LWT - Food Science and Technology 50 (2013) 361–365

Contents lists available at SciVerse ScienceDirect

LWT - Food Science and Technology

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

Research note

Effect of vacuum inclusion on the quality and the sensory attributes of carrot snacks

V. Dueik, C. Marzullo, P. Bouchon*

Department of Chemical and Bioprocess Engineering, Pontificia Universidad Católica de Chile, PO Box 306, Santiago 6904411, Chile

ARTICLE INFO

Article history:
Received 20 September 2011
Received in revised form
8 May 2012
Accepted 20 May 2012

Keywords:
Two-step drying
Vacuum drying
Carotenoids
Browning
Crispness
Flash profile
Frying
Vacuum frying

ABSTRACT

The objective of this research was to study the quality attributes of vacuum and atmospheric dried carrot snacks, as well as their sensory map compared to atmospheric and vacuum fried samples, to understand their potential as a healthy snack. Carrot slices were dehydrated until they reached a water activity of 0.44. Atmospheric drying was done in two-steps (100 °C, 10 min followed by 80 °C, 110 min), whereas vacuum drying (6.5 kPa) was carried out at 60 °C, to provide a product with the required water activity in 2 h, as in atmospheric drying. Vacuum (6.5 kPa) and atmospheric frying were carried out at 98 and 160 °C, respectively. Dried products were compared in terms of color, carotenoids content, Maillard reaction occurrence and texture. A flash-profile test was performed to evaluate sensory attributes of dried and fried snacks. Carotenoids retention and color were similar for atmospheric and vacuum dried products, but, texture was negatively affected in vacuum dried ones. Regarding sensory perception, vacuum inclusion had a better effect in frying compared to drying. As a final point, some instrumental analyzes were successfully related to sensory evaluation, and therefore, could be used as a good proxy in future studies.

1. Introduction

In the last years, the consumption of snacks has strongly grown. Snack categories that are showing the greatest growth are those that offer a wide range of product alternatives, adhering to convenience, sensory and health trends. In relation to health, interest in salty snack products that are organic or all natural, low-calorie, low-fat, low-carbohydrate, low-sodium, rich in fiber and vitamins, or offer some health-promoting benefit, are in great demand. Nevertheless, even health-conscious consumers are not willing to sacrifice organoleptic properties, and intense full-flavor snacks remain an important trend in the salty snack market (Mariscal & Bouchon, 2008).

Major salty snacks manufacturing technologies include food exposure to high temperatures (usually above 100 °C) and presence of oxygen, processing conditions that may induce degradation of nutritional compounds, oxidation of beneficial compounds or even worse, formation of toxic compounds (Dueik & Bouchon, 2011a). Raw materials used for snacks production are also changing. Non-traditional raw materials are being increasingly processed, including new growing snack categories such as apple, beetroot, carrot and pineapple chips, among others. These raw materials are a good source of fiber and micronutrients, however, alternative manufacturing technologies must be developed in order to preserve their healthy profile after processing.

Through vacuum, it is possible to substantially lower the boiling point of water in a low-oxygen environment, protecting heat-sensitive food during dehydration (Dueik & Bouchon, 2011a). Vacuum inclusion in food dehydration processes has shown to preserve natural color and nutrients (Dueik, Robert, & Bouchon, 2010; Leeratanarak, Devahastin, & Chiewchan, 2006), as well as reducing toxic compounds generation (Granda, Moreira, & Tichy, 2004).

Carrots are an interesting raw material to be used, since they are the most important source of dietary carotenoids. Nevertheless, processing may cause major carotenoids degradation due to the isomerization of *trans*-carotenoids, which represent almost 100% of total carotenoid content in raw carrots (Kopas-Lane & Warthesen, 1995), and oxidation, with a subsequent loss of biological activity (Rodríguez-Amaya, 2001).

In relation to consumer acceptance, these results are not sufficient. Most consumers are not willing to sacrifice organoleptic properties for health benefits; therefore, sensory attributes are of paramount importance. In accordance, the objective of this study was to identify the potential of vacuum application in the manufacture of carrot dried slices, in order to develop novel carrot based snacks with desired sensory attributes.

* Corresponding author. Tel./fax: +56 2 3547962.
E-mail address: pbouchon@ing.puc.cl (P. Bouchon).

0023-6438/$ – see front matter © 2012 Elsevier Ltd. All rights reserved.
doi:10.1016/j.lwt.2012.05.011

2. Materials and methods

2.1. Sample preparation

Carrots (*Daucus carota cv.* Abaco) were purchased from a local supermarket and were stored at 7 °C and 85–95% relative humidity. They were washed and cut into 2-mm thickness slices using a Mandolin Slicer (Danesco International Inc., USA) from which 3.8 cm discs were extracted.

2.2. Drying experiments

Atmospheric and vacuum drying were carried out until achieving a final water activity of 0.44 in dried slices, since the range of maximum carotenoids stability is 0.31–0.54 (Lavelli, Zanoni, & Zaniboni, 2007) and the upper limit for snacks sensory acceptability is 0.47 (Katz & Labuza, 1981). Experiments were carried out at least in triplicate (three independent batches), unless otherwise specified. In addition, all determinations and measurements were carried out in triplicate on each batch.

