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Research note

Furan and 5-hydroxymethylfurfural removal from high- and low-moisture foods

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ABSTRACT

Foods with different moisture and fat contents (i.e. meat sauce and biscuits) were subjected to treatments at 4, 12 and 19 kPa for increasing lengths of time to remove furan and 5-hydroxymethylfurfural (HMF). The vacuum treatments were ineffective in removing HMF from both food types, as well as furan from the biscuits, unless this food was preliminary hydrated at high water activity. However, the vacuum treatments allowed furan to be removed from the high moisture food. In particular, 67% furan removal from the meat sauce was achieved by applying 12 kPa for 10 min. Sensory analysis results showed that meat sauce subjected to such a treatment presented the same odor intensity of the untreated sample. The post-process vacuum treatment could represent a reliable strategy to mitigate the furan levels in high moisture foods.

1. Introduction

Furan and 5-hydroxymethylfurfural (HMF) are heterocyclic compounds that are formed in a variety of heat-treated commercial foods (Crews & Castle, 2007; Morales, 2009) where they can significantly contribute to the sensory properties. Although furan has been classified as "possibly carcinogenic to humans" (IARC, 1995) and HMF was supposed to induce genotoxic and mutagenic effect in bacterial and human cells and promote colon cancer in rats (Monien, Engst, Barknowitz, Seidel, & Glatt, 2012), the risk associated with the furan and HMF exposure has not been elucidated yet with certainty (EFSA, 2011). Nevertheless, due to their widespread presence in foods, furan and HMF have generated great concern, and a number of strategies are reported in the literature to keep their levels as low as reasonably achievable (Crews & Castle, 2007). However, only a few find practical application at the industrial level, due to the difficulty to minimize toxicants generation without compromising the sensory acceptability of the food. Furan and HMF mitigation in food can be achieved by means of preventive or removal interventions (Anese & Suman, 2013). Among the removal strategies, the vacuum technology has been already studied as a tool to remove furfural, HMF and acrylamide from different foods (Anese, Suman, & Nicoli, 2010; Quarta & Anese, 2012; Zhaoyang, 2003). The efficacy of the vacuum treatment was found to greatly depend on the molecule nature and food physical state. By applying a same combination of temperature, pressure and time conditions, the removal was higher for low molecular sized molecules, while it was hindered by viscosity constraints (i.e. food glassy state).

The aim of the present study was to investigate the possibility to physically remove furan and HMF from foods that had different chemical composition. To this purpose meat sauce and biscuits with different water and fat contents were chosen. Although the highest furan and HMF concentrations were found in coffee products, jarred foods and cereal products may also contribute to the furan and HMF contents of the diet (EFSA, 2011). Samples were subjected to vacuum treatments by applying different pressures for increasing lengths of time and subsequently analyzed for their furan and HMF concentrations. As the vacuum treatment may cause loss of volatile compounds, the effect of this technology on meat sauce and biscuits sensory properties was also evaluated.

2. Materials and methods

2.1. Sample preparation

Commercial meat sauce and short dough biscuits, having respectively water contents of 80.7 and 3.0 g/100 g, and fat concentrations of 5.0 and 19.9 g/100 g (as reported in the respective labels) were used for experiments. Biscuits previously hydrated in

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vacuum desiccators saturated with water vapor were also considered (Quarta & Anese, 2012).

2.2. Vacuum treatments

Experiments were carried out using an oven (5 Pascal, VS-25 SC, Trezzano S/N, Milano, Italy), connected to a vacuum pump (BOC Edwards, E2M40, Crawley, West Sussex, UK). 10 g sample, previously weighed in aluminum dishes, were introduced in the oven once the desired temperature was reached. Afterwards, the vacuum pump was immediately switched on. Treatments were carried out at pressures of 4, 12 and 19 kPa at 30 °C or 60 °C for 10, 30 and 60 min. Computation of treatment duration started once set pressure value was achieved.

2.3. Analytical procedures

2.3.1. Furan concentration

Furan determination was carried out by SPME/GC–MS analysis according to the slightly modified method of Bianchi, Careri, Mangia, and Musci (2006). In brief, aliquots of 2 g sample were added with 2 mL NaCl 20 g/100 g water solution of d_4-furan (30 µg/kg; internal standard). SPME experiments were performed with an 85 µm carboxen-polydimethylsiloxane fiber (Supelco, Bellfonte, PA, USA). Incubation time and temperature of the fiber were 5 min and 40 °C, respectively; extraction time and temperature were 20 min and 40 °C, respectively. Desorption was carried out at 270 °C for 2 min. GC oven temperature program was: 40 °C for 5 min, 15 °C/min to 300 °C. Mass spectrometer was operated in selected ion monitoring mode and the current of the following ions was recorded: *m/z* 68 and 39 for furan and *m/z* 72 and 42 for d_4-furan. Ion ratios were used to confirm the identification of the analyte; standard addition calibration method was applied for the correspondent quantification.

