SCIENTIFIC / TECHNICAL REPORT submitted to EFSA

CONSUMER EXPOSURE TO FURAN FROM HEAT-PROCESSED FOODS and KITCHEN AIR[1]

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Abstract

Levels of furan were determined in a range of foods before and after cooking, and also in the air of kitchens during cooking. Furan was measured in food using an established in-house validated method, and in air by collection in inert bags, transfer to carbon-based traps, and thermal desorption gas chromatography-mass spectrometry.

The results confirm that coffee is the major dietary furan source for adults. High levels of furan were also measured in toasted bread.

The project has shown that furan can be measured in the air of kitchens when food is cooked, that the levels vary with cooking technique and food product, and that emission profiles can be generated from certain cooking activities.

Results were both low and variable for cooking activities of short duration. For lengthier cooking practices such as cooking in ovens and frying chipped potatoes the consistency of data was much improved. This suggests that sampling at single points within a room with static air is a source of considerable variability, whereas when the cooking is prolonged furan distribution becomes more uniform and its measurement more consistent.

The data show that the highest degree of furan inhalation results from the addition of hot water to coffee in a cafetiere, the frying of chipped potatoes in an open chip pan, and baking some foods in an oven.

Exhalation experiments indicate that furan is exhaled at elevated levels after drinking coffee, and that the levels do not return to the pre-consumption (background) level in breath in less than 10 minutes. There was insufficient data to make reliable estimates of intake from air samples, measured as the difference between inhaled and exhaled levels in the same breath.

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Summary

Levels of furan were determined in a range of foods before and after cooking using normal domestic techniques, and also in the air of kitchens during such cooking. Furan was measured in food using an established in-house validated method, and in air by collection in inert bags, transfer to carbon-based traps, and thermal desorption gas chromatography-mass spectrometry.

This project confirms that furan exposure from the diet is dependent on the food type with coffee being the major source for adults. Coffees prepared from a commercial bean-to-cup machine in which the beverage was prepared in a largely enclosed environment, provided the highest levels of furan. The next most important source of dietary furan for adults was toasted bread, although there is evidence of rapid loss from this food.

The project has shown that furan can be measured in air using appropriate equipment. The system of sampling into inert bags, transferring the sample to a trapping medium and its analysis by thermal desorption gas chromatography-mass spectrometry has been shown to be a useful tool. It was demonstrated that furan can be determined in the interior air of kitchens when food is cooked, that the levels vary with cooking technique and food product, and that emission profiles can be generated from certain cooking activities.

It has been shown that results are both low and variable for cooking activities of short duration (less than 10 minutes) even when the levels of furan expected to be released were high (the case of coffees). For cooking practices that lasted longer than 10 minutes (cooking in ovens, frying chipped potatoes) the consistency of data was much improved. This seems to demonstrate that sampling at single points within a room (e.g. near the consumer’s mouth) with static air is a source of considerable variability, whereas when the cooking is prolonged it might be the case that the furan distribution within the air of the room becomes more uniform. Also the oven cooking is more likely to disperse furan on account of it having a higher total heat output, therefore encouraging thermal convection currents within the kitchen at large.

The available data show that the highest degree of furan inhalation results from the addition of hot water to a coffee in a cafetiere, the frying of chipped potatoes in an open chip pan, and baking some foods in an oven.

Exhalation experiments showed elevated levels of furan in exhaled breath after drinking coffee and that the levels did not return to the pre-consumption (background) level in breath within 10 minutes. Furan levels in breath collected after cooking breaded fish in an oven mostly remained similar to the level in the inhaled air. These are early and speculative data on exhalation. The net intake from breathing, estimated as the difference in levels between inhaled and exhaled air in the same breath, cannot be calculated without the accumulation of more data.

Key words: Furan, processing contaminant, consumer exposure, cooking, air sampling

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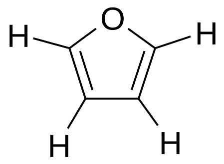
INTRODUCTION

Furan is a small cyclic ether with aromatic character and a low boiling point of 31ºC. Occasional early descriptions of the occurrence of furan in food, mainly from flavour investigations, were first collated by Maga (1979) who reported that furan and its derivatives had been isolated from a number of food groups, with the highest levels being found in coffee. Furan has been classified as ‘possibly carcinogenic to humans’ (IARC 1995).

Figure 1 The structure of furan



In 2004 the US Food and Drug Administration (FDA) reported that many heat-treated foods contained detectable furan (FDA 2004a). The analytical method used had a limit of quantification of about 5 ug/kg (parts per billion) for most foods and 2 ug/kg for most liquids including coffee.

The European Food Safety Authority (EFSA) has also reported data (EFSA 2009) which indicated that furan levels of over 100 ug/kg were found certain foods. Higher levels of furan are formed in the coffee bean.

Furan can be formed in foods on account of heating in during industrial processing for the purpose of cooking and/or sterilization. It can also be formed during the domestic processing, i.e. cooking, of foods regardless of whether or not the uncooked food contained furan.

The highest levels of furan have been reported in coffees, probably on account of the roasting process where the high temperatures exceed most other food processing procedures, and in sealed containers such as canned foods.

It has been well demonstrated that furan can be lost to the air by evaporation when food are warmed ready to eat (Hasnip et al. 2006). There have been no studies into the comparative rates of formation and loss, in fact the presence and levels of food-derived furan in air have not yet been demonstrated. Also, its presence in the atmospheric environment has not been studied. This might be because furan is not an expected environmental contaminant, its high volatility has excluded its determination from surveys of volatiles (including those in food), and as a liquid it has not been included in studies of gaseous contaminants.

The substantial differences between the furan levels measured in coffee beans and coffee powders and their corresponding brews is so far the only significant indicator that furan is lost from foods on heating. The addition of hot water to coffee powders is sufficient to produce furan, but only at low levels over a brief period of time (furan formation will cease below about 50°C), therefore it may be assumed with some confidence that the heat of the water causes furan to evaporate from the coffee at a much faster rate than it is formed.

This project was intended to study and where possible quantify consumer exposure to furan from both food and atmospheric sources on domestic preparation.

Procedures

The first part of the project was to carry out a review of the occurrence of furan in foods, and mainly the methods of analysis of furan in foods, and the methods of analysis of furan in air. That report was presented to EFSA in 2009. Its important conclusions were 1) that good methods were available for the determination of furan in food, based on gas chromatography and mass spectrometry (GCMS) following sampling of the headspace above food samples contained in sealed vials, and 2) that no method for air analysis had been targeted at furan but that some procedures that had been used for the determination of volatile compounds in general could be applied to furan.

The method most likely to suit the requirements of the project to measure furan in air as it was inhaled was to sample a reasonably large volume of air at a rate as close as possible to natural breathing. To extract volatile compounds from the air for instrumental analysis the review indicated that trapping on to carbon based traps followed by thermal desorption and GCMS analysis could be effective. For high trapping efficiency only a low air flow can be used, much lower than the breathing rate, and so the air samples were first collected in polyvinylfluorine (Tedlar) bags. The air was then pumped at a low flow rate through the traps.

The air was sampled by use of a 1 litre syringe fitted with a 0.7 L Tedlar bag and tap. The bags were filled by pulling the plunger at a rapid rate (0.7 L in about 15 seconds) that fell short of the breathing rate but was the most rapid available.

For the experiments a wide range of foods was chosen that covered various cooking techniques, but all were widely consumed food products. The foods and cooking procedures are described in Table 1.

The food ingredients are described in Appendix 1. The foods were mostly prepared in a laboratory kitchen that replicated a domestic one. It was well removed from the chemical laboratories and sources of fumes, and could be well ventilated between experiments on account of having a large area (1 x 2 m) of windows that could be opened wide, a large door, a ceiling based extractor fan that could be closed, and a large portable expeller fan.

Cooking experiments commenced at 8:30 to 9:00 am, generally took 30-45 minutes and were followed by a minimum ventilation period of 2 hours. Some experiments such as toasting and microwave cooking took considerably less time so that each day up to 4 cooking experiments could be conducted.

Table 1. Foods and cooking procedures

Sample	Cooking method
Coffee	Cup brewed with hot water
Coffee	Cafetiere brewed with hot water
Coffee	Percolated
Coffee	Percolated, home
Coffee espresso	Bean to cup machine
Coffee latte	Bean to cup machine
Coffee regular	Bean to cup machine
Coffee espresso	Vending machine
Coffee regular	Vending machine
White bread	Toasted
White bread	Toasted home
Wholemeal bread	Toasted
Wholemeal bread	Toasted home
Bread part-baked	Baked
Cookies	Baked from mixture
Bean based convenience meal	Microwaved
Meal based convenience meal	Microwaved
Soup based convenience meal	Microwaved
Infant food vegetable	Microwaved
Infant food meat	Microwaved
Tomato soup	Saucepan heated
Tomato soup	Microwaved
Pizza chilled	Baked
Pizza frozen	Baked
Breaded chicken	Oven cooked
Breaded vegetables	Oven cooked
Breaded fish	Oven cooked
Chips part cooked, frozen	Microwaved
Chips frozen	Oven cooked
Chips from fresh potatoes	Fried

When cooking was complete the cooked food samples were placed in sealed containers, cooled to room temperature, and then chilled prior to analysis. The food samples were usually analysed on the day of cooking, and occasionally on the following day. The GCMS autosampler had spaces for 32 samples. The air samples, collected in Tedlar bags as described below, were taken to the laboratory for trapping of the volatiles on to a Carboxen trap. About five bags and traps were used for each cooking experiment. The thermal desorption autosampler used for analysis of the trap contents had spaces for 100 samples allowing all traps to be analysed and reconditioned (cleaned at high temperature) overnight for re-use the next day.

