Furan formation in heat treated food products

Identification

Key words
heat treatment, process-induced contaminant, possible carcinogen, furan, precursors, furan mitigation

Latest version
2012/06/14
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How does it work?

Primary objective
Furan mitigation strategies are applied to reduce the content of the heat-induced contaminant and possible carcinogen furan in foods

Working principle
Formation of furan mainly takes place during intensive thermal treatments in food processing and preservation. As reflected by the variety of food products in which furan is detected, several natural components of food are known to be potential furan precursors (1,2,3):

• Carbohydrates can be very potent furan precursors through thermal degradation or Maillard reactions.
• Ascorbic acid can be thermally degraded, depending on the amount of oxygen available, in an oxidative and non-oxidative manner to yield furan.
• Furan can be formed through thermal oxidation of unsaturated fatty acids. However, research has shown that very high degrees of oxidation may have to be achieved before considerable amounts of furan are detected.
• To a smaller extent, furan can also be formed from amino acids (serine, cysteine) and carotenoids.

For most foods, it is very difficult to remove the undesired furan fraction from the product without affecting its safety or quality attributes. Therefore, mitigation measures focusing on the reduction of furan formation in different foods seem to have the highest potential to keep the furan concentration as low as reasonably achievable (ALARA) (1). With regard to process conditions, there may be little room left to lower heating times and temperatures because the processes of pasteurisation and sterilisation are designed for the microbiological safety of foods. Innovative processing techniques, either non-thermal (ionizing radiation) or aiming to reduce the thermal load on the product by reducing heating-up times (microwave heating, ohmic heating), are being investigated as possible processing alternatives with respect to the formation of process-induced contaminants.

On the food composition side, the best approach so far to reduce furan formation appears to be intervention in the reaction mechanisms. Furan has a wide range of precursors and it is not desirable to remove them from the matrix because of their structural properties and health benefits. Reduction of the formation of furan in complex food matrices can be achieved by the addition of free radical scavengers (mannitol, sulphite) or by modification of the atmospheres within the heating systems (reduced oxygen conditions).
Furan and its derivatives are known to be important end-products of the Maillard reactions in foods (4). As a result, the formation of furan is strongly connected to the formation of hundreds of other (desired) compounds which all together determine the flavour of these products. Consequently, measures to reduce furan formation might result in processed products with a different and maybe unacceptable flavour profile by the consumer.

**Important process parameters**
- processing conditions (heating time and temperature), handling (evaporation)

**Important product parameters**
- food composition (precursors, retention of furan), product characteristics (oxygen level, pH) (5,6,7)

**What can it be used for?**

**Products**
A recent report of the European Food Safety Authority (EFSA) on the monitoring of furan levels in different food categories shows that the coffee categories have the highest furan content in comparison to the other food groups, with mean values of 45 µg/kg for brewed coffee, 394 µg/kg for instant coffee powder, 1936 µg/kg for roasted ground coffee, 2016 µg/kg for non-specified coffee and 3660 for roasted coffee beans (8). The highest 95th percentile was determined for roasted coffee beans at 6407 µg/kg. For the non-coffee products mean values ranged between 3,2 µg/kg for infant formula and 49 µg/kg for jarred baby food containing vegetables only, the latter also with the highest 95th percentile of 123 µg/kg. However, the occurrence of furan and its derivatives has been reported in a wide variety of food systems, including beverages, fruits and vegetables, meat, milk and nut products (4). Remarkably, not all of these products have undergone an extensive heat treatment.

**Operations**
As the formation of furan in foods is induced by heating, highest furan concentrations are found in food products which have received a considerable thermal load, mostly for preservation purposes. In coffee products, furan formation is most probably due to the intensive proceeding of Maillard reactions during the roasting process of the coffee beans. In the other matrices, mainly vegetable-based food products with high moisture content, most furan formation is caused by subjecting these products to thermal sterilisation intensities. Furan appeared to accumulate particularly in heat-processed canned and jarred foods because they are sealed containers that do not allow furan to escape from the food product. One should also notice that considerable amounts of furan can be found in food products which were subjected to a rather moderate heat treatment, like for example fruit juices. The effect of alternative food processing techniques on furan formation still needs thorough evaluation. For example, research has shown that ionizing radiation can directly or indirectly induce furan formation in complex food matrices like fruit juice (9).

