



Kinetics of furan formation during pasteurization of soy sauce



Xuesong Huang^a, Sheryl A. Barringer^{b,*}

^a Department of Food Science and Engineering, Jinan University, Guangzhou, 510632, China

^b Department of Food Science and Technology, The Ohio State University, 2015 Fyffe Road, Columbus, OH, 43210, USA

ARTICLE INFO

Article history:

Received 3 September 2015

Received in revised form

19 November 2015

Accepted 27 November 2015

Available online 8 December 2015

Keywords:

Furan

Kinetics

Soy sauce

Selected ion flow tube-mass spectrometry (SIFT-MS)

ABSTRACT

To investigate the kinetics of furan formation during pasteurization in soy sauce, the furan concentration in five samples was determined with Selected Ion Flow Tube-Mass Spectrometry (SIFT-MS) after hot water bath heating at 30, 50, 70, or 80 °C for 10 min to 7.25 h, respectively. The furan concentrations in soy sauce were 12–215 ng/mL. Furan formation in soy sauce is a zero-order reaction and the reaction rate constants were 3.71×10^{-9} mol/L.h for Pearl River Bridge brand (PRBB) soy sauce and 6.99×10^{-9} mol/L.h for Koon Chun brand (KCSB) at 80 °C respectively. In addition, by the Arrhenius equation and active complex theory, the apparent activation energy (E_a), enthalpy ($\Delta H_{\ddagger}^{\circ}$) and entropy ($\Delta S_{\ddagger}^{\circ}$) were summarized as the equations, $\ln k = -77237/RT + 6.61$ and $\ln k/T = -74522/RT - 0.18$ for PRBB, and $\ln k = -72018/RT + 5.35$ and $\ln k/T = -63301/RT + 0.08$ for KCSB, where k is the rate constant, T is the absolute temperature and R is the universal gas constant. E_a , $\Delta H_{\ddagger}^{\circ}$ and $\Delta S_{\ddagger}^{\circ}$ for PRBB are 77.237 kJ/mol, 74.522 kJ/mol, and -199.01 J/K·mol. E_a , $\Delta H_{\ddagger}^{\circ}$ and $\Delta S_{\ddagger}^{\circ}$ for KCSB are 72.018 kJ/mol, 63.301 kJ/mol, and -209.72 J/K·mol. These results can be used to calculate or predict furan formation in soy sauce during pasteurization.

Published by Elsevier Ltd.

1. Introduction

Furan (PubChem CID:8029), a colorless and highly volatile aromatic compound with a boiling point of 31 °C, is a possible human carcinogen (Group 2B) confirmed in animal tests (Lyon, 1995; Merten, Roldan, & Cappe, 2011; NTP, 2004). It is found in a variety of thermally processed foods, such as coffee, soy sauce, baby foods, canned vegetables, fruits, meat and fish at levels of about 100 ng/mL (Crews, Roberts, Laurysen, & Kramer, 2009; Guenther, 2012). Therefore, a great amount of effort has been given to the analysis of this possibly carcinogenic substance occurring in food (Bakhiya & Appel, 2010).

Literature data have shown multiple sources of furan formation originating from (i) thermal degradation/Maillard reaction of reducing sugars, with or without amino acids, (ii) thermal degradation of serine and cysteine, and thermal oxidation of (iii) ascorbic acid, (iv) poly-unsaturated fatty acids and (v) carotenoids (Go, 2013). For every source, furan may be produced by different pathways or routes just as glucose may form furan by three kinds of chemical reactions and ascorbic acid by two kinds of reactions,

including 7 different steps (Nie et al., 2013). The variety of precursors and processing for furan formation is not surprising because furan can be seen as a rather stable reaction product that may be generated from different chemical classes by the degradation and/or recombination of small fragments.

In addition to those formation pathways, the furan content in food is affected by environmental conditions such as pH value, temperature, shelf life, pressure, food processing and so on (Huang, Duan, & Barringer, 2011; Palmers, Grauwet, Celus, Kebede, et al., 2015).