For the home cooking experiments the kitchen was 4 x 4 x 3.5 m with three windows, two doors and an extractor fan to the outside. Home-cooked food samples were prepared in the morning (7:30 to 8:30 am) and taken to the laboratory in sealed bottles for analysis that day. Coffee samples were prepared using the same percolator and coffee powder as used in the laboratory. The coffee samples were collected as in the laboratory. Bread samples were toasted using a two-slice toaster. The toast was taken in sealed polythene bags to the laboratory.

The home air samples were collected in the same manner as in the laboratory. Furan in the Tedlar bags was transferred to the traps in the home kitchen. This was achieved by warming the bags to 50-80 deg C in an electric oven while drawing the air through the trap with the laboratory pump.

1.1. General

For all cooking experiments the laboratory kitchen had been well ventilated since the previous experiment by opening the large windows and doors and turning on a ventilation fan.

The windows and doors were then closed and room blank air samples were taken. The foods were weighed using a top-pan laboratory balance and cooked following the manufacturers' instructions as closely as possible. At the end of the air sampling the (cooked) food sample was re-weighed and a portion placed in a sealed container for analysis. Then the room was ventilated. All residues of food were removed from the kitchen. Temperatures were recorded using an infra-red remote thermometer.

For foods being cooked on the gas ring, in the oven or the bread toaster, air samples were taken from a position above the cooker, at head height, about 5 feet, where the consumer would be likely to stand.

For prepared coffee and for foods removed from the oven, the foods were placed on the kitchen worksurface and air samples were taken from a position above the food, at head height, where the consumer would be likely to stand.

1.1.1. Instant coffee

Instant coffee was prepared by weighing 2.0 g instant coffee powder into a ceramic mug of about 240 ml volume. The mug was placed on the kitchen workbench and filled with boiling water to about 1 cm from the top of the mug (220 ml).

Room blank samples were taken before the coffee jar was opened. Some air samples were taken from directly above the coffee jar as it was opened, to replicate the inhalation of the powder's aroma.

The main air samples were taken from a position above the mug, at head height, where the consumer would be likely to stand whilst preparing the coffee. These samples were taken at 1, 2, 3, and 4 minutes after adding the water.

The coffee beverage was allowed to cool to about 50° C and a sample of about 50 ml retained in a sealed 50 ml sample bottle for furan determination. This sample was left to cool to room temperature and then refrigerated until analysis.

The preparation of both air samples and liquid coffee brews for analysis was carried out on the day of coffee preparation, and the samples analysed overnight using autosamplers.

1.1.2. Percolated coffee

Percolated coffee was prepared as instructed in the percolator operating leaflet by weighing 10g coffee powder into the powder holder of the percolator. Cold water (100 ml) was added to the body of the percolator. The percolator was assembled and was placed on the small gas ring of the kitchen cooker. The gas burner was lit and left on the lowest setting.

The percolation began after about 4 minute’s heating. When percolation had finished (after about 5 minutes) the coffee was poured into a ceramic mug of about 100 ml volume standing on the kitchen workbench.

Room blank samples were taken before the coffee packet was opened. Some air samples were taken from directly above the coffee packet as it was opened, to replicate the inhalation of the powder’s aroma.

Initially some air samples were taken from a position above the percolator as it heated up, at head height, where the consumer would be likely to stand whilst preparing the coffee. Later, most air samples were taken during and after pouring the coffee from the percolator into the mug, from a position above the mug, at head height, where the consumer would be likely to stand whilst pouring the coffee. These samples were taken at 1, 2, 3, and 4 minutes after pouring the coffee.

The coffee liquid and air samples were treated and analysed as for the instant coffee above.

Coffee percolated in the home kitchen used the same percolator but with the coffee weight estimated at 10 g (the filled coffee holder contained 10 g coffee). The percolator body was filled to an interior line with water (150 ml). The percolator was heated on a small gas ring at the lowest setting.

1.1.3. Cafetiere coffee

Cafetiere coffee was prepared as instructed in the cafetiere operating leaflet by weighing 10g coffee powder into the body of the cafetiere. The cafetiere had a capacity of 400 ml. Boiling water (100 ml) was poured on to the coffee in the cafetiere and the brew left for 4 minutes. The plunger was depressed and the coffee liquid poured into a ceramic mug of about 100 ml volume standing on the kitchen workbench.

Room blank samples were taken before the coffee packet was opened. Some air samples were taken from directly above the coffee packet as it was opened, to replicate the inhalation of the powder’s aroma.

1.1.4. Machine made coffees.

Two types of machine were used. One type was a bean to cup vendor (BTC). this provided coffee by grinding roasted beans and extracting the coffee powder with hot water. The machine provided normal or decaffeinated espresso coffee (45 ml), regular coffee without milk (double serving portion 250 ml), and café latte with milk (single serving portion 220 ml). The machine was situated in the Fera atrium (approximately 25 x 35 x 20 m) and in accordance with Fera policy the brewed coffees dispensed into PLA-coated paperboard cups were sealed with a plastic lid. The lid has a small ventilation hole. The brews were taken to the laboratory for analysis.

The second machine produced a range of coffees from soluble powders. For this project espresso (90 ml) and regular black (190 ml) drinks were dispensed into polystyrene cups and handled as for the BTC brews.

For some experiments all 5 types of coffee samples were taken to an office and the lids removed for air sampling.

1.1.5. Coffee roasting

Green coffee beans were roasted as instructed in the roaster operating leaflet. In the roasting process the temperature is raised in a series of steps over about 12 minutes. The instructions specified that the roasting should be carried out in a well ventilated space with windows open. It proved to be very uncomfortable to remain in the kitchen with the roaster operating and the door and windows closed, because of the fumes that were emitted. For this reason only a single roasting was carried out.

1.1.6. Bread – toasting

Bread (mass-produced sliced soft white and wholemeal) was toasted using a 4-place electric pop-up toaster operated at setting 5 from a setting scale of 0 to 7. The slices of bread popped up at about 2.5 minutes and were returned as they were not fully browned at this stage.

Air samples were taken from above and beside the toaster at 1, 2, 3, and 4 minutes, at which time the toasting was complete. A final air sample was taken from the same place at 6 minutes, with the bread remaining in the toaster.

For home toasting experiments a 2-place electric non-pop-up toaster was used, operated at a setting of three minutes. When the toast was fully browned (2.5 minutes) the heating was turned off and the toast raised up from the body of the toaster while the final air sample was taken.

1.1.7. Bread – baking

Part-baked bread rolls (2 x white, 2 x brown and 2 x mixed grain) were purchased as a pack sealed in a protective atmosphere. The rolls were cooked from room temperature in an electric oven pre-heated for 15 minutes with the temperature set to 200°C as recommended in the cooking instructions for the rolls. The bread rolls were placed evenly spaced directly on the rack in the centre of the oven. The rolls were cooked for 10 minutes, removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 5, and 10 minutes during cooking, and a final air sample was taken from above the worksurface at 15 minutes.

1.1.8. Cookies – oven cooking

The cookie samples were (large) dough biscuits prepared from a commercial cookie mixture to which water and butter were added. The dough was divided to produce eight individual cookies that were evenly spaced on a metal oven tray. They were baked in an electric oven pre-heated for 15 minutes with the temperature set to 190°C.

The kitchen air was sampled at 4, 8 and 12 minutes. The cookies were removed from the oven after 12 minutes and left to cool on the kitchen workbench. A final air sample was taken after cooling, at 14 minutes.

1.1.9. Convenience meals – microwave oven cooking

The chilled bean-based meals were cooked from chilled. The plastic packet was pierced as instructed and placed singly into the microwave oven. The meals were cooked at the maximum setting (800 watts) for 4.5 minutes. At 2.5 minutes they were removed from the oven and placed on the worksurface in front of the oven. The was lid peeled off, and the contents briefly mixed. The film lid was replaced and the food returned to the oven. The fully cooked meals were removed from the oven and placed on the worksurface. Air samples were taken from above the food on the worksurface at 2.5, and 4.5 minutes with the microwave oven door open, and a final air sample was taken from above the worksurface at 6.5 minutes.

The chilled meat-based meals were cooked from chilled. The plastic packet was pierced as instructed and placed singly into the microwave oven. The meals were cooked at the maximum setting for 6 minutes. At 4 minutes they were removed from the oven and placed on the worksurface in front of the oven. The lid was peeled off, and the contents briefly mixed. Cold water (30 ml) was added to the rice. The film lid was replaced and the food returned to the oven. The fully cooked meals were removed from the oven and placed on the worksurface. Air samples were taken from above the food on the worksurface in front of the oven at 4, and 6 minutes with the microwave oven door open, and a final air sample was taken from above the food on the worksurface at 8 minutes.

The chilled vegetable pot soup meals were cooked from chilled. The plastic packet was pierced as instructed and placed singly into the microwave oven. The meals were cooked at the maximum setting for 2 minutes. At 1 minute they were removed from the oven and placed on the worksurface in front of the oven. The lid was peeled off, and the contents briefly mixed and returned to the oven. The fully cooked meals were removed from the oven and placed on the worksurface. Air samples were taken from above the food on the worksurface in front of the oven at 1 and 2 minutes with the microwave oven door open, and a final air sample was taken from above the food on the worksurface at 4 minutes.