2.2.1. Atmospheric drying experiments

Atmospheric drying was performed in a convective oven (Model SCC61, Rational, Germany) using a flow of dry air of 2.5 m s^{-1}. A two-step drying process was followed (10 min at 100 °C followed by 110 min at 80 °C), since it conferred better quality attributes to the dried chips as revealed in preliminary studies. Once the oven reached the drying temperature (100 °C), ten carrot slices were placed on the rack of the oven and let dried at that temperature for 10 min, that is, when the chips attained a water activity of 0.9. Below this water activity, the Maillard reaction rate increases significantly, showing a peak (Labuza, 1971), reason why the temperature was reduced at this point. Chips were further dried at 80 °C for 110 min (that is, the total processing time was 2 h). Thereafter, samples were removed from the oven and allowed to cool to room temperature in a desiccator.

2.2.2. Vacuum drying experiments

Vacuum drying was carried out in a vacuum oven (model 5831, Napco, USA) connected to a vacuum pump (Vacuumbrand model D-97877, Wertheim, Germany) that could reduce the pressure up to 6.5 kPa, as in vacuum frying. Carrot slices were dried at 60 °C, which was the minimum temperature that could be used to provide a product with a water activity of 0.44 in 2 h, as in atmospheric drying. Once the vacuum oven reached the drying temperature, ten carrot slices were placed on the rack of the oven and the chamber was depressurized to 6.5 kPa. After 2 h, the chamber was pressurized; the chips were removed and were allowed to cool in a desiccator.

2.3. Frying experiments

In order to rank the different carrot-based snack products, a sensory comparison between vacuum and atmospheric dried and fried carrot snacks was performed. Atmospheric (160 °C) and vacuum (98 °C; 6.5 kPa) frying experiments were carried out in the equipment described in Dueik et al. (2010). Carrot slices were fried until a water activity of 0.44. All determinations and measurements were done in triplicate on each batch unless otherwise specified. Vacuum and atmospheric frying procedures are described in detail in Dueik et al. (2010).

2.4. Analytical methods

2.4.1. Moisture content

Moisture content of raw and dried carrot slices was determined using the AOAC method (1995).

2.4.2. Water activity determination

The water activity of carrot chips was measured using a Lufft aw-wert-Messer (Durotherm, Germany) at 20 °C.

2.4.3. Texture analysis

Texture of carrot chips was analyzed as described by Da Silva and Moreira (2008), using a three-point bending test in a TA.XT2 Texture Analyzer. The force (N) at the fracture point (highest value in the plot) was used as the resistance to breakage.

2.4.4. Determination of α- and β-carotene

Carotenoids were extracted from raw and dried carrot slices as described in Dueik et al. (2010). Their content was determined by HPLC using the methodology described by Robert, Carlsson, Romero, and Masson (2003).

2.4.5. Nonenzymatic browning

Non-enzymatic browning measurements were carried out using the method described by Baloch, Buckle, and Edwards (1977) with modifications, proposed by Dueik and Bouchon (2011b).

2.4.6. Color analysis using a computer vision system

Color analysis was performed using the computer vision system described in Dueik et al. (2010) and Mariscal and Bouchon (2008).

2.5. Sensory analysis

Carrot chips obtained using the four dehydration procedures were analyzed using the Flash Profile methodology, which allows a rapid positioning of products according to their major sensory differences (Delarue & Sieffermann, 2004). The panel dedicated to the Flash profile consisted in eight women, who were experienced in sensory evaluation. The judges met in three sessions. During the first session, they were asked to individually generate the vocabulary to describe most important attributes, which should be sufficiently discriminant to allow the differentiation of the samples. The selected attributes were appearance, aroma, flavor, off-flavors and texture. In the second session, judges proceeded to the evaluation itself using a 10 point evaluation scale for each descriptor, where 0 meant no perception of the attribute and 9 intense perception of the attribute. Session 3 was a replicate of the evaluation step. Collected data were analyzed using Senstools 3.3.1 software (Compusense® Inc., EE.UU.) in order to develop the sensory map of each product.

2.6. Statistical analysis

Statistical analysis was done using Statgraphics 5.0 software (Manugistic Inc., USA). One-way variance analysis was carried out to confirm that there were no significant differences between measurements of a sample dehydrated under specific conditions. Differences between samples processed under different conditions were determined through confidence interval analysis using Bonferroni test with a confidence level of 95%.

3. Results and discussion

3.1. Moisture content and water activity

The basic objective of drying is the removal of water up to a certain level, at which microbial spoilage and deteriorative chemical reactions are greatly minimized (Krokida, Karathanos, Maroulis, & Marinos-Kouris, 2003). Table 1 shows the final moisture content and a_w value determined at 20 °C for carrot chips obtained by two-step atmospheric drying (AD) and vacuum drying