Innovative Food Science and Emerging Technologies 26 (2014) 265–270

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Mitigation of acrylamide and hydroxymethylfurfural in biscuits using a combined partial conventional baking and vacuum post-baking process: Preliminary study at the lab scale

Burçe Ataç Mogol, Vural Gökmen *

Department of Food Engineering, Hacettepe University, 06800, Beytepe, Ankara, Turkey

ARTICLE INFO

Article history:
Received 26 February 2014
Accepted 2 May 2014
Available online 11 May 2014

Editor Proof Receive Date 30 May 2014

Keywords:
Acrylamide
Hydroxymethylfurfural
Biscuit
Conventional and vacuum baking
Combined process

ABSTRACT

A combined conventional and vacuum process was introduced as a new baking technology to mitigate acrylamide and 5-hydroxymethylfurfural (HMF) in biscuits in this study. Firstly, these processes were compared for acrylamide and HMF formations, drying rate, and browning development at different temperatures. Acrylamide concentrations in biscuits attained during vacuum baking were significantly lower than those attained during conventional baking at all temperatures studied ($p < 0.05$). Besides, there was no HMF formation in biscuits during vacuum baking. Comparing to conventional baking, heating under lower pressure provided lower time–temperature profile with slightly accelerated evaporation of water in dough. However, development of surface browning was lacking in vacuum baked biscuits. Secondly, combinations of conventional and vacuum processes were used to produce biscuits. The dough that was partially baked at 220 °C for 2–4 min under conventional conditions was post-baked under vacuum for accelerated drying at 180 °C and 500 mbar for 4–6 min until the desired final moisture content was attained. Doing so, exposure of biscuits to higher temperatures for longer time, which was essential to facilitate the chemical reactions leading to thermal process contaminants, was prevented. The combined process formed no acrylamide or HMF (<LOQ) in biscuits. It was considered as a promising alternative to produce safer biscuits for targeted consumers like infants.

Industrial relevance: The study has been performed in the course of the FP7 project PROMETHEUS that aimed to develop new or alternative technologies for the mitigation of thermal processing contaminants in foods. Mitigation of thermal processing contaminants, especially acrylamide in heated foods has been an intensive area of research in the last decade. It was confirmed repeatedly by many researchers that increasing processing temperature also increases the formation rates of those undesired compounds. Therefore, one approach to mitigate them is to lower temperature during processing. However, this is not viable practically, because lowering temperature requires longer time to achieve desired final moisture contents in the final product. The approach presented in this manuscript takes the advantage of faster drying of biscuits during heating under vacuum. Using the combination of conventional par-baking with vacuum post-baking seems to produce safer biscuits than the conventional counterparts in terms of their acrylamide and HMF contents. At industrial level vacuum application has been used in bread processing for cooling purposes. In that case, breads are cooled rapidly after baking in semi-continuous vacuum chambers. As implementation of vacuum application into the process has already been practiced, it is likely that partially baked biscuits could be post-baked for short times in semi-continuous vacuum chambers maintained at specified conditions. To the best of our knowledge, such combined baking process has not been investigated to date for the mitigation of thermal processing contaminants in biscuits. So, it is believed that the results of present manuscript would be interesting for bakery industry dealing with the above-mentioned safety problem, but also for the readers of this journal.

1. Introduction

Baking is a complex process in which certain chemical and physical changes take place simultaneously. It is important not only in terms of shelf life stability of biscuit, but also in terms of eating quality, taste and texture (Manley, 2000). Beside its desired properties, baking process comes with certain food safety concerns caused by neo-formed contaminants, a range of compounds formed in foods during heat treatment, such as acrylamide and HMF.

Acrylamide is a toxic and probably human carcinogen molecule (International Agency for Research on Cancer (IARC), (1994)), which was also detected in certain heated foods as a consequence of the Maillard reaction between asparagine and a carbonyl source (Becalski,

* Corresponding author. Tel.: +90 312 2977108; fax: +90 312 2992123.
E-mail address: vgokmen@hacettepe.edu.tr (V. Gökmen).

