Innovative Food Science and Emerging Technologies xxx (2015) xxx–xxx

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Effect of high pressure processing or freezing technologies as pretreatment in vacuum fried carrot snacks

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ARTICLE INFO

Article history:
Received 22 May 2015
Received in revised form 29 October 2015
Accepted 5 November 2015
Available online xxxx

Keywords:
High pressure processing
Freezing
Carrot
Vacuum frying
Snack
Antioxidant

ABSTRACT

Vacuum fried carrot snacks were prepared using high pressure processing or freezing as pretreatment before the vacuum frying process. Physicochemical, organoleptic and antioxidant parameters were evaluated in order to determine the effect of pretreatment on the final product.

The results showed that the use of high pressure and freezing pretreatments had significant effects on the final product. Both pretreatments caused cell modification, as observed from microstructural analysis. Pretreatment application helped in maintaining phenolic content and antioxidant capacity of the samples, effect which could be observed over storage. Freezing pretreatment increased crispness values of the samples, as compared to HPP-pretreated or control samples. On the other hand, freezing pretreatment also favoured oil absorption. The use of the proposed pretreatments (HPP or freezing) resulted in a feasible approach for improving the nutritional and organoleptic properties of vacuum-fried carrot snacks.

Industrial relevance: Vegetable consumption remains lower than the recommended intake by health authorities. One possible strategy to increase the consumption of vegetable is the development of snacks. Most of vegetable snacks in the market are made through drying. However, dried products are far from the textural, appearance and mouthfeel properties of deep-fried products. The use of vacuum frying is an option for the development of appealing and yet healthy vegetable snacks. Nevertheless, pre-treatments are required to provide adequate final texture. To this regard, most studies are focused on osmotic pre-treatments. This study demonstrated that freezing and HPP pretreatments can be successfully applied in order to obtain crispy carrot chips. Furthermore, the use of pretreatments helped to maintain phenolic content and antioxidant capacity of the snacks.

1. Introduction

Vegetable snacks, as convenient and ready-to-eat products, can help population increase their consumption of fruits and vegetables. Consumer demand towards healthier food and low fat products is otherwise not compatible with fried products (Dueik & Bouchon, 2011). The use of vacuum frying is a feasible option for the development of fruit and vegetable snacks with lower oil content than conventionally fried counterparts, while preserving natural colour and flavour, and obtaining the expected textural properties of these products (Garayo & Moreira, 2002). Although extensive research has been done in vacuum frying of fruit and vegetables, most of it has been focused on the optimisation of processing temperature and pressure, with few studies evaluating the effect of pretreatment, mainly osmotic dehydration (Da Silva & Moreira, 2008; Dueik & Bouchon, 2011; Fan, Min, Gong-Nian, Jin-Cai, & Quin, 2005; Shyu, Hau, & Hwang, 2005). This pretreatment is actually required for delicate products, such as certain fruits, in order to provide a firm structure (Da Silva & Moreira, 2008). As a consequence of the use of this pretreatment, an unfavourable impact on the final product occurs, due to the increase in the total sugar content (Shyu et al., 2005).

Freezing is an alternative pretreatment for reducing the initial moisture content and maintaining the initial quality (Fan et al., 2005; Shyu et al., 2005), an option that has received little attention in vacuum-fried products. The potential use of high-pressure processing (HPP) as pretreatment, originally a non-thermal preservation technology, has not been explored in fried products whatsoever. According to Oey, Lille, Van-Loey, and Hendrich (2008), HPP can partially modify the cell permeability of fruits and vegetables. This pretreatment could be beneficial for obtaining high-quality fruits and vegetables. However, HPP may possibly impact on colour, oxidation or the occurrence of enzymatic and non-enzymatic reactions, which should be taking into account.

The aims of this work are to explore the use of freezing or HPP as pretreatments for vacuum fried carrot snacks, and evaluate their effect on carotenoid content, antioxidant capacity, oxidative status and textural properties of the final product.

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http://dx.doi.org/10.1016/j.ifset.2015.11.004
1466-8564/

2. Material and methods

2.1. Material

Carrot (*Daucus carota* sp.) variety Nantesa grown in Spain under commercial conditions was kindly provided by a local supplier (Sociedad Cooperativa del Campo Sanchonuño, Segovia) and stored at 4 °C for 12 h and 80–95% of humidity until processing.

2.2. Methods

2.2.1. Experimental design

Experiments were conducted from June 2012 to May 2014. Carrot samples were minimally processed (washed, peeled and sliced) previously to the frying step. Pretreatments (high pressure processing — HPCC or freezing — FPCC) were independently applied on samples. Control samples (NPCC) were left without any pretreatment. Then, the samples were vacuum fried and packaged, and physicochemical, organoleptic and antioxidant markers evaluated after 1, 15 and 30 days of storage. Two independent experiments were carried out on different product batches. All analytical measurements were made in triplicate.

2.2.2. Vegetable minimal processing

Carrot minimal processing consisted in washing, peeling and slicing into pieces of 5 mm thickness (automatic vegetable cutter, Fimar S.p.a, Villa Verucchio, Italy). Pretreatments were applied at different points of the minimal process, as explained in the following section (Pretreatments). All procedures were performed in a vegetable food processing room at 18–20 °C.