2.3.2. HMF concentration

HMF was determined by HPLC according to the slightly modified method of García-Villanova, Guerra-Hernández, Martínez-Gómez, and Montilla (1993). Briefly, HMF was extracted with water and the extract clarified with Carrez I and II solutions and subsequent centrifugation before HPLC analysis. The external method was used for the determination of HMF content.

2.3.3. Total solid content

Total solid content was determined gravimetrically (AOAC, 1995).

2.3.4. Water activity

Water activity (a_w) was determined by means of a dew-point measuring instrument (AQUA LAB, Decagon, Pullman, WA, USA) at 25 °C.

2.3.5. Sensory analysis

The procedure of Manzocco and Lagazio (2009) was followed. A panel of ten Italian assessors, aged between 18 and 60 years and approximately balanced between males and females, having a minimum of 2 years of experience in discrimination and descriptive sensory methods, was selected. Sample (5 g), indicated by a three-digit code, was submitted to the panel paired with a reference (untreated) sample in 50 mL capacity odorless plastic cups at ambient temperature. Assessors were asked to sniff the samples after the reference one and evaluate the intensity of odor, differentiating the treated sample from the reference one on a 9-cm unstructured scale anchored with “high”.

2.4. Statistical analysis

Analyses were carried out at least twice on two replicated experiments. Results are presented as mean value ± SD. Analysis of variance was carried out with significance level set to $P < 0.05$ (STATISTICA for Windows, 5.1, Statsoft Inc., Cary, NC, USA). The Tukey procedure was used to test for differences between means.

3. Results and discussion

Vacuum treatments at 4, 12 or 19 kPa and 30 °C for increasing lengths of time of meat sauce samples caused a significant decrease in furan concentration (Fig. 1). After 10 min the removal varied from 54% to 67% depending on the pressure applied. As expected, the lowest removal was achieved by carrying out the vacuum treatment at the highest pressure (19 kPa). By prolonging the time, no significant or slight further removal was observed. Similar results were obtained by carrying out the vacuum treatments at 60 °C instead of 30 °C (data not shown). By contrast, the HMF concentrations of the vacuum treated meat sauce samples, ranging from 77 ± 9 mg/kg_{dm} to 104 ± 16 mg/kg_{dm}, were not significantly different from that of the control (66 ± 11 mg/kg_{dm}). The diffusion rates of furan and HMF through the food matrix are supposed to be different due to their different molecular weight (Goubet, Le Quere, & Voilley, 1998). By virtue of its lower molecular weight, furan would diffuse through the matrix and reach the meat sauce surface faster than HMF. As a result, in our experimental conditions, only furan was removed from the meat sauce, while HMF was mostly retained.

Table 1 shows the moisture and a_w values of the meat sauce samples subjected to treatments at 4, 12 or 19 kPa and 30 °C for increasing lengths of time. It can be observed that the lower the pressure and the longer the time, the greater the moisture and a_w decrease. As expected the minimum moisture and a_w values (i.e. 70.8 g/100 g and 0.969) were obtained by applying 4 kPa for 60 min. It is noteworthy that the 10 min treatments, which allowed a great furan loss to be achieved, did not cause significant moisture and a_w changes as compared with the control sample.

No significant changes in furan and HMF concentrations were found in biscuits subjected to the vacuum treatments at 4, 12 or 19 kPa and 30 °C for 10 min. On average, furan and HMF concentrations, initially equal to 62 ± 9 ng/kg_{dm} and 10 ± 2 mg/kg_{dm}, after the vacuum treatments were 62 ± 11 ng/kg_{dm} and 7 ± 1 mg/kg_{dm}, respectively. These results are in agreement with previous findings

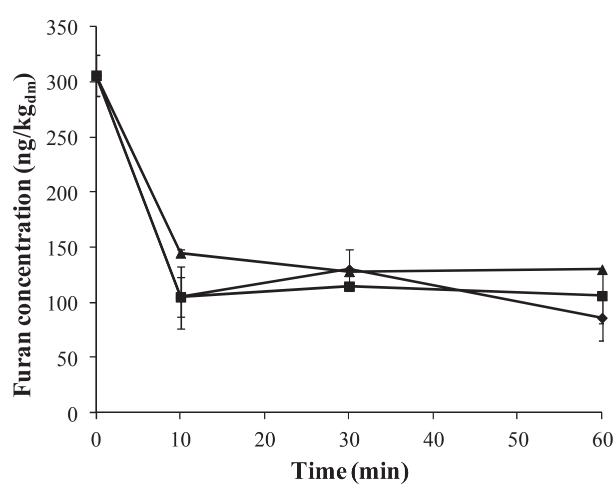

Fig. 1. Furan concentration of meat sauce samples subjected to vacuum treatment at 4 (◆), 12 (■) or 19 (▲) kPa and 30 °C for increasing lengths of time.