http://dx.doi.org/10.1016/j.ifset.2014.05.002
1466-8564/

Lau, Lewis, and Seaman, 2003; Mottram, Wedzicha, and Dodson, 2002; Stadler et al., 2002; Tareke, Rydberg, Karlsson, Eriksson, and Tornqvist, 2002; Yaylayan and Stadler, 2005; Zyzak et al., 2003). In 2010, the results of descriptive statistics for acrylamide levels in different food groups have been reported by European Food Safety Authority (European Food Safety Authority (EFSA), 2012). According to this report mean and maximum acrylamide values were found as follows; 675 μg kg^{-1} and 4533 μg kg^{-1} for potato chips, 338 μg kg^{-1} and 2174 μg kg^{-1} for French fries, 256 μg kg^{-1} and 1932 μg kg^{-1} for roasted coffee, 30 μg kg^{-1} and 425 μg kg^{-1} for bread, 289 μg kg^{-1} and 5849 μg kg^{-1} for biscuits, 138 μg kg^{-1} and 1290 μg kg^{-1} for breakfast cereals, and 51 μg kg^{-1} and 578 μg kg^{-1} for processed cereal based foods for infants and young children. After its discovery in 2002, exposure assessments were performed and researchers started to work on its formation ways and mitigation. As safety evaluation, Tardiff, Gargas, Kirman, Carson, and Sweeney (2010) estimated the tolerable daily intake (TDI) of acrylamide for neurotoxicity to be 40 μg kg^{-1} day^{-1} and for cancer to be 2.6 μg kg^{-1} day^{-1}.

HMF has been detected in a wide variety of heated foods, such as coffee (100–1900 mg kg^{-1}), cookies (0.5–74.5 mg kg^{-1}), white bread (3.4–68.8 mg kg^{-1}), toasted bread (11.8–87.7 mg kg^{-1}), breakfast cereals (6.9–240.5 mg kg^{-1}) and cereal based baby foods (0–57.2 mg kg^{-1}) (Capuano and Fogliano, 2011). HMF was reported as cytotoxic at very high concentrations, causes irritation to the eyes, upper respiratory tract, skin, and mucus membranes (Morales, 2009). According to in vitro data, HMF does not pose a serious risk to human health, but there are concerns in the potential genotoxic properties of its specific metabolites (Surh, Liem, Miller, and Tannenbaum, 1994). As concluded in the literature review overall evidence for carcinogenic potential of HMF was very limited and the maximum dose observed with no adverse effects (NOAEL) regarding acute and subacute toxicity in animal experiments is in the range of 80–100 mg/kg bw per day (Abraham et al., 2011). On the other hand, HMF is considered as an indicator of heat damage during thermal process (Gökmen & Şenyuva, 2006; Ibarz, Pagán, and Garza, 2000; Rufián-Henares, García-Villanova, and Guerra-Hernández, 2008). In order to monitor heat damage in certain foods, an upper limit of 40 mg/kg, 20 mg/L and 25 mg/kg was set for HMF in honey, fruit juices and concentrates, respectively (AIJN, 1996; Codex Alimentarius, 1981).

Acrylamide formation is affected by precursors concentration, pH, water content and activity, physical state of the food, and process temperature and time (Biedermann, Noti, Biedermann Brem, Mozzetti, and Grob, 2002; Elmore, Koutsidis, Dodson, Mottram, and Wedzicha, 2005; Hedegaard, Frandsen, Granby, Apostolopoulou, and Skibsted, 2006; Mestdagh, De Meulenaer, Cucu, and Van Peteghem, 2006; Mottram et al., 2002; Rydberg et al., 2003, 2005). Mitigation strategies propose modifying the product formulations or processing conditions. Among these, using asparaginase, eliminating reducing sugars, replacing ammonium bicarbonate with alternative leavening agents, addition of amino acids or protein hydrolizates, addition of calcium, and lowering baking temperature are the most prominent applications for bakery products. (Açar, Pollio, Di Monaco, Fogliano, and Gökmen, 2012; Amrein, Schonbachler, Escher, and Amado, 2004; Brathen, Kita, Knutsen, and Wicklund, 2005; Ciesarova, Kiss, and Boegl, 2006; Claus, Mongili, Weisz, Schieber, and Carle, 2008; Gökmen, Açar, Köksel, and Acar, 2007; Gökmen & Şenyuva, 2007; Hendriksen, Kornbrust, Ostergaard, and Stringer, 2009; Taeymans et al., 2004). Although lowering the temperature may generate less acrylamide, prolonged cooking time is usually required to achieve desired moisture content and textural properties in the final product. Recently, application of radio frequency heating as a rapid post drying treatment in the last stage of baking process has been found promising for lowering acrylamide in bakery products (Anese, Sovrano, and Bortolomeazzi, 2008; Palazoğlu, Coşkun, Kocadağlı, and Gökmen, 2012). Beside these attempts, researchers have also introduced vacuum treatment to remove thermal process contaminants such as furfural, HMF and acrylamide from biscuits, potato chips and coffee (Anese, Suman, and Nicoli, 2010; Quarta and Anese, 2012).