1.1.10. Infant foods

The infant meals were removed from their cans or jars at room temperature and placed into a glass dish. The meals were cooked at the maximum setting for 2 minutes. At 1 minute they were removed from the oven and the contents briefly stirred and returned to the oven. The cooked meals were removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 1 and 2 minutes with the microwave oven door open, and a final air sample was taken from above the worksurface at 6 minutes.

1.1.11. Soups – microwave oven cooking

Tomato soup (canned) was heated in a saucepan on a low gas setting or microwaved in a glass dish. In both instances the product was stirred. The saucepan-heated soups were heated for 5 minutes. The microwaved soups were removed from the oven after 2 minutes and the contents briefly stirred and returned to the oven. The soups were removed from the oven after 5 minutes and placed on the worksurface. Air samples were taken from above the oven at 2 and 5 minutes with the microwave oven door open, and a final air sample was taken from above the worksurface at 7 minutes.

1.1.12. Pizzas – oven cooking

Pizzas were cooked from both chilled and frozen products. For chilled pizzas the oven was pre-heated for 15 minutes with the temperature set to 220°C. A single pizza was placed directly on to the oven rack in the centre of the oven. For frozen pizzas the oven was pre-heated for 12 minutes with the temperature set to 190°C. A single pizza was placed directly on to the oven rack in the centre of the oven.

The chilled pizzas were cooked for 12 minutes, removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 4, 8, and 12 minutes during cooking, and a final air sample was taken from above the worksurface at 14 minutes.

The frozen pizzas were cooked for 15 minutes, removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 5, 15, and 25 minutes during cooking, and a final air sample was taken from above the worksurface at 27 minutes.

1.1.13. Breaded chicken pieces – oven cooking

The breaded chicken pieces were cooked from frozen. The oven was pre-heated for 15 minutes with the temperature set to 220°C. One packet (ten portions) of the breaded chicken pieces were placed evenly spaced on a metal oven tray and put into the centre of the oven. The pieces were cooked for 15 minutes, removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 5, 10, and 15 minutes during cooking, and a final air sample was taken from above the worksurface at 20 minutes.

1.1.14. Breaded vegetables – oven cooking

The breaded vegetable product was cooked from frozen. The oven was pre-heated for 15 minutes with the temperature set to 200°C. One packet (nine portions) of the breaded vegetable product were placed evenly spaced on a metal oven tray and put into the centre of the oven. The pieces were cooked for 15 minutes, removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 5, 10, and 15 minutes during cooking, and a final air sample was taken from above the worksurface at 17 minutes.

1.1.15. Fried potatoes – fryer cooking

Chips (fries) were prepared from fresh potatoes according to a published recipe (BBC 2009). The potatoes were cleaned, peeled and cut into chips (fries) of approximate size 4 x 1 x 1 cm by hand. The chips were soaked in cold water for 10 minutes.

Cooking oil (rapeseed oil) was preheated to 180 °C in a domestic electric chip fryer that was thermostatically controlled. The soaked chips were briefly dried using paper kitchen towel and placed into the hot oil using the fryer basket. After 6 minutes the basket and chips were removed from the oil and shaken briefly. The oil was heated to the maximum setting until the maximum temperature (190 °C) had been reached (the thermostat light was extinguished). The basket was then lowered into the oil and the chips cooked for a further 3 minutes (total 9 minutes). The chips were then removed from the wire basket and held in a plastic bowl for two minutes before the final air sample was taken (11 minutes).

1.1.16. Breaded fish – oven cooking

Breaded fish products (fingers) were cooked in an electric oven pre-heated for 15 minutes with the temperature set to 220°C. Five fish fingers were evenly spaced on a metal oven tray and placed in the centre of the pre-heated oven.

For later breaded fish cooking experiments breath samples were taken from one of the cooking personnel (18 years old, male, non-smoker) during the cooking by breathing into a sampling bag. Ten fish fingers were cooked in these experiments. Air and breath samples were taken simultaneously at two minute intervals after the fish fingers had been removed from the oven. A blank breath sample was taken simultaneously with the room blank.

1.1.17. Frozen chips – oven cooking

Frozen part-cooked chips were cooked from frozen. The oven was pre-heated for 15 minutes with the temperature set to 220°C. Portions of the frozen chips (500g) were placed evenly spaced on a metal oven tray and put into the centre of the oven. The chips were cooked for 12 minutes. At 10 minutes they were briefly mixed and turned. The cooked chips were removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 5, 10, and 15 minutes during cooking, and a final air sample was taken from above the worksurface at 17 minutes.

1.1.18. Microwave chips – microwave oven cooking

Frozen part-cooked microwaveable chips were cooked from frozen. The card packet was partially opened as instructed and placed into the microwave oven. The chips were cooked at the maximum setting for 3 minutes. After 1 minute they were removed from the oven, briefly shaken and returned. The cooked chips were removed from the oven and placed on the worksurface. Air samples were taken from above the oven at 2 minutes (following shaking at I minute), and finally from above the worksurface at 3 minutes.

1.1.19. Fried potatoes – fryer cooking

Chips (fries) were prepared from fresh potatoes according to a published recipe (BBC 2009). The potatoes were cleaned, peeled and cut into chips (fries) of approximate size 4 x 1 x 1 cm by hand. The chips were soaked in cold water for 10 minutes.

Cooking oil (rapeseed oil) was preheated to 180 °C in a commercial domestic thermostatically controlled electric chip fryer. The soaked chips were briefly dried using paper kitchen towel and placed into the hot oil using the fryer basket. After 6 minutes the basket and chips were removed from the oil and shaken briefly. The oil was heated to the maximum setting until the maximum temperature (190 °C) had been reached (the thermostat light was extinguished). The basket was then lowered into the oil and the chips cooked for a further 3 minutes (total 9 minutes). The chips were then removed from the wire basket and held in a plastic bowl for two minutes before the final air sample was taken (11 minutes).

1.2. FURAN DETERMINATION IN FOODS

The method used for the analysis of furan in foods was based on that devised by the US FDA (FDA 2004) as modified to allow quantification based on comparing the furan response with that of deuterated d4-furan as used previously. This compensates for matrix effects without requiring numerous standard addition samples. It has been found to be equivalent in performance to external calibration and standard additions methods and used elsewhere.

The GCMS system was a ThermoFinnigan Voyager benchtop instrument fitted with a ThermoFinnigan HS2000 static headspace autosampler. The column was of 15 m x 0.32 mm i.d. fused silica, with a 20 µm bonded polystyrene-divinylbenzene phase (HP-Plot Q). The carrier gas was helium at a constant flow of 1.7 mL/min. The split/splitless injector port and mass spectrometer interface were heated to 200 and 250°C respectively. The column oven temperature was programmed from 50°C held for 1 min, to 225°C at 10°C per min and held 12.5 minutes.

Foods were chilled and transferred to a beaker immersed in an ice bath and homogenised using a blender for about 20 seconds. Portions of each sample (1 to 5 g depending on food type) were weighed accurately into 20 ml headspace vials and chilled water (up to 5 mL depending on food type) was added quickly. Internal standard (0.2 ug) was added to each vial. The vials were cooled in ice prior to and during the addition of internal standard to avoid loss of furan. The headspace incubation oven temperature was 50°C and the syringe needle 80°C. Samples were incubated for 30 minutes with shaking. The injection volume was 1 ml and the injection speed 30 ml/minute. Spit injections were made at a ratio of 2:1.

The mass spectrometer was operated in electron ionization mode. Furan was detected by selected ion monitoring of the molecular ion at m/z 68. Peak identity was confirmed by monitoring the fragment ion at m/z 39. The deuterated internal standard was detected by monitoring the molecular ion at m/z 72.

The criteria for the identification of furan were the GC retention time (± 2% of that of standards), and the ratio of the molecular ion for furan at m/z 68 to its fragment ion at m/z 39 (± 20% of that of standards). The limit of detection of the method had been established previously as around 3 ug/kg for solid foods and around 1 ug/kg for coffee brews.

The food samples were usually analysed on the day of cooking, and occasionally on the following day.

1.3. FURAN DETERMINATION IN AIR

Air samples were obtained using the 1 L syringe (Figure 2) fitted with a 0.7 L. Tedlar bag (Figure 3).

Figure 2 1 L Syringe used for air sampling

Figure 3 Tedlar bag used for air sampling

Within 30 minutes of sampling the bags were connected in line with 60 mm x 6 mm od x 4 mm id Carboxen traps to an air pump using PTFE tubing. The traps were placed in an oven pre-heated to 50 °C. with the tubing passed through a thermometer port in the oven wall. The bag air was pumped through the traps at a rate of 50 ml/minute. This was close to the maximum possible because of the packing density and it was recommended by the manufacturer. The Carboxen traps were then placed in the thermal desorption autosampler.

In operation the thermal desorption trap is picked up by a robot arm and placed into the thermal desorption unit. The GC column is then cooled under a stream of liquid carbon dioxide. The thermal desorption tube is heated rapidly to 230 ºC and held at this temperature for a few minutes. The furan is thus desorbed off of the heated Carboxen and trapped at the beginning of the chilled GC column. The tube heating and column chilling are stopped and the GC column is then heated to chromatograph the sample.