**Solutions for shortcomings**
In 1995, furan was classified as ‘possibly carcinogenic’ to humans after it was proven to be carcinogenic in rats and mice. A recent update on the monitoring of furan levels in food by EFSA shows that considerable amounts of furan are present in a variety of commercially available heat-processed foods ranging from coffee over vegetable-based soups and sauces to solid baby foods. Untill more information on the toxicology of furan and the exposure through human diet becomes available, furan levels in food should be kept as low as reasonably achievable (ALARA). Jarred baby foods are products of particular interest in the context of furan formation due to the higher vulnerability of babies and infants for toxicants in general, combined with their high food intake to their body weight ratio.
What can it NOT be used for?

<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
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<tbody>
<tr>
<td><strong>Products</strong></td>
<td>Mitigation of furan formation in foods could be challenging when Maillard reactions are essential for the development of the characteristic food flavour. An obvious example is coffee, which happens to be one of the most likely important food products with respect to furan content.</td>
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<tr>
<td><strong>Operations</strong></td>
<td>The current standards on microbiological safety for foods could be a limitation to mitigate the furan levels in foods. As for food products in which Maillard reactions play an important role, one has to weigh the different food safety and quality attributes against each other in a profound risk analysis.</td>
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<td><strong>Other limitations</strong></td>
<td>Because of legal restrictions and technological limitations, novel technologies like ionizing radiation, microwave heating and ohmic heating have not yet found their way into the large-scale European market of food processing. There are still many research challenges left on the general applicability and development stages of these processing techniques.</td>
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<td><strong>Risks or hazards</strong></td>
<td>Mitigation of furan formation by applying processing conditions on the edge of microbial safety, bears the risk of underprocessing and subsequent delivery of potentially unsafe foods, especially for young, elder, pregnant and immunocompromised people (YOPI risk group).</td>
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Implementation

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<td><strong>Maturity</strong></td>
<td>Since furan is only recently adopted as a hot topic, limited research has been done on mitigation of furan levels in food. However, in anticipation of upcoming research and European legislation concerning furan, furan levels in foods should be kept as low as reasonably achievable (ALARA). There are no clear furan-limiting measures readily available. More research is necessary, not only on mitigation measures, but also on the formation of furan and the exposure through the human diet. For a long time, research data on the occurrence of furan in foods have been limited because of the high volatility of furan (boiling point of about 32°C at atmospheric pressure). This volatility makes the analysis of furan in a standardized and reproducible way very difficult. However, several protocols for the analysis of furan are available in literature (10).</td>
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<td><strong>Modularity</strong></td>
<td>Adjustment of product composition and/or processing conditions. In the future alternative or advanced processing techniques?</td>
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<td><strong>Consumer aspects</strong></td>
<td>Consumer awareness of furan seems limited. Part of the furan concentrations in heat treated foods may be lost by proper stirring of the products before consumption. However, in most cases these evaporative losses are largely compensated by the formation of an extra amount of furan during domestic heating (11). In the end, it does not seem advisable to place the responsibility for reducing the furan levels in foods on the consumer. There is no specific information available on the consumer attitude towards alternative or advanced processing techniques of foods.</td>
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<td><strong>Legal aspects</strong></td>
<td>Currently no European maximally accepted levels for furan in foods defined. Novel food legislation for novel technologies.</td>
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**Environmental aspects**
## Facilities that might be interesting for you

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<th>Title</th>
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<tr>
<td>Auditorium IRTA</td>
<td>IRTA</td>
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<td>Clean room – Histocell</td>
<td>Noray</td>
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<td>Video observation system for market research and product development tasks - Keki</td>
<td>NAIK EKI</td>
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## Further Information

### Institutes
KU Leuven LFT, EFSA, Ghent University - NutriFOODchem, FSA, fera, ETH Zurich, McGill Uni DFSAC, FDA

### Companies
Nestlé Research Centre

### References