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Heat toxicant contaminant mitigation in potato chips

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ABSTRACT

Heating foods immersed in oil during frying provides many attractive sensorial attributes including taste, flavor and color. However, some toxic compounds formed during frying of potatoes such as furan and acrylamide may constitute an increased cancer risk for consumers. The objective of this work was to mitigate the furan and acrylamide formation in potato chips without increasing their oil uptake by optimizing the blanching treatment before final frying. Potato slices were blanched in order to simultaneously leach out ascorbic acid and reducing sugars, the most important precursors of furan and acrylamide generation in thermally treated starchy foods. A central composite design was implemented to optimize the temperature-time blanching conditions under which furan, acrylamide and oil content in potato chips were minimized. The optimum blanching conditions were 64 °C and 17 min in which significant reductions of furan, acrylamide and oil content (91%, 54% and 19% respectively) were reached.

1. Introduction

The processing of foods at high temperature has many advantages since it adds taste, color, texture and minimizes harmful germs. However, during the heating of foods various hazardous compounds are produced by high temperature reactions, such as furan and acrylamide (Van Boekel et al., 2010). Both furan and acrylamide are potential human carcinogens that can be formed in foods processed at high temperatures (IARC., 1994, 1995).

Multiple pathways have shown to be involved in furan formation in foods. The thermal degradation and rearrangement of sugars and amino acids, as well as the thermo oxidation of polyunsaturated fatty acids (PUFAS) and ascorbic acid have been proposed as the mechanisms responsible for its formation in thermally treated foods (Hasnip, Crews, & Castle, 2006; Vranova & Ciesarova, 2009). Furan is commonly detected in food packed in sealed containers which are heat treated such as baby foods (Hasnip et al., 2006). However, despite the most important physicochemical property of furan is its high volatility, furan has also been found in foods not cooked in closed containers such as crackers, chips, and toasted breads (Crews, Hasnip, Roberts, & Castle, 2007; Crews, Roberts, Lauryssen, & Kramer, 2009). Since high levels of furan were found in coffee (~50 μg L^{-1}) and baby foods (70 μg kg^{-1}), most mitigation efforts have been focused into reducing the furan content of these products by its evaporation (Mariotti, Granby, Rozowski, & Pedreschi, 2013). To the best of our knowledge, research on furan mitigation in other food matrixes, such as potato chips, has not yet been carried out.

On the other hand, acrylamide is formed through Maillard reaction, fried potatoes being the main source of its dietary exposure (~272–570 μg kg^{-1}) (EFSA, 2012).

In this sense, a variety of techniques have been proposed to decrease the acrylamide level in potato products. Some of these methods are based on the reduction of acrylamide precursor levels such as reducing sugars in the food raw materials, for instance blanching (Mariotti, Pedreschi, Carrasco, & Granby, 2011). Blanching is a unit operation widely used in the potato-processing industry for leaching of accumulated sugars to control the Maillard reaction during subsequent frying (Gonzalez-Martinez, Ahrne, Gekas, & Sjoholm, 2004). The usual range of blanching water temperature is from 60 to 80 °C and the blanching residence time vary between 5 and 20 min (Califano & Calvelo, 1988). However, most of the companies currently work with blanching processes up to 90 °C during short periods (~2 min).

Studies performed in potato chips have shown that although blanching at high temperature and short time (85 °C, 3 min) improved their color it also increased their oil uptake (Pedreschi &

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Moyano, 2005b). It could be attributed to the fact that, under extreme blanching conditions; the vegetable tissue loose firmness as consequence of softening of cell walls and decreasing in the turgor pressure (Alvarez, Morillo, & Canet, 2000). Previous information suggests that an optimization of the blanching conditions is necessary to improve the chemical safety of chips, not only by diminishing the amounts of heat contaminants such as furan and acrylamide, but also by avoiding an increase in the oil uptake of the fried products. The objective of this work was to reduce the level of furan and acrylamide in chips without increasing their oil uptake. To accomplish this purpose a central composite design was used to study the effect of blanching time and temperature on the reduction of furan and acrylamide precursors (reducing sugars and ascorbic acid) in potato slices. Additionally, the impact of both factors was evaluated over the furan and acrylamide formation as well as over oil absorption. Finally, a multiple optimization of blanching conditions was performed to obtain potato chips with lower content of furan, acrylamide and oil.

2. Materials and methods:

2.1. Raw materials

Potatoes (variety Ditta, moisture content of 80 g/100 g) and sunflower oil (Solsikkeolie, Copenhagen, Denmark). Potatoes (stored at 8 °C and 95% relative humidity) were washed and cut in slices of 2.2 mm thickness from the pith of the parenchymatous region of tubers. A circular cutting mold was used to provide chips with a diameter of 40 mm.

2.2. Blanching and frying conditions

Potato slices were blanched (potato/water ratio of 0.015) between 5 and 15 min in combination with blanching temperature varying from 50 °C to 80 °C All blanching treatments were performed in distilled water (Pedreschi, Kaack, & Granby, 2004). After the pre-treaments, potatoes slices were fried at 170 °C (±1 °C) until reaching a final moisture content of 2 g/100 g. The samples were fried in a 20 L capacity deep-fryer (FKI, Copenhagen, Denmark). The fryer was filled with 15 L of oil that was preheated for 2 h prior to frying (Blumenthal, 1991). Throughout the frying process, 10 chips of 2 ± 0.03 g were placed in a basket and held in position with a wire grid to prevent them from floating. The fried chips were drained over a wire screen for 5 min. Then, fried samples were frozen in order to prevent the furan evaporation (Mariotti et al., 2012).