The thermal desorption apparatus was a Gerstel TDU, and the GCMS system an Agilent Model 5973 fitted with a CombiPal CTC autosampler. The thermal desorption parameters were as follows. The inlet trapping (cryofocus) temperature -55 ºC. The desorption time was 6 minutes, and the desorption temperature was 180 ºC. The GCMS conditions used were with the GC column oven held at 35 ºC for 8 minutes, then heated at 5 ºC/minute to 100 ºC. The oven was then heated rapidly to 230 ºC to remove any higher boiling compounds. These conditions gave a good furan signal and appropriate retention time.

The method was validated as described in the interim report and found to be suitable. The repeatability was considered good for a complex procedure (17 to 44% RSD). The detection limit was estimated to be 0.2 ng furan desorbed.

The criteria for the identification of furan was the GC retention time (± 20% of that of standards), and the ratio of the molecular ion for furan at m/z 68 to its fragment ion at m/z 39 (± 20% of that of standards).

Calibration series were prepared by injecting furan at various levels into a heated 500 mL flask and drawing air from it into the Tedlar bag using the syringe system as described in the validation report. No internal standard was used because the additional air sampling manipulations that this required introduced further errors.

All air samples were analysed on the day of cooking and sampling.

RESULTS

1.4. FURAN DETERMINATION IN FOODS

Results for the determination of furan in foods are provided in Tables 2 to 15.

Results for the in house reference materials were within acceptable ranges and similar to previous surveys. Peak identity confirmations based on retention time and m/z 68:39 ratios could be made in all cases.

1.4.1. Instant coffee

Table 2 shows the furan levels measured in instant coffee powders and the beverage made from these powders. It also shows the calculated intake from the beverage.

Table 2. Furan in instant coffee powder and beverages

Description	set	coffee	water	Analysis						Portion	Intake
		g	ml	1	2	3	4	5	Mean	ml	ug/cup
powder			0	770	749	750			757		
powder			0	819	708	764	710	778	756		
beverage	A	2	220	3	2	2	4	2	3		
beverage	B	2	220	3	1	1	2	2	2		
beverage	C	2	220	3	3	4	-	-	3		
beverage	D	2	220	1	1	2	2	2	2		
beverage	E	2	220	1	1	1	1	1	1		
beverage	F	2	220	2	2	2	2	2	2		
beverage	G	2	220	2	2	3	2	-	2		
Not analysed								Av.	2	222	0.5

Levels of furan in the instant coffee powder (about 750 ug/kg) fell within the ranges expected and were similar to those reported elsewhere (FDA 2004b, Kuballa et al. 2005, Zoller et al. 2007). Levels of furan in the coffee beverage prepared from these powders (about 2 ug/kg) also fell within the ranges expected and were similar to those reported elsewhere (FDA 2004b, Kuballa et al. 2005, Zoller et al. 2007). Drinking one medium to large sized mug (220 ml) would provide an intake of about 0.5 ug furan.

1.4.2. Cafetiere coffee

Table 3 shows the furan levels measured in coffee powders intended for brewing by percolation or using a filter device or a cafetiere. It also describes furan levels in the coffee prepared from these powders with the cafetiere (French press), and the calculated intake from the brews.

Table 3. Furan in coffee powder and cafetiere beverages

Description cafetiere	Set	coffee g	water ml	Analysis 1	2	3	4	5	Mean	Portion ml	Intake ng/cup
powder				3487	4040	3418	-		3649		
powder				1998	1858	1560	1586		1751		
beverage	A	10	400	34	37	33	35	31	34		
beverage	B	10	400	30	34	37	32	-	33		
beverage	C	10	400	29	33	30	31	-	31		
beverage	D	10	400	12	12	12	12	-	12		
Not analysed								Av.	28	220	6.1

Levels of furan in two coffee powder samples were about 1750 ug/kg and 3600 ug/kg. These levels were again within the range expected.

Levels of furan in the cafetiere brews prepared from these powders (about 30 ug/kg) fell within the ranges expected and were similar to those reported elsewhere (Kuballa et al 2005). Consumption of one medium to large sized mug (250 ml) would provide an intake of about 6 ug furan.

1.4.3. Percolator coffee

Table 4 shows the furan levels measured in coffee brewed using a percolator (Moka), and the calculated intake from the brews.

Levels of furan in the percolator brews were typically about 100 ug/kg, mostly within the ranges expected and similar to those reported elsewhere (Kuballa et al 2005). Some samples were considerably higher, and two of the home brewed samples were much lower. It is possible that these variations were due to coffee powder fines being carried into the brew, as variable amounts of residue were present in the cups after the liquid was removed. Use of 100 ml water in the percolator produced about 40 ml brew, consumption of which would provide on average an intake of about 1-2 ug furan.

Table 4. Furan in coffee powder and percolator beverages

Description percolator	Set	coffee g	water ml	Analysis 1	2	3	4	5	Mean	Portion ml	Intake ng/cup
powder				349	369	383	394	416	382		
powder				206	224	210	251	252	228		
powder				156	167	170	171	178	168		
beverage	A	10	100	156	167	170	171	178	168		
beverage	B	10	100	349	369	383	394	416	382		
beverage	C	10	100	206	224	210	251	252	228		
beverage	D	10	100	144	137	138	133	-	138		
beverage	E	10	100	115	127	126	105	-	118		
beverage	F	10	100	159	155	162	159	-	159		
								Av.	199	40	8.0
beverage	home G	10	150	147	176	173	165		165		
beverage	home H	10	150	155	173	172	174		169		
beverage	home I	10	150	61	46	52	47		51		
beverage	home J	10	150	51	50	54	50		51		
Not analysed								Av.	127	40	5.1

1.4.4. Bean to cup coffees

Data for the machine-made BTC coffees are given in Table 5.

Table 5. Furan in coffee beans and machine beverages

Description machine	Set	Analysis 1	2	3	4	5	Mean	Portion ml	Intake ug/cup
Regular bean	A	4069	4316	4160	3992	-	4134		
	B	5890	6472	6509	6467	7245	6517		
Decaff bean	A	3252	3173	3109	3176	3816	3305		
	B	3729	3514	3952	3910		3776		
BTC Espresso	A	152	160	156	162	173	161		
	B	203	205	212	213	215	209		
	C	220	225	231	224	233	227		
	D	202	200	266	234	236	227		
	E	113	113	114	-	-	114		
						Av.	188	45	8.5
BTC Latte	A	122	129	135	137	131	131		
	B	175	182	189	195	191	186		
	C	242	232	235	238	235	237		
	D	369	368	281	283	274	315		
						Av.	217	220	47.7
BTC Regular	A	95	129	98	99	101	104		
	B	244	246	256	259	253	252		
	C	322	328	327	320	311	321		
						Av.	226	250	56.5
Machine regular	A	17	24	21	20	23	21		
	B	29	30	30	30	32	30		
	C	38	39	42	39	43	40		
	D	79	81	78	81	88	81		
						Av.	43	190	8.2
Machine espresso	A	25	25	25	25	24	25		
	B	35	37	36	37	39	37		
	C	44	51	48	47	47	47		
						Av.	36	90	3.3

- Not analysed

Coffee powder from the bean to cup machines contained between 3000 and 6500 ug/kg furan with less in the decaffeinated bean powder (3300to 3800 ug/kg) than in the regular (4000 to 6500 ug/kg). Similar levels have been reported elsewhere (Kuballa et al. 2005).

Espresso coffee brew from the BTC machines contained levels of furan that varied from about 100 to 230 ug/kg. These levels are similar to but slightly higher than those (50-150 ug/kg) reported by Zoller et al. (2007) for espresso coffees prepared from powder with similar furan content. Consumption of one cup of the dispensed coffee would provide about 9 μg furan.

Latte coffee brew from the BTC machines contained furan ranging from about 130 to 315 ug/kg. These levels are higher than for espresso coffees. This might be due to differences in the quantity of coffee bean used but the inner workings of the machine were not accessible and this could not be checked. However, observation suggested that the machine dispensed a shot of coffee identical to espresso and then added the milk. The higher furan levels may be due to a high degree of retention cause by the larger total volume, the fat in the milk, and the froth on the top. Consumption of one cup of the coffee would provide about 50 μg furan.

Regular coffee brew, without milk, from the BTC machines contained furan that were very similar to the latte coffee of similar volume. Consumption of one cup of the coffee would provide about 50 μg furan.

The coffee used for the espresso, latte and regular coffees was produced from the same machine, however the quantities of coffee beans used in each brew were unknown and therefore the relative furan production rates unknown. The variation in furan levels between samples is could be caused by the fact that usage of the machines by staff is high, the bean capacity is relatively low, and thus the beans used can come from different bags of beans. It may also be that the bean-to-powder grinder operates at .a different temperature (e.g. it may get hot during intensive use during staff breaks). Such variations and the consequences in furan levels, are of course normal.

1.4.5. Vending machine coffees

Data for the vended coffees are given in Table 5. The vending machine coffees had similar furan concentrations, about 20 to 80 ug/litre, providing 3 to 10 ug furan per cup.

1.4.6. Bread

Furan levels in breads before and after cooking are given in Table 6.