Because of the complex and multiple furan formation routes, most of the proposed pathways of furan formation were performed in model systems. There is very little data on furan formation under different food processing conditions. The kinetics of furan formation in different sources, especially, are very seldom reported as models (J.-S. Kim, Her, & Lee, 2014). This information is important for industrial production. Only recently, Palmers, Grauwet, Celus, Wibowo, et al. (2015) reported that the rates of furan formation in orange and mango juices were clearly matrix-dependent, which could be attributed to the differences in juice composition such as sugars and ascorbic acid content. It has been further confirmed that the increase in furan during storage was best described by an empirical, logistic model and that the maximum reaction rate constant followed the Arrhenius law, while the rate constant during

* Corresponding author.

E-mail address: barringer.11@osu.edu (S.A. Barringer).

the lag phase decreased as a linear function of the storage temperature. It seems that for furan formation pasteurization is not important because the furan concentrations originated from the storage phase for the two juices, not from the thermal preservation step. On the other hand, Kim, Her, Kim, and Lee (2015) found that the pasteurization step was more important because the furan concentration in soy sauce after pasteurization increased by 211%, compared to without pasteurization (M. Y. Kim et al., 2015). However, it is unfortunate that Kim did not present the kinetic data of furan formation during soy sauce pasteurization.

Due to its high volatility, furan is mainly determined by headspace gas chromatography-mass spectrometry (HS/GC/MS). A simple HS/GC/MS method for furan detection in food was developed by US FDA (2004) and is still frequently used. A 5 g sample diluted with water, fortified with internal standard (d4-furan), sealed in headspace vials, equilibrated at 80 °C for a minimum of 30 min with automated headspace sampling is used to detect furan and d4-furan in selected-ion monitoring mode (SIM) by GC/MS. In 2007, the 5 g of sample was changed to 10 g by the FDA and the headspace oven temperature was reduced from 80 to 60 °C to prevent low levels of furan formation that can occur during the analysis of a few relatively high fat foods. All of the furan data reported in food were determined by this method or modifications of this method, such as solid-phase micro-extraction (SPME) in combination with GC/MS (Hu, Zhu, Hernandez, Koutchma, & Shao, 2016; Kim, Kim, & Lee, 2010), proton transfer reaction mass spectrometry and gas chromatography-mass spectrometry (PTR-MS/GC/MS) (Märk, Pollien, Lindinger, Blank, & Märk, 2006). The disadvantage of the FDA method is still that furan might be formed during analysis when foodstuff is heated at 80 °C for a minimum of 30 min (FDA, 2004), in spite of reducing the temperature from 80 °C to 60 °C (FDA, 2007), just as in the studies mentioned above where furan increased when pasteurized at 80 °C. Märk et al. (2006) and Senyuva & Gökmen, 2005 also described the formation of furan in unprocessed foods including green coffee, tomato juice, and orange juice during analysis even under mild (40 °C) thermal conditions. Therefore, it is important to develop an analysis method for samples without heat, pre-concentration and so on.

Selected ion flow tube-mass spectrometry (SIFT-MS) allows highly sensitive, real-time analysis of complex mixtures of volatile compounds without trapping, pre-concentration or pre-heating (Spaněl & Smith, 1999). Thus, artifacts or changes in relative proportions are not introduced by pre-heating and other steps. SIFT-MS has been used in the analysis of volatiles in coffee, onion, garlic, banana, tomatoes and oxidation of olive oil and so on (Sumonsiri & Barringer, 2013).

The purpose of this research is to investigate the kinetics of furan formation during pasteurization of soy sauce using the advantage of SIFT-MS. This provides a reference for understanding the production of furan during pasteurization of soy sauce production and during its shelf life.