2.3. Reagents and chemicals

Chemical reagents for furan analyses were: furan (68.07 g mol^{-1}, >99%, Sigma–Aldrich, Steinheim, Germany); d_4-furan (72.07 g mol^{-1}, 98 atom% D, Isotec, Ohio, USA); methanol (32.04 g mol^{-1}, HPLC grade, Rathburn, Walkerburn, Scotland); NaCl (58.44 g mol^{-1}, >99%, Merck, Darmstadt, Germany).

For acrylamide analysis, acrylamide (2-propene amide) (71.01 g mol^{-1} >99.5%, Sigma–Aldrich, St. Louis, Missouri, USA); labeled d_3-acrylamide (74.01 g mol^{-1}, >98%, Polymer Source Inc., Dorval, Quebec Canada) and acetonitril (HPLC grade, Rathburn, Walkerburn, Scotland) were used.

D-(+) glucose (180.16 g mol^{-1}, >99.5%, Sigma–Aldrich, Steinheim, Germany); fructose: (180.16 g mol^{-1}, >99.5%, Sigma–Aldrich, Steinheim, Germany); L (+) ascorbic acid (176.12 g mol^{-1} >99.5%, Sigma–Aldrich, Steinheim, Germany) were used to measure reducing sugar and ascorbic acid respectively. For both analyses the eluent was made from a solution of 50 g/100 g of NaOH (40 g mol^{-1} >99.5%, J.T. Baker 7067, New Jersey, USA) and water.

Petroleum ether (>99%, Sigma–Aldrich, Steinheim, Germany) was used as extraction solvent for oil determination by Soxhlet.

2.4. Chemical analyses

2.4.1. Dry solid content

Dry solid content of chips was determined gravimetrically. To accomplish this purpose, raw material (potato slices) was placed in a Petri dish, dried in a forced air oven at 105 °C to constant weight, and cooled in a desiccator (A.O.A.C., 1995).

2.4.2. Oil content

Total oil content of chips was determined gravimetrically by Soxhlet extraction with petroleum ether (A.O.A.C., 1995).

2.4.3. Precursors: glucose, fructose and ascorbic acid

Sugars, glucose and fructose, as well as ascorbic acid analyses were performed by High Performance Anion Exchange Chromatography with Pulsed Amperometic Detection (HPAEC-PAD).

Sample extraction. All samples were frozen at −18 °C, for 12 h in order to ensure a correct homogenization between the dry solids and the water content of potatoes. Furthermore the samples were homogenized using a mixer machine (model 4169/4297, Braun AG, Kronberg, Germany) and 0.3 g of firmly homogenized sample were put in an ultrasonic bath (Branson 5510, Thermo Fisher Scientific, USA) with 30.0 mL of Milli-Q water (60 °C) for 20 min. After that, the samples were centrifuged (Heraeaus Multifuge, Osterode, Germany) 10 min at 3424 × g. Finally 1 mL of supernatant was transferred through a 0.45 μm filter (Whatman Inc., USA) into an HPLC vial. The samples were made in three replicates.

Instrumentation and chromatographic conditions. Ascorbic acid and reducing sugars were detected by High Performance Anion Exchange Chromatography with Pulsed Amperometric Detector (HPAEC-PAD) fitted with an AS-model autosampler (Dionex ICS-3000, Thermo Fisher Scientific, Sunnyvale, CA, USA) using a Carbopac PA20Guard precolumn (Dionex, 3 × 30 mm) and CarboPac PA20 column (Dionex, 3 × 150 mm) and a gradient of deionized water and 0.2 mol L^{-1} of NaOH.Autosampler temperature, run time and eluent flow; were: 40 min, 0.45 mL min^{-1} and 10 °C respectively, both for reducing sugars (glucose and fructose) and ascorbic acid. Injection volume was: 5 μL for reducing sugars (glucose and fructose) and 15 μL for ascorbic acid. The column temperature was set at 30 °C (slightly above room temperature). The detection of both reducing sugars (glucose and fructose) and ascorbic acid was made with PAD in integrated amperometric mode. Retention times for glucose, fructose and ascorbic acid were 5.78, 6.75 and 8.85 min respectively. Finally, for the operating of the system and data collection Chromeleon Windows-based data system with full control and digital data acquisition was used.

2.4.4. Furan quantification

Furan was quantified according to the methodology of the National Food Institute of DTU which is a revised version of the FDA (2004) methodology.

Sample preparation. Half gram of fried sample previously pulverized was weighed into headspace vials, diluted with 5 mol L^{-1} NaCl solution. After adding the internal standard (d_4-furan), the vials were sealed. Automated headspace sampling followed by gas chromatography/mass spectrometry (GC/MS) analysis was used to detect furan and d_4-furan in the scan mode. Furan was quantified by a standard addition curve, where the concentration of furan in the fortified test portions was plotted versus the furan/d_4-furan response factors. For constructing the calibration curve, seven vials were used of which