Table 6. Furan in bread and toast

Description	Set	Weight		Analysis					Mean	Portion	Intake
bread		before	after	1	2	3	4			g	ug
Bread white	A			< 3	< 3	< 3	< 3		< 3		
	B			< 3	< 3	< 3	< 3		< 3		
				3	3	3	3		3		
Bread white	A	176	125	338	243	304	301		297		
toasted	B	174	122	249	260	264	220		248		
	C	180	134	184	200	172	192		187		
	D	175	124	447	386	327	379		385		
	E	169	131	318	335	434	426		187		
								Av.	260	130	33.9
Bread white	A			3	5	3	5		4		
home toasted	B			3	3	3	3		3		
	C			< 3	< 3	< 3	< 3		< 3	130	-
Bread wholemeal	A			< 3	4	3	3		3		
	B			< 3	< 3	< 3	< 3		< 3		
	C			< 3	< 3	< 3	< 3		< 3		
Bread wholemeal	A	199	149	132	265	145	199	185	132		
toasted	B	200	151	143	117	114	109	121	143		
	C	198	151	160	142	141	169	153	160		
	D	190	140	32	36	21	29	29	32		
	E	202	162	122	146	202	166	159	122		
	F	-	-	148	172	165	162	162	148		
	G	178	131	229	243	243	239	238	229		
								Av.	150	150	22.5
Bread wholemeal	A	nr	nr	5	6	7	6		6		
home toasted	B	nr	nr	< 3	3	3	3		3		
	C	nr	nr	< 3	< 3	< 3	< 3		< 3	150	
Part baked bread											
uncooked		< 3	< 3	< 3	< 3						
baked	A	262	240	2.8	2.2	-	3.3		3		
	B	267	244	5.9	6.3	5.4	6.0		6		
	C	262	236	6.6	8.0	6.2	5.6		7		
	D	269	241	10.0	9.7	11.1	15.1		11		
								Av.	7	150	1004

nr not recorded - not analysed

White bread contained not more than 3 ug/kg furan before toasting. After toasting the levels from the laboratory kitchen experiments were variable but noticeably high at about 200 to 400 ug/kg. Surprisingly, those from the home cooking experiments were much lower, hardly above the pre-toasting level. The most likely explanation for this is that the home-toasted samples experienced a considerable time lag between cooking and analysis - they were transported from home to the laboratory in polyethylene bags at ambient temperature and lost furan as a result. Such a facile loss of furan is of course relevant in assessing intake and the influence of time between cooking and consumption.

The results for wholemeal bread match were quite similar to those for white bread. The bread contained not more than 3 ug/kg furan before toasting and after toasting in the laboratory kitchen levels were about 120 to 230 ug/kg. Once again the home cooked toast was very low in furan.

The levels for the laboratory toasted bread appear at first sight to be unexpectedly high. However in a single report of similar analyses Zoller et al. (2007) reported between < 2 and 28 ug/kg furan in untoasted bread, but up to about 200 ug/kg in the crust, presumably some considerable time after the bread was baked. The same workers reported furan at 1000 to 3700 ug/kg in starches roasted at high temperature (230ºC; similar to those in a toaster) and therefore high levels in toasted bread are feasible.

The part baked breads were packets of six rolls, two each of white, wholemeal and mixed grain. Before laboratory baking the breads contained 2 ug/kg furan and after cooking the furan was up to about 10 ug/kg. Consumption would provide about 1 ug furan.

1.4.7. Cookies

Results for the cookie baking are given in Table 7.

Table 7. Furan in cookies

Description	Set	weight	Analysis					Mean	Portion	Intake
cookies		before	after	1	2	3	4		g	ug
Cookie dough	A			<3	<3	<3	<3			
Cookies baked	A	328	313	7	7	7	6	7		
	B	329	309	7	7	7	7	7		
	C	325	303	9	9	9	9	9		
	D	331	309	5	5	5	5	5		
							Av.	7	150	1.0

Before baking the cookie mixture, with added butter and water, did not contain detectable furan. After cooking the cookies contained about 7 to 10 ng furan, providing about 1 ug per portion (half of the batch of cookies baked).

1.4.8. Convenience foods

Results for the furan determinations on the convenience foods are given in Table 8.

Table 8. Furan in microwave convenience foods

Description	Set	Analysis				Mean	Portion	Intake
		1	2	3	4		g	ug
Bean meal								
uncooked		< 3	< 3	< 3	< 3			
cooked	A	5	5	4	5			
	B	< 3	< 3	< 3	< 3			
	C	< 3	< 3	< 3	< 3			
	D	< 3	< 3	< 3	< 3			
	E	< 3	< 3	< 3	< 3	< 3	400	<1.2
Meat meal		3	4	3	4			
uncooked	A	3	3	4	3	3		
cooked	B	< 3	< 3	< 3	< 3			
	C	8	8	8	9	8		
	D	5	5	5	5	5	400	<2.0
Veg soup								
uncooked			< 3	< 3	< 3			
cooked	A	< 3	5	8	< 3	4		
	B	< 3	< 3	< 3	< 3			
	C	< 3	< 3	< 3	< 3			
	D	4	3	4	3	4	340	<1.4

As reported in earlier work (Roberts et al. 2007) the furan content of these foods was low and it did not clearly increase significantly on cooking. These foods provide very little furan in the diet.

1.4.9. Infant foods

Results for the furan determinations on the infant foods are given in Table 9. Levels in the uncooked and cooked foods (15-20 ug/kg) were as expected (FDA 2004, EFSA 2009).

Table 9. Furan in infant foods

Description	Set	Analysis					Mean	Portion	Intake
		1	2	3	4			g	ug
Infant food lasagne	A	13	13	13	15		14		
	B	13	12	17	20		15		
						Av.		180	2.7
Infant food beans and bacon	A	16	16	19	15		17		
	B	19	19	14	16		17		
	C	13	18	24	20		19		
						Av.	17	120	2.1

1.4.10. Tomato soup

Results for the furan determinations on the tomato soups are given in Table 10. Levels in the uncooked and cooked foods (25-30 ug/kg) were as expected. Cooking had little effect on the levels. Consumption of a 400g portion (the can size) would provide 10 to 15 ug furan.

Table 10. Furan in tomato soup

Description	Set	Analysis					Mean	Portion	Intake
		1	2	3	4	5		g	ug
uncooked		27	26	26	25	23	25		
microwaved	A	36	39	36	37	39	37		
	B	28	30	29	33	34	31		
	C	30	33	32	28	32	31		
	D	27	29	28	29	28	28		
						Av.	32	400	13
saucepan heated	A	26	29	28	27	23	26		
	B	26	29	24	26	23	25		
	C	25	27	28	24	19	25		
	D	26	31	26	29	28	28		
						Av.	26	400	10

1.4.11. Pizzas

Results for the furan determinations on pizzas are given in Table 11. There was no detectable furan in the uncooked chilled pizza and only about 3 ug/kg in the frozen pizza. After cooking levels rose to about 3 ug/kg from the chilled pizza and to 10 to 30 ug/kg from the frozen pizza. The dietary contribution would be 5-6 ug and 1 ug per pizza, respectively.

Table 11. Furan in pizza

Description	Set	Analysis					Mean	Portion	Intake
		1	2	3	4	5		g	ug
Chilled uncooked		<3	<3	<3	<3	-	<3		
Chilled cooked	A	9	6	3	4		6		
	B	<3	<3	3	<3	<3	<3		
	C	4	<3	3	3	4	3		
	D	<3	3	4	<3	4	3		
						Av.	4	300	1.1
Frozen uncooked		3	3	3	4		3		
Frozen cooked	A	7	11	10	12		10		
	B	14	20	15	23		18		
	C	26	29	21	30		27		
	D	16	26	17	33		23		
						Av.	19	300	5.8

1.4.12. Breaded chicken pieces

Results for the furan determinations on breaded chicken pieces are given in Table 12. The chicken pieces had little detectable furan prior to cooking, and low levels of 6 to 8 ug/kg after cooking. A large (300g) portion would provide about 2 ug furan.

Table 12. Furan in breaded chicken

Description	Set	Analysis				Mean	Portion	Intake
		1	2	3	4		g	ug
Uncooked		<3	<3	<3	<3	<3		
Cooked	A	8	8	7	8	8		2.3
	B	8	9	4	6	7		2.0
	C	8	9	6	6	7		2.2
	D	7	6	5	5	6		1.7
					Av.	7	300	2.1

1.4.13. Breaded vegetable pieces

Results for the furan determinations on breaded vegetable product are given in Table 13. This product comprised breaded nuggets of mixed vegetables rather than identifiable individual vegetables. The product had little detectable furan prior to cooking and only low levels of 5 to 8 ug/kg after cooking. A moderate (150g) portion would provide about 1 ug furan.

Table 13. Furan in breaded vegetables

Description	Set	Analysis				Mean	Portion	Intake
		1	2	3	4		g	ug
Uncooked		<3	<3	<3	<3			
Cooked	A	4.9	4.3	5.2	3.9	5		
	B	9.7	8.8	10.5	8.0	9		
	C	6.7	6.1	5.9	5.5	6		
	D	3.9	3.5	3.7	3.9	4		
	E	6.1	3.8	3.8	3.5	4		
					Av.	6	200	1.1

1.4.14. Breaded fish pieces

Results for the furan determinations on breaded fish product are given in Table 14. This product was in the form of fish fingers (minced fish) rather than fillets. The product had little detectable furan prior to cooking and about 5 ug/kg after cooking. A 200g portion would provide about 1 ug furan.

