Innovative Food Science and Emerging Technologies 43 (2017) 1–6

Contents lists available at ScienceDirect

Innovative Food Science and Emerging Technologies

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

Ohmic heating: A promising technology to reduce furan formation in sterilized vegetable and vegetable/meat baby foods

J. Hradecky[a], E. Kludska[a], B. Belkova[a], M. Wagner[b], J. Hajslova[a,*]

[a] Department of Food Analysis and Nutrition, University of Chemistry and Technology (UCT), Technická 5, 166 28 Prague 6, Czech Republic
[b] Centre Technique de la Conservation et des Produits Agricoles (CTCPA), Site Agroparc, F-84911 Avignon Cedex 9, France

ARTICLE INFO

Keywords:
Furan mitigation
Ohmic heating
Retort sterilization
Vegetable/meat puree
Headspace volatiles fingerprinting

ABSTRACT

Occurrence of furan, classified as carcinogen 2B by the International Agency for Research on Cancer, in heat-processed foods, especially sterilized baby foods, is of a health concern. On this account, innovative processing practices ensuring microbial safety, acceptable sensorial features, and, at the same time, minimizing furan formation have to be searched. In this study, the potential of ohmic heating to mitigate furan formation was demonstrated. Compared to conventional retort sterilization, significant mitigation (70–90%) of furan was achieved, assumingly due to reduced degradation of furan precursor under faster terms heating conditions. In purees containing meat, approx. two times less furan was formed, regardless of the processing technology. In addition to furan, also other headspace volatiles were measured and statistically evaluated. Compounds originated through fatty acids oxidation and Maillard reaction products were more abundant in conventionally sterilized samples compared to those treated by ohmic heating.

Industrial relevance: Ohmic heating is an emerging technology being employed in the field of food processing which applies a direct electric current to food products, providing rapid and uniform heating throughout the product. Shorter heating times used in ohmic heating, as compared to conventional retort sterilization, reduce potential losses of valuable nutrients and as well as reduce the formation of undesirable processing contaminants, in particular furan.

The presented work examines furan concentrations across various stages of baby food production, in order to compare ohmic heating and retort sterilization processes. Volatile compound fingerprints for baby food purees processed via both sterilization methods, both prior and post sterilization were assessed. The results presented in this work are of high potential interest to the baby food industry to reduce both heat induced chemical changes and exposure of infants and babies to hazardous processing contaminants such as furan.

1. Introduction

Thermal treatments such as pasteurization or sterilization represent important processing practices aimed at avoiding microbial spoilage of processed food, thus increasing their shelf-life. Various reaction products, including undesirable ones, may originate under elevated temperature conditions from natural matrix components. Investigations made on generated volatiles have shown that in some heat treated foods, relatively high concentrations of furan are present in this fraction. A number of this processing contaminant formation pathways has been reported, such as degradation and/or rearrangement of carbohydrates in the presence of amino acids, degradation of certain amino acids, oxidation of ascorbic acid, oxidation of polyunsaturated fatty acids and/or carotenoids (Becalski & Seaman, 2005; Crews & Castle, 2007). Likewise in the case of other processing contaminants, the presence of furan in commercial foods is of high concern, since it has been shown to be carcinogenic and genotoxic in animal experiments. The overview of the respective toxic effects is available in the Joint FAO/WHO Expert Committee on Additives report (IARC, 1995; JECFA, 2011). Considering the health risk associated with dietary exposure to furan, small children and toddlers are of highest concern, due to their highest vulnerability. According to the earlier study, jarred baby food may represent the major contributor to furan dietary intake for this group of consumers (Lachenmeier, Reusch, & Kuballa, 2009). Levels as high as 233 μg/kg were found in some vegetable baby food, in meat-–vegetable products, the maximum measured content was 169 μg/kg (EFSA, 2011).

Microbial safety is obviously a critical issue in baby food production; nevertheless, the heat treatment process employed for this sterilization purpose should ideally maintain maximum nutritional value of

* Corresponding author.
E-mail address: jana.hajslova@vscht.cz (J. Hajslova).

http://dx.doi.org/10.1016/j.ifset.2017.07.018
Received 24 February 2017; Received in revised form 7 July 2017; Accepted 7 July 2017
Available online 10 July 2017

respective product. Recently, ohmic heating, one of the several electromagnetic based methods, has re-emerged as a promising technology minimizing undesirable changes thus preserving 'freshness'. While in traditional retorting, heat energy is generated externally and then transferred to the food material by conduction, in case of the above mentioned approach, the heat is generated directly within the system by an alternating electric current. Solid-liquid mixtures act as an electrical resistor and the substance is uniformly heated by the dissipation of electrical energy. (Jaeger et al., 2016; Sakr & Liu, 2014; Varghese, Pandey, Radhakrishna, & Bawa, 2012). Several studies have demonstrated advantages of ohmic heating over traditional thermal sterilization, pointing out: (i) better nutritional characteristics due to e.g. reduced losses of vitamins (Vikram, Ramesh, & Prapulla, 2005) and carotenoids in fruit juices (Achir et al., 2016); (ii) better overall sensorial features and more natural and homogenous appearance during the product's shelf life (Icier, Yildiz, & Baysal, 2006; Leizerson & Shimoni, 2005), and (iii) lower capital cost together with better energy efficiency and an environment friendly (Jaeger et al., 2016; Sakr & Liu, 2014). The effectiveness of ohmic heating in terms of microbial lethality depends on several factors including the rate of heat generation in the system, the electrical conductivity of the food, electrical field strength, residence time and the method by which the food flows through the system (Varghese et al., 2012). Mercali, Schwartz, Marczak, Tessaro, and Sastry (2014) observed more extensive degradation of ascorbic acid in acerola puree when using electric field frequency lower than 100 Hz compared to the use of higher frequencies. The consequences associated with the use of various electrode materials was addressed by Athmaselvi, Kumar, and Poojitha (2017), who documented 30% reduction of ascorbic acid losses in papaya pulp when replacing stainless steel electrodes by titanium ones.