The literature is lacking in investigation of the effects of low pressure (vacuum) at elevated temperatures exceeding 150 °C on the formation of thermal process contaminants in bakery products. Therefore, the objective of this study was to investigate the effect of heating under vacuum on acrylamide and HMF formations in biscuits. Color development and drying behavior of biscuits were also determined during heating. A combined conventional and vacuum baking process was introduced for the first time as a new technology to mitigate certain undesired neo-formed compounds in biscuits.

2. Materials and methods

2.1. Chemicals and consumables

Raw material and ingredients for biscuit were kindly supplied by Kraft (Germany) and Eti (Turkey). Springarom® GN 7001 flavor was kindly supplied by Bio Springer (France). Acrylamide (>99%) was purchased from Sigma (Diesenhofen, Germany). HMF (98%) was purchased from Acros (Geel, Belgium). Formic acid (98%), acetonitrile and methanol (HPLC grade) were purchased from J.T.Baker (Deventer, Holland). Potassium hexacyanoferrate (II) trihydrate and zinc sulphate heptahydrate were purchased from Merck (Darmstadt, Germany). Carrez I and Carred II solutions were prepared by dissolving 15 g of potassium hexacyanoferrate in 100 mL of water, and 30 g of zinc sulfate in 100 mL of water, respectively. Ultra-pure water was prepared by the system of TKA GenPure (Niederelbert, Germany). Nylon membrane syringe filters (0.45 μm) and glass vials with septum screw caps were supplied by Agilent (Waldbronn, Germany). Oasis MCX solid-phase extraction cartridges (1 mL, 30 mg), Atlantis dC18 column (4.6 mm 4.6 mm 5 μm) and Acquity UPLC HSS T3 C18 column (100 × 2.1 mm i.d., 1.8 μm) were supplied by Waters (Milford, MA, USA).

2.2. Preparation of biscuits

The biscuits with a basic recipe were prepared according to the American Association of Cereal Chemists Method 10-54 with some modifications (AACC, 2000). The recipe contains 80.0 g standard wheat flour, 35.0 g grained sucrose, 20.0 g palm oil, 1.0 g NaCl, 0.4 g NH_4HCO_3, 0.8 g of $NaHCO_3$ and 17.6 mL water. All ingredients were thoroughly mixed in accordance with the AACC Method 10-54 procedure using a dough mixer Artisan Kitchen Aid 5KSM150 (MI, USA). Dough was rolled in 3-mm thickness and cut in three disks having a 5-cm diameter prior to baking.

Biscuits were baked using three different processes, namely conventional baking, vacuum baking, and combined conventional-vacuum baking in order to determine their effects on acrylamide and HMF contents of biscuits. Conventional baking process was performed using an oven (Memmert, UNE 400, Germany) at 180, 190, 200 °C for different times up to 15 min. Vacuum baking process was performed using a vacuum oven (Memmert, VO 200) at 160, 180, 200 °C and at 500 mbar for different times up to 17 min. Lab-scale vacuum oven was used throughout experiments has a capacity of 100 g dough per baking. For combined conventional-vacuum baking process, a set of biscuits was first partially baked in the conventional oven at 220 °C for 2, 3, and 4 min, and then they were post-baked in the vacuum oven set at 180 °C and 500 mbar for 6, 5, and 4 min, respectively, keeping a total baking time of 8 min for final products. Another set of biscuits was first baked in the conventional oven at 230 °C for 2 min, and then post-baked in the vacuum oven set at 180 °C and 500 mbar for 6 min. Control biscuits were baked in the conventional oven at 220 °C for 8 min. In the combined conventional-vacuum process, the basic recipe was modified by adding a brown-colored powder at different amounts (none, 0.5%, and 1.0%). All baking experiments were performed in triplicate.