Table 14. Furan in breaded fish

Description	Set	Analysis				Mean	Portion	Intake
		1	2	3	4		g	ug
Uncooked		<3	<3	<3	<3			
Cooked	A	5.3	5.7	4.9	5.3	5		
	B	5.2	4.8	5.7	4.4	5		
	C	5.2	4.8	5.7	4.4	5		
	D	3.9	3.5	3.7	3.9	4		
	E	5.3	4.5	4.5	4.6	5		
					Av.	5	200	1.0

1.4.15. Potato chips (fries).

Results for the furan determinations on various fried potato products are given in Table 15.

Furan was not detected in the microwave chips either before or after cooking. The oven chips contained very low levels (3 ug/kg furan) before cooking and this did not increase on cooking. The fresh potatoes did not contain detectable furan and on frying in oil about 10-15 ug/kg furan was formed, providing 4 to 8 ug per 500g portion.

Table 15. Furan in potato products

Description	Analysis					Mean	Portion	Intake
potato products	1	2	3	4	5		g	ug
Microwave chips uncooked	<3	<3	<3	<3		<3		
Microwave chips cooked	<3	<3	<3	<3	<3	<3		
	<3	<3	<3	<3	<3	<3		
							100	<0.3
Oven chips uncooked	3	3	3	3	3	3		
Oven chips cooked	<3	<3	<3	<3		<3		
	<3	3	3	3		3		
	<3	<3	<3	<3		<3		
	<3	<3	<3	<3		<3		
							500	< 1.5
Fresh potatoes uncooked	<3	<3	<3	<3		<3		
Fresh chips cooked	12	11	9	12		11		
	17	12	14	21		16		
	9	6	7	10		8		
	14	12	13	13		13		
					Av.	12	500	6.0

1.4.16. Summary

This work has confirmed that exposure to furan in the diet is dependent on the food type and cooking method. Coffee is the major source for adults. Coffees prepared from a commercial bean-to-cup machine in which exposure to the atmosphere (hence presumably furan evaporative loss) was minimal, provided the highest levels of furan. The next most important source of dietary furan for adults was toasted bread.

1.5. FURAN DETERMINATION IN AIR SAMPLES

Results for the determination of furan in air samples are provided in Tables 16 to 32.

No reference samples for quality assurance were available. Calibration graphs were linear and the slopes for calibration series prepared on different days were in good agreement. Confirmation criteria for peak identity and purity based on retention time and m/z 68:39 ratios were met in most cases although for the breath samples the GC retention times were extended by a few seconds, possibly due to the effect of moisture in the breath, and there was occasional interference in the qualifier ion channel (m/z 39). Occasionally room blank samples and analytical samples gave unexpectedly high results.

1.5.1. Instant coffee

Table 16 shows the furan in laboratory kitchen air while instant coffee was prepared. Seven batches were prepared. There were occasional increases in furan above the room blank value but these were variable and not clearly related to the sampling time.

Table 16. Furan in kitchen air during instant coffee preparation

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.7
	Air above coffee jar on opening		0.7
	Kitchen air on adding water		0.5
	Kitchen air after 1 min	1	0.4
	Kitchen air after 2 mins	2	0.5
	Kitchen air after 3 mins	3	0.2
	Kitchen air after 4 mins	4	0.3
B	Room blank		0.5
	Air above coffee jar on opening		0.3
	Kitchen air on adding water	0	0.7
	Kitchen air after 1 min	1	1.8
	Kitchen air after 2 mins	2	1.4
	Kitchen air after 3 mins	3	0.3
	Kitchen air after 4 mins	4	0.4
C	Room blank		0.2
	Air above coffee jar on opening		0.3
	Kitchen air on adding water		1.0
	Kitchen air after 1 min	1	0.3
	Kitchen air after 2 mins	2	0.3
	Kitchen air after 3 mins	3	0.4
	Kitchen air after 4 mins	4	0.2

Table 16 (continued). Furan in kitchen air during instant coffee preparation

Set	Sampling	Time mins	Furan ng/litre
D	Room blank		0.6
	Kitchen air on adding water		0.6
	Kitchen air after 1 min	1	0.8
	Kitchen air after 2 mins	2	1.3
	Kitchen air after 4 mins	4	0.3
E	Room blank		nd
	Air above coffee jar on opening		0.8
	Kitchen air on adding water		0.6
	Kitchen air after 1 min	1	0.4
	Kitchen air after 2 mins	2	0.5
	Kitchen air after 3 mins	3	0.3
	Kitchen air after 4 mins	4	0.3
F	Air above coffee jar on opening		0.3
	Kitchen air on adding water		0.7
	Kitchen air after 1 min	1	1.9
	Kitchen air after 2 mins	2	1.4
	Kitchen air after 3 mins	3	0.4
	Kitchen air after 4 mins	4	0.4
G	Room blank		nd
	Air above coffee jar on opening		0.3
	Kitchen air after 1 min	1	0.3
	Kitchen air after 2 mins	2	0.4
	Kitchen air after 3 mins	3	0.2
	Kitchen air after 4 mins	4	nd

1.5.2. Cafetiere coffee

Table 17 shows the furan levels in the laboratory kitchen air while cafetiere coffee was prepared. Five batches were prepared. In the first batch air samples were not taken after the coffee was poured out. For subsequent experiments samples were taken after pouring the coffee into the cup as it was realised that much more coffee odour was present in the room after pouring.

Table 17. Furan in kitchen air during cafetiere coffee preparation

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.3
	Kitchen air on adding water	0	61.3
	Kitchen air	4	2.8
	Kitchen air	4 mins + 1	11.6
	Kitchen air on pouring into cup	4 mins + 1	14.8
B	Room blank		0.4
	Kitchen air on adding water	0	125.0
	Kitchen air on pouring into cup	4	11.5
	Kitchen air after pouring into cup	4 mins + 1	1.1
	Kitchen air after pouring into cup	4 mins + 2	14.6
	Kitchen air after pouring into cup	4 mins + 3	2.1
	Kitchen air after pouring into cup	4 mins + 4	2.2
C	Room blank		0.4
	Kitchen air on adding water		32.9
	Kitchen air on pouring into cup		10.6
	Kitchen air after pouring into cup	4 mins + 2	7.1
	Kitchen air after pouring into cup	4 mins + 3	1.6
	Kitchen air after pouring into cup	4 mins + 4	0.7
D	Room blank		0.4
	Kitchen air on adding water		27.4
	Kitchen air on pouring into cup		1.1
	Kitchen air after pouring into cup	4 mins + 1	0.4
	Kitchen air after pouring into cup	4 mins + 2	0.7
	Kitchen air after pouring into cup	4 mins + 3	1.0
	Kitchen air after pouring into cup	4 mins + 4	0.4
E	Room blank		3.3
	Kitchen air on adding water		199.5
	Kitchen air on pouring into cup		3.2
	Kitchen air after pouring into cup	4 mins + 1	8.4
	Kitchen air after pouring into cup	4 mins + 2	5.5
	Kitchen air after pouring into cup	4 mins + 3	7.5
	Kitchen air after pouring into cup	4 mins + 4	3.4

The results show a considerable increase in the furan level than was observed for instant coffee, but the results are rather variable both over the time scales monitored and between experiments. It appears that the greatest level of furan is produced on adding the hot water to the coffee powder. The concentration of furan was abnormally high on addition of water in experiments B and E and these data points might not be acceptable. In the four minutes after the initial release of furan the average level in the kitchen air was about 5 ng/L, whereas the corresponding value for instant coffee was 0.6 ng/L.

1.5.3. Percolator coffee

Table 18 shows the furan levels in the laboratory and home kitchen air while percolator coffee was prepared. Levels of furan in the kitchen air during and just after preparing percolator brews averaged about 4 ng/L, slightly lower than for cafetiere coffee after the initial release of furan. The results are highly variable. The air concentrations in the domestic kitchen were lower than in the laboratory kitchen which was of a smaller size.

Table 18. Furan in kitchen air during percolator coffee preparation

Set	Sampling	Time mins	Furan ng/L
A	Room blank		8.0
	Kitchen air, percolator on heat 1 min	1	3.1
	Kitchen air, percolator on heat 2 mins	2	3.0
	Kitchen air, percolator on heat 3 mins	3	2.6
	Kitchen air, percolator on heat 4 mins	4	3.2
B	Room blank		1.1
	Kitchen air, percolator on heat 1 min	1	1.4
	Kitchen air, percolator on heat 2 mins	2	1.7
	Kitchen air, percolator on heat 3 mins	3	7.6
	Kitchen air, percolator on heat 4 mins	4	2.1
C	Room blank		
	Kitchen air, percolator on heat 1 min	1	0.2
	Kitchen air, percolator on heat 2 mins	2	0.6
	Kitchen air, percolator on heat 3 mins	3	0.5
	Kitchen air, percolator on heat 4 mins	4	0.6
	Kitchen air on pouring coffee	5	1.7
D	Room blank		0.6
	Kitchen air, percolator on heat 1 min	1	0.3
	Kitchen air, percolator on heat 2 mins	2	0.6
	Kitchen air, percolator on heat 3 mins	3	0.6
	Kitchen air, percolator on heat 4 mins	4	0.6
	Kitchen air on pouring coffee	5	1.8
E	Room blank		3.6
	Room blank		3.2
	Kitchen air, percolator on heat 1 min	1	17.8
	Kitchen air, percolator on heat 3 mins	3	11.3
	Kitchen air, percolator on heat 5 mins	5	36.2
	Kitchen air 2 mins after pouring		3.7
F	Room blank		0.2
	Kitchen air, percolator on heat 1 min	1	0.3
	Kitchen air, percolator on heat 2 mins		0.4
	Kitchen air, percolator on heat 4 mins	4	0.4
	Kitchen air, percolator on heat 5 mins	5	0.2
	Kitchen air, percolator on heat 6 mins	6	no data