The research conducted within the EU PROMETHEUS (PROcess contaminants: Mitigation and Elimination Techniques for High food quality and their Evaluation Using Sensors & Simulation) project (7th EU framework) was, besides of other objectives, concerned with the application of ohmic heating technology for production of a safe and high quality baby food. One of the studies showed the benefit of this approach: in ohmically sterilized vegetable based purees, the total content of amino acids remained the same as that in the raw sample, while in retort processed products, a significant decrease in the total amino acid content was documented (Mesías, Wagner, George, & Morales, 2016).

The objective of this study was to document an assumption on a potential of ohmic heating to enable production of safe vegetable/meat baby food, with a significantly lowered furan content compared to products sterilized by conventional retorting. In addition to monitoring furan formation under various production conditions, we also investigated formation of other heat-induced volatiles to understand changes occurring in vegetable/meat matrix during two alternative sterilization processes. To our best knowledge, no other similar study, documenting superiority of ohmic heating over conventional thermal sterilization, in terms of mitigation of hazardous processing contaminant has been published yet.

2. Materials and methods

2.1. Chemicals

Furan (CAS 110-00-9; purity > 99%) was purchased from Sigma-Aldrich (Germany), sodium chloride were from Penta (Czech Republic). Methanol was of HPLC grade quality from Merck (Germany) and water was distilled and deionized using Milli-Q system (Merck, Germany).

2.2. Samples

Vegetable and vegetable/meat puree samples were provided by Centre Technique de la Conservation et des Produits Agricoles (CTCPA, France). The composition of both puree products, as declared from the manufacturer, is shown in Table 1. Puree production started by pre-cooking (10 min at 90 °C) of cleaned frozen materials. Following homogenization, the smooth puree was reheated to 85 °C and filled into glass jars, which then underwent retort sterilization (traditional approach-control) in static retort system (Lagarde multiprocess, France). Alternatively, the reheated puree was sterilized in a static ohmic heater constructed from a cylindrical polycarbonate tube (SIMACO, Italy) and employing stainless steel electrodes, which were installed at both ends of the tube. Electrodes were alternatively connected to the ground potential and the 25 kHz high voltage from the regular 50 Hz network. Sterilized puree was then filled into aseptic pouches. The entire process of sample preparation, including the setup of both apparatus used for sterilization was described by Mesías et al. (2016). It should be noted, that according to CTCPA control analyses, all the sterilized products were shelf-stable, complying to the French regulation NF V08–408 (AFNOR, 1997).

Table 1
Raw materials used for vegetable and vegetable/meat puree production.

	Puree composition	
	Vegetable	Vegetable/meat
Component	(%)	(%)
Carrots	40.0	30.0
Peas	20.0	10.0
Chicken	–	10.0
Zucchini	15.0	–
Rice semolina	–	4.0
Salt	0.1	0.1
Water	24.9	45.9

To trace furan formation across the production process, this processing contaminant was determined in (i) mixture of pre-cooked and homogenized raw materials (meat/vegetables) before reheating; (ii) reheated mixture just before sterilization; (iii) final product after sterilization – either by ohmic heating or retort sterilization. Samples were sterilized to almost the same F_0 values. While for samples, obtained by ohmic heating F_0 values were 3, 15, 24, 31 and 38 min, in the case of retorted samples, F_0 values were 3, 15, 24, 34 and 38 min.

To further investigate, whether additional furan formation or its decrease occurred during storage, a set of four retorted and four ohmically sterilized products were held at room temperature (21 °C) for four months. Vegetable samples sterilized by retorting and ohmic heating were treated at F_0 values 11 and 20 min, while vegetable/meat samples were treated by both methods at F_0 values 8 min and 11 min for ohmically and 16 min for retort sterilized samples.

2.3. Analysis of furan and other volatiles

2.3.1. Standard solution preparation

Furan stock solution A was prepared by diluting 20 μl of furan in 10 ml of methanol, thus obtaining concentration of approximately 1500 μg/ml. Working solution B was prepared from stock solution A and deionized water yielding a concentration of approximately 8 μg/ml. Exact concentrations were calculated gravimetrically. All solutions were diluted in 10 ml sealed glass vials with no headspace. All syringes and vials used for the stock and working solution preparation were chilled to 4 °C prior to use and once prepared, the solutions were stored at 4 °C.

2.3.2. Sample preparation for analysis

For furan analysis, the content of a jar or a bag containing puree was intensively mixed by shaking and then, 1.5 g of sample was weighted into a 10 ml glass vial for GC analysis. Prior to sealing with a magnetic-cap with a polytetrafluoroethylene/silicon septum, 2 ml of a pre-chilled