2. Materials and methods

2.1. Materials

D-glucose, sodium chloride, citric acid, furan, and sodium glutamate were purchased from Sigma (St. Louis, MO, USA). Furan was 99% purity and purchased from Acros Organics (Geel Belgium, NJ, USA).

Five soy sauces brewed naturally were purchased from the Crestview Market in Columbus, Ohio. They are ① Superior Dark Soy sauce (Pearl River Bridge brand, abbreviated PRBB) produced by Guangdong PRB Bio-tech Co., LTD (Guangdong, China), ② Thin Soy sauce (Koon Chun brand, abbreviated KCSB) produced by Koon

Chun Soy sauce Factory (Hong Kong), ③ Soy sauce (Kikkoman brand) produced by Kikkoman Foods, Inc. (Walworth, WI USA), ④ Premium Dark Soy sauce and ⑤ Shenchou Soy sauce brewed by Lee Kun Kee Food Co. LTD. (Xinhui, Guangdong, China).

One milliliter of each soy sauce sample was diluted with 24 mL of simulated soy sauce solution to determine the furan content, in order to fall within the linear range of the furan standard curve.

2.2. Soy sauce degasification

The 500 mL glass bottles were filled with 80 mL of soy sauce, and connected to a Pierce Reactive-Vap TM III to degas from 15 to 40 min. The residual furan was determined by SIFT-MS after degasification so as to make sure there was no furan remaining in the soy sauce. The soy sauce only, without the volatile furan, was used as the sample for the kinetics determination.

2.3. Preparation of the simulated soy sauce solution

Simulated soy sauce solution was prepared with glucose (15 g), sodium chloride (15 g), glutamate acid (1 g) and distilled water (70 g) referring to the Chinese National Standard of fermented soy sauce (GB 18186-2000).

2.4. Furan standard solution prepared for standard curve

Furan (500 mg) was weighed and dissolved in 200 mL 70 mL/100 mL ethanol solution to obtain a 2.5 g/L stock furan solution. Four grams of 2.5 g/L solution was diluted into 1 L of distilled water and 10 mg/L furan solution. Ten grams of 10 mg/L furan solution was diluted into 1 L distilled water and 100 ng/mL furan solution was obtained.

The standard solution, 4, 12, 20, 28, 36 and 44 ng/mL furan, were prepared with 100 ng/mL of the simulated solution as shown with two burettes (25.00 mL), and were used immediately after they were prepared. The simulated solution was used so that the standard furan solution will vaporize under the same conditions as the natural soy sauce.

2.5. Temperature treatments

The samples of 25.00 mL degassed soy sauces in 500 mL bottles (Pyrex 1395, Corning, NY) were heated at 80 °C from 10 to 60 min, 70 °C from 10 to 60 min, 50 °C from 30–150 min and 30 °C from 1.5 h to 7.25 h in a hot water bath (Precision Inc., Winchester, VA USA), equipped with a temperature sensor (± 0.1 °C) to ensure a homogeneous temperature distribution in the hot water bath. One batch of samples consisted of 20 bottles. After the heated time finished, the samples were removed from the bath for determination with SIFT-MS. In order to avoid the equilibration variation produced at the different temperatures, the determined furan value was subtracted from the value produced by the simulated solution at the same temperature.

2.6. Selected ion flow mass spectrometry

The furan released from the samples was measured by SIFT-MS. The SIFT-MS instrument has been described elsewhere (Smith & Španěl, 2005). Analysis was performed using a SIM model, and the concentration of furan was calculated using known kinetic parameters with Syft VOICE-200 software (v.1.4.9.17754, Syft Technologies Ltd., Christchurch, New Zealand). Using the pre-determined reaction rate constant for the volatile with that precursor ion, and accounting for dilution of the sample gas into the carrier gas, the furan concentration was calculated. In SIFT-MS,

Download English Version:

<https://daneshyari.com/en/article/4563830>

Download Persian Version:

<https://daneshyari.com/article/4563830>

[Daneshyari.com](https://daneshyari.com)