Table 18 (continued). Furan in kitchen air during percolator coffee preparation

Set	Sampling	Time mins	Furan ng/L
G	Room blank		0.2
	Room blank		0.7
	Kitchen air, percolator on heat 1 min	1	1.2
	Kitchen air, percolator on heat 2 mins	2	1.1
	Kitchen air, percolator on heat 3 mins	3	1.3
	Kitchen air on pouring coffee		2.2
	Kitchen air 2 mins after pouring	5	0.8
H	Room blank		1.0
	Room blank		1.0
	Room blank		1.3
	Kitchen air, percolator on boiling		3.5
	Kitchen air, percolator on boiling 1 min	1	3.0
	Kitchen air, percolator on boiling 2 min	2	2.8
	Kitchen air, percolator on boiling 3 min	3	12.3
	Pouring into cup	4	2.7
	Above cup 2 mins	6	1.8
I	Room blank		1.3
	Room blank		0.4
	Kitchen air, percolator on boiling		12.4
	Kitchen air, percolator on boiling 1 min	1	10.4
	Kitchen air, percolator on boiling 2 min	2	2.7
	Kitchen air, percolator on boiling 3 min	3	10.7
	Pouring into cup	4	1.5
	Above cup 2 mins	6	0.7
J	Room blank		1.9
	Kitchen air, percolator on boiling		6.0
	Kitchen air, percolator on boiling	1	2.7
	Kitchen air, percolator on boiling 1 min	2	4.1
	Kitchen air, percolator on boiling 2 min	3	2.1
	Kitchen air, percolator on boiling 3 min	4	2.7
	Above cup 2 mins	6	2.3
K	Room blank		0.3
	Room blank		0.3
	Room blank		0.4
	Kitchen air, percolator on boiling	0	29.5
	Kitchen air, percolator boiling 1 min	1	8.4
	Kitchen air, percolator boiling 2 mins	2	4.6
	Kitchen air, percolator boiling 3 mins	3	3.6
	Kitchen air on pouring coffee	4	8.6
	Kitchen air 2 mins after pouring	6	4.9

Table 18 (continued). Furan in kitchen air during percolator coffee preparation

Set	Sampling	Time mins	Furan ng/L
L	Room blank		0.2
	Room blank		0.2
	Kitchen air, percolator on boiling		6.5
	Kitchen air, percolator boiling 1 min	1	1.2
	Kitchen air on pouring coffee	2	5.7
	Kitchen air 2 mins after pouring	4	0.8
	Kitchen air 5 mins after pouring	5	1.4
M	Room blank		0.3
	Room blank		0.3
	Kitchen air, percolator on boiling		0.5
	Kitchen air, percolator boiling 1 min	1	1.0
	Kitchen air on pouring coffee	2	0.6
	Kitchen air 2 mins after pouring	4	0.8
	Kitchen air 5 mins after pouring	5	0.7
N	Room blank		0.7
	Room blank		0.3
	Kitchen air, percolator on boiling		0.6
	Kitchen air, percolator boiling 1 min	1	1.9
	Kitchen air on pouring coffee	2	1.1
	Kitchen air 2 mins after pouring	4	0.9
	Kitchen air 5 mins after pouring	5	1.0
A	Home kitchen room blank		0.6
	Home percolator on boiling		0.8
	Home kitchen air, percolator boiling 1 min	1	0.8
	Home kitchen air, percolator boiling 2 mins	2	0.9
	Home kitchen air, percolator boiling 3 mins	3	1.0
	Home kitchen air on pouring coffee	4	1.4
	Home kitchen air 2 mins after pouring	6	1.0
B	Home kitchen room blank		0.2
	Home percolator on boiling		0.2
	Home kitchen air on pouring coffee	1	0.2
	Home kitchen air 2 mins after pouring	3	0.4
C	Home kitchen room blank		0.4
	Home percolator on boiling		0.4
	Home kitchen air on pouring coffee	1	0.5
	Home kitchen air 2 mins after pouring	3	0.7
	Home kitchen air 5 mins after pouring	6	0.8
D	Home kitchen room blank		0.4
	Home percolator on boiling		1.1
	Home kitchen air on pouring coffee	1	0.5
	Home kitchen air 2 mins after pouring	3	0.6

1.5.4. Machine made coffees

Table 19 shows the furan levels in the atrium space while machine-made coffees were prepared. Time related formation could not be measured as this was in a large public area that is heavily used by staff at breaks. Air samples were taken from the consumer's position near to the vending machine.

Table 19. Furan in atrium air during machine coffee dispensing

Set	Sampling	Furan ng/litre
A	Room blank Atrium	2.1
	Air dispensing BTC espresso	1.9
	Air dispensing BTC decaff latte	2.5
	Air dispensing BTC large regular	8.1
	Air dispensing machine espresso	1.6
	Air dispensing machine regular	0.7
	Room blank office	1.3
	Room office + all 5 coffees after 5 mins	0.9
B	Room blank Atrium	0.9
	Room blank Atrium	1.1
	Air dispensing BTC espresso	0.8
	Air dispensing BTC decaff latte	1.4
	Air dispensing BTC large regular	5.9
	Air dispensing machine espresso	1.0
	Air dispensing machine regular	1.4
	Room blank office 1	1.0
	Room blank office 2	0.5
	Room office + all 5 coffees after 5 mins	0.9
C	Room blank Atrium	2.3
	Air dispensing BTC espresso	1.9
	Air dispensing BTC decaff latte	2.6
	Air dispensing BTC large regular	8.4
	Air dispensing machine espresso	1.7
	Air dispensing machine regular	0.8
	Office blank	1.0
	Room office + all 5 coffees after 1 min	1.4
	Room office + all 5 coffees after 5 mins	1.0
D	Room blank Atrium	0.9
	Air dispensing BTC espresso	4.2
	Air dispensing BTC decaff latte	2.2
	Air dispensing BTC large regular	6.8
	Air dispensing machine espresso	2.2
	Air dispensing machine regular	2.4

Levels of furan in the atrium air averaged about 3 ng/L, rather high considering its volume. However furan levels when dispensing the large volume bean to cup regular black coffee were consistently higher (about 7 ng/L) than for the other samples (mostly 1 to 2 ng/L) suggesting that the furan was being sampled near the source and before its dispersal into the atrium.

For experiment sets A, B, and C the five coffees dispensed were taken to an office (5 x 5 x 4 m) and left with the lids removed before taking air samples. There was however no obvious increase in the furan content of the office air after 5 minutes.

For one BTC latte coffee a single experiment was carried to see whether furan could be detected in the breaths exhaled after drinking the coffee. As this experiment showed indications of success it was followed by a more detailed study using a black regular coffee. These investigations were limited as they were outside the planned work and used several carbon traps. The results are shown in Table 20. For the first experiment 90 ml latte coffee were consumed by a non-smoking male investigator and exhaled air collected by breathing into the Tedlar bag. It was difficult to collect successive breaths and the first sample was missed. Nevertheless the level of furan began at 36 ng/L and decreased in almost linear fashion with the next two breaths.

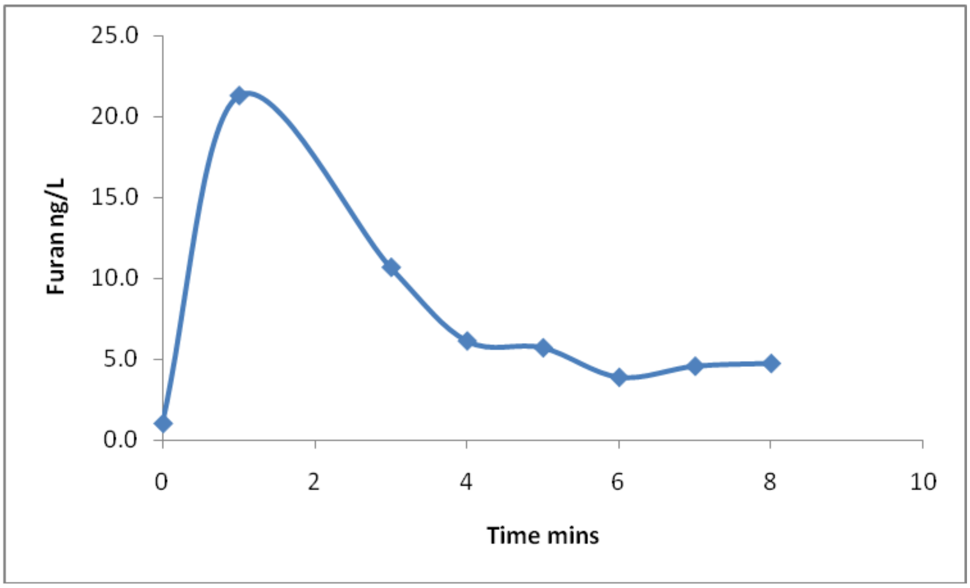
For the follow up experiments 90 ml black coffee was consumed by a non-smoking female investigator and exhaled air was analysed. Samples were collected every minute and so not all exhaled breath was measured. The results are shown in Table 20 and Figure 4. There was a strong increase from the baseline level of furan in the breath after drinking the coffee, followed by a relatively smooth decline that was in this case less linear. In both cases there was a levelling off of furan content within 10 minutes, at which stage the level had still not returned to the pre-ingestion value.

