_2O = 1.0–4.8$ torr) using a gaseous secondary electron detector (GSED). Specimens about 1 mm thick were cut from apple samples. For the low vacuum analysis they were mounted onto SEM stubs by means of double sided adhesive carbon discs and observed at 10–20 kV acceleration voltage. For the ESEM analysis, specimens were placed on the cooling stage setting the temperature at 1 °C and observed at 20–30 kV acceleration voltage.

2.4. Re-hydration rate of dried apple slices

Dried apple slices (around 0.5 g) produced under the various drying conditions were re-hydrated at room temperature by being immersed in 100 ml of water at room temperature. Slices were unpacked before immersion. Rehydration rate was described by:

$$(W_t - W_e)/(W_0 - W_e) = \exp(-kt)$$

where W_0 is initial weight (g), W_e is equilibrium weight (g), W_t is weight (g) after re-hydration for t minutes, k is re-hydration rate constant (min^{-1}), and t is re-hydration time (min) (Therdthai and Zhou, 2009). Correlation coefficient (R) was calculated to determine the performance. Three samples were analyzed for each process.

2.5. Electronic nose

A commercial portable electronic nose (PEN 3), including the Win Muster software for data mining, Airsense Analytics Inc. (Schwerin, Germany), was used to analyze the olfactory quality of apple samples. The instrument was equipped with an array of 10 metal oxide semiconductors (MOS) type chemical sensor, the sensors differed in thickness and chemical composition to provide selectivity towards volatile compounds (Buratti et al., 2004) to provide selectivity towards volatile compound classes as indicated by the instrument supplier: W1C (aromatic compounds), W5S (broad-range compounds, polar compounds, nitrogen oxides and ozone), W3C (ammonia, aromatic compounds, aldehydes, chetons), W6S (hydrogen), W5C (alkanes, aromatic compounds, less polar compounds), W1S (methane, broad-range compounds), W1W (sulphur compounds, terpenes and sulphur organic compounds), W2S (alcohols, partially aromatic compounds, chetons), W2W (aromatic compounds, sulphur organic compounds, chlor), W3S (methane, aliphatic compound). The sensor response is expressed as resistivity (Ω). The MOS sensors rely on changes in conductivity induced by the adsorption of molecules in the gas phase and on subsequent surface reactions. They consist of a ceramic substrate coated by a metal oxide semiconducting film, and heated by a wire resistor. Due to the high operating temperatures (200–500 °C) the organic volatiles transferred to the surface of the sensors are totally combusted to carbon dioxide and water, leading to a change in the resistance. The high temperature allowed no interference from water and fast response and recovery times (Kohl, 1992). The detection limit of hot sensors was in the range of 1 mg kg^{-1} (Torri et al., 2008).

Three grams of each sample were placed in air tight 20 ml glass vial, sealed with a PTFE/silicone septum and a screw cap, stored at 25 °C for 1 h to equilibrate, and analysed at the same temperature. The measurement device sucked the gaseous compound from the headspace of the sample trough the sensory array at 400 ml min^{-1} for 180 s. The period of measurement allowed a steady state in the sensors response, the analyses were performed by using recording data in the steady state. A second pump transported the filtered air to the sensor array at 600 ml min^{-1} for 400 s to rinse the system between two consecutive samples. The results have been displayed in a two dimensional view (Gardner, 1991), as shown in Fig. 6.

2.6. Statistical analysis

Principal Component Analysis (PCA) and Correlation Matrix of the data were performed by using the Win Muster software. PCA defines the structure of variance–covariance of a data set through a system of coordinates whose number of dimensions is less than the number of original variables. Correlation Matrix shows the discrimination power measuring the severability of classes. In this process the overlapping pattern data is examined. Values are in the range of 0 and 1, low values show a rather bad severability and the classes are difficult to discriminate by the measurement, while high values, near 1, indicate a good severability of classes. In the present work values of discrimination index $\geqslant 0.95$ were considered significant.

3. Results and discussion

3.1. Microstructural characteristics of fresh apples and of apples dehydrated by classical technologies

The microstructure of fresh and dehydrated fruits was observed by ESEM. Pictures of fresh apple and of apples dehydrated by the different methods are shown in Fig. 1–4. The reduced field of view