2.2.3. Pretreatments

HPP pretreatment was carried out in a high pressure unit (Wave 6000/135, NC Hyperbaric, Burgos, Spain) with a pressure vessel of 135 l and 200 mm diameter. Tap water was used as pressure transmission fluid. The temperature of the water inside the chamber was monitored during the processing. Freezing pretreatment was applied using a blast air freezer (C 80M/RD, ILPRA Systems, Pontarme, France) set at −20 °C for 2 h and afterwards maintaining the frozen samples at −20 °C overnight, before frying. A preliminary study was carried out in order to optimise pretreatment conditions. HPP pretreatment was evaluated at different pressure levels (100, 200, and 300 MPa), times (2 and 6 min) and processing steps where pressure was applied (on the whole unprocessed carrot, after peeling or after peeling and slicing). Freezing pretreatment was also tested either on peeled or peeled and sliced carrots. Based on this preliminary study (data not shown), conditions were selected as 100 MPa and 2 min on samples before peeling and slicing for HPP pretreatment, and regarding freezing pretreatment, this was decided to be carried out on already peeled and sliced samples. During high pressure pretreatment (100 MPa, 2 min), an increase in temperature within the pressure chamber from 13,8 °C to 16,7 °C over the 2-min treatment was recorded. The pressure come-up time was 3 min and decompression time was 3 s for 100 MPa.

Both pretreatments were carried out on the samples vacuum packaged with co-extruded polyamide/polyethylene (30/130 μm thickness) flexible bags (oxygen permeability: 30 ml mm^{-2} day^{-1} bar^{-1}; water vapour transmission: 1.4 g m^{-2} day^{-1}; Industry Pargón, Salamanca, Spain).

2.2.4. Vacuum frying

The experiments were performed using an electrically heated vacuum fryer (GASTROVAC®), with modifications. The frying stainless steel vessel was connected to a rotary vacuum pump (Model RA 0025 F, BUSCH Ibérica SA, Granollers, Spain). The samples were fried at 106 °C, 80 mm Hg, for 9 min, with high-oleic sunflower oil (Casado Group, S.L.U., Valladolid, Spain). Once the oil reached the temperature, the samples placed in the frying basket were immersed in the frying oil, in a ratio of 25 g/l of oil. A total of fifteen frying cycles (five per pretreatment) were randomly carried out and the resulting products with same pretreatment pooled together. After frying, samples were allowed to cool down and the surface oil was removed. The samples were packaged with the same film used for vacuum packaging in pretreatments, but in this case the bags were flushed with 100% nitrogen atmosphere, and stored at dark, room temperature conditions (19 ± 3 °C) during 30 days.

2.2.5. Physicochemical markers

2.2.5.1. Proximate parameters. Moisture was measured by drying carrot chips at 100 °C for 24 h (AOAC, 1997). Oil content was extracted from dried samples with petroleum ether (BP 40–60 °C) for over 4 h, in an extracting unit (Soxtec System 2055 Tecator, FOSS, Hillerød, Denmark) and gravimetrically determined. Protein content (total nitrogen) was determined by the Dumas method (AOAC, 2005), using a CN-2000 elemental analyser (Leco Corp., St. Joseph, MI, USA). Protein content was calculated from total nitrogen values, using 6.25 as conversion factor, advised for vegetables without a different specific factor, such as cereals and oilseeds (FAO, 2002). Ash content was determined by heating samples in a furnace at 550 °C for 24 h (AOAC, 1990).

2.2.5.2. Lipid oxidation parameters. Total lipids were extracted according to the method of Bligh and Dyer (1959). Peroxide value (PV) was measured directly on the Bligh and Dyer extract according to the method described by the International IDF Standards (1991). Conjugated hydroperoxides (dienes and trienes) were measured on the Bligh and Dyer extract dissolved in hexane, as described by Frankel, Huang, Kanner, and German (1994).

2.2.5.3. Total carotenoid content. Carotenoids were determined following the method described by Talcott and Howard (1999) with slight modifications proposed by Martín-Sánchez et al. (2014). Values were expressed as mg/100 g of fresh weight.

2.2.6. Organoleptic markers

2.2.6.1. Colour parameters. CIE L*a*b* parameters were measured using a colorimeter (Minolta CM-2002, Osaka, Japan) with D65 as illuminant and 45/0 sensor. Colour determination was carried out on six slices per pretreatment and day.

2.2.6.2. Texture. Hardness was determined as an indicator of crispness in snacks using a texture analyser (TA XT2 Texture Analyser, Texture Technologies Corp., Scarsdale, NY) equipped with a crisp fracture rig probe (1/4″ ball probe P/0,25 S). The probe run at a speed of 10 mm s^{-1} for 10 mm. Hardness (N) was considered as the maximum force used to break the sample. Ten measurements were performed for each treatment.

2.2.6.3. Cryo scanning electron microscopy. Microstructure was observed by Cryo scanning electron microscopy (Cryo-SEM). Samples were cut in rectangular pieces approximately 5 mm long, 4 mm wide, and 2.5 mm thick. The surface and the section of the slice cut were perpendicular to the main axe of the carrot. Pieces were frozen by immersion in slush nitrogen (−210 °C). After that, the samples were fractured, etched (at −94.5 °C, 10^{-5} Torr vacuum, for 15 min), gold coated and viewed in the cold-stage scanning electron microscope (JEOL JSM-5410). Using this technique, the fractured surface of the frozen sample was viewed directly while being maintained at −150 °C or lower (Bomben & King, 1982).

2.2.6.4. Sensory analysis. Samples were subjected to sensory analyses (ranking and triangle tests). The panel consisted of 12 trained judges, Sample sets of the pretreatments were randomly arranged and

Please cite this article as: Albertos, I., et al., Effect of high pressure processing or freezing technologies as pretreatment in vacuum fried carrot snacks, *Innovative Food Science and Emerging Technologies* (2015), http://dx.doi.org/10.1016/j.ifset.2015.11.004