Table 20. Furan in exhaled breath after drinking coffee

Sample		Furan ng/L
Breath blank		1.6
Breath 2 after BTC decaffeinated latte coffee		36.1
Breath 3 after BTC decaffeinated latte coffee		11.5
Breath 4 after BTC decaffeinated latte coffee		6.5

Sample	Time mins	Furan ng/L
Breath blank	0	0.5
Coffee Breath A 0 min	1	6.0
Breath 1 min after BTC black coffee	2	7.2
Breath 2 min after BTC black coffee	3	2.9
Breath 3 min after BTC black coffee	4	3.3
Breath 4 min after BTC black coffee	5	2.3
Breath 5 min after BTC black coffee	6	1.7
Breath 6 min after BTC black coffee	7	1.6
Breath 7 min after BTC black coffee	8	1.7

Sample	Time mins	Furan ng/L
Breath blank	0	1.1
Coffee Breath A 0 min	1	21.3
Breath 2 min after BTC black coffee	3	10.7
Breath 3 min after BTC black coffee	4	6.2
Breath 4 min after BTC black coffee	5	5.7
Breath 5 min after BTC black coffee	6	3.9
Breath 6 min after BTC black coffee	7	4.6
Breath 7 min after BTC black coffee	8	4.8



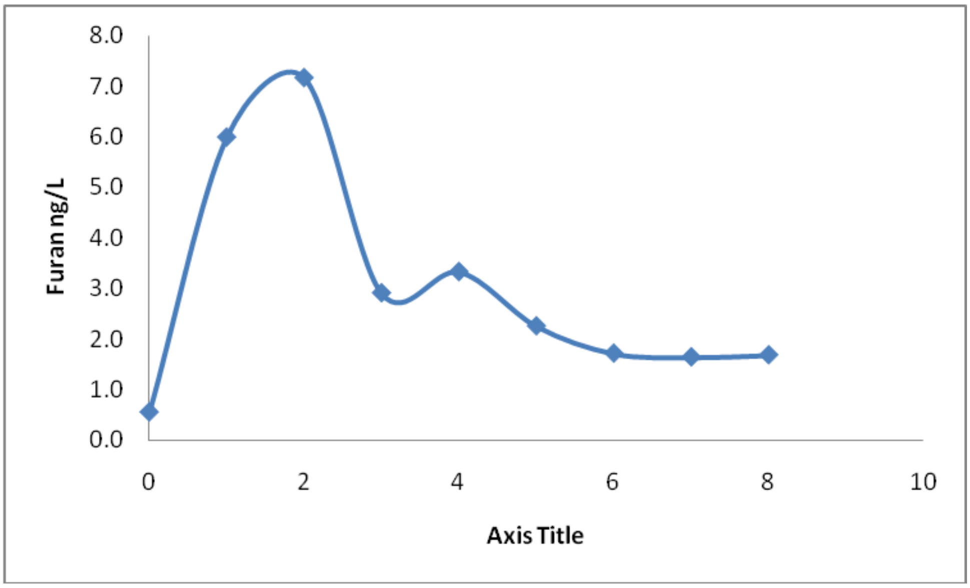


Figure 4 Furan exhaled after consuming coffee (two experiments)

The breath furan results are in broad agreement with those found for smokers (HSDB 2001). Furan was detectable more than 2 hours after smoking (Sanchez and Sacks (2006).

1.5.5. Coffee roasting

When green coffee beans were roasted furan was detected in the kitchen air only when the cooling cycle began. This was somewhat surprising as the atmosphere was acrid towards the end of the heating period, suggesting that volatiles had been emitted then. The furan level in the air reached a maximum of 11 ng/L during the cooling cycle but this reduced almost to background level after a further 3 minutes. The furan profile is shown in Table 21 and Figure 5.

Table 21. Furan in kitchen air on roasting green coffee beans

Sample	Time mins	Action	Furan ng/L
Room blank			2.6
Room blank			1.7
Room blank			2.9
	2	heating	2.3
	4	heating	1.1
	6	heating	2.8
	8	heating	1.9
	10	cooling	11.3
	13	end	3.6

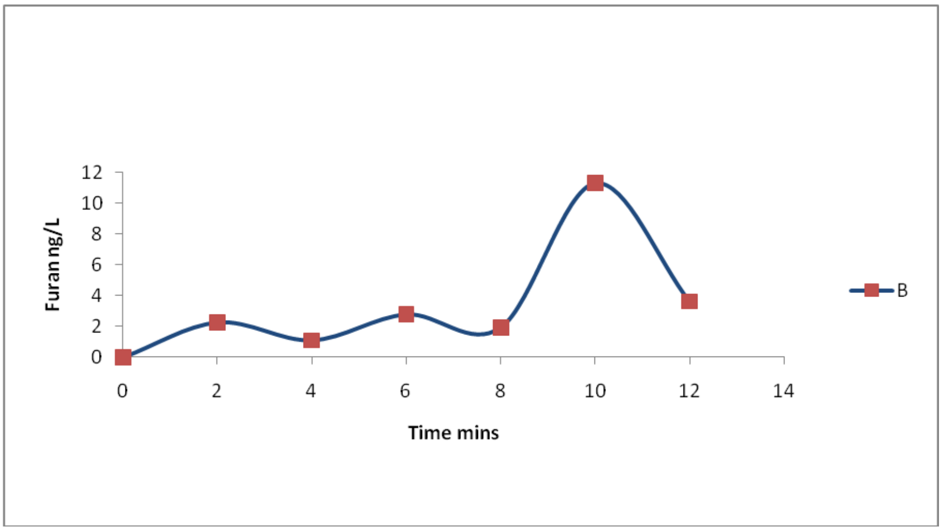


Figure 5 Furan emitted during coffee bean roasting

1.5.6. Bread

Furan levels in the air whilst toasting bread are given in Table 22. There was no consistent profile of furan produced against time or temperature, and levels were generally low - surprisingly so considering the high furan content of the toast. Occasional samples were high, although samples taken either side of these points were low. Baking part baked bread produced levels only slightly above the room blank, up to about 1 ug/L.

Table 22. Furan in kitchen air on toasting and baking bread

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		3.7
	Room blank		2.4
	Bread white	1	3.5
		2	4.1
		3	3.9
		4	3.2
		6	95.1
B	Room blank		0.5
	Bread white	1	2.1
		2	1.2
		3	1.0
		4	15.1
		6	3.3
C	Room blank		0.3
	Room blank		0.5
	Bread white	1	1.5
		2	0.3
		3	0.4
		4	2.9
		6	0.8
D	Room blank		0.4
	Room blank		0.5
	Bread white	1	0.6
		2	0.5
		3	0.5
		4	0.7
		6	0.6
E	Room blank		0.2
	Room blank		0.4
	Bread white	1	0.7
		2	1.2
		3	3.7
		4	1.2
		6	30.5

Table 22 (continued). Furan in kitchen air on toasting and baking bread

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.2
	Room blank		0.2
	Bread white home	1	0.3
		2	0.3
		3	1.4
		4	2.2
		6	0.4
B	Room blank		1.0
	Bread white home	1	1.3
		2	1.0
		3	0.7
		6	1.1
A	Room blank		1.0
	Room blank		0.2
	Bread wholemeal	2	0.9
		3	0.4
		4	7.7
		6	0.8
B	Room blank		0.2
	Room blank		0.3
	Bread wholemeal	1	0.8
		2	1.0
		3	2.5
		4	11.6
		6	1.4
C	Room blank		0.2
	Room blank		0.3
	Bread wholemeal	1	0.6
		2	0.7
		3	0.1
		4	30.1
		6	0.5
D	Room blank		0.2
	Room blank		0.2
	Bread wholemeal	1	0.4
		2	0.3
		3	0.4
		4	0.3
		6	0.3

Table 22 (continued). Furan in kitchen air on toasting and baking bread

Set	Sampling	Time mins	Furan ng/litre
E	Room blank		0.3
	Room blank		0.2
	Bread wholemeal	1	0.3
		2	0.2
		3	0.4
		4	
		6	0.4
F	Room blank		0.5
	Room blank		0.3
	Bread wholemeal	1	0.2
		2	0.3
		3	0.3
		4	0.7
		6	1.3
G	Room blank		0.4
	Room blank		1.7
	Bread wholemeal	1	0.6
		2	0.5
		3	0.7
		4	2.1
		6	0.8

A	Room blank		
	Room blank		0.5
	Bread wholemeal home	1	1.0
		2	1.4
		5	2.6
B	Room blank		0.4
	Bread wholemeal home	1	0.6
		2	0.5
		3	0.4
		5	0.4
C	Room blank		0.2
	Room blank		0.2
	Bread wholemeal home	1	0.2
		2	0.2
		3	0.3
		4	0.3
		6	0.3

Table 22 (continued). Furan in kitchen air on toasting and baking bread

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.6
	Part baked bread	3	1.9
		6	2.1
		9	0.9
		12	0.7
B	Room blank		0.2
	Room blank		0.3
	Part baked bread	5	0.4
		10	0.8
		15	0.4
C	Room blank		0.3
	Room blank		0.3
	Part baked bread	5	0.4
		10	0.8
		15	0.4
D	Room blank		0.3
	Room blank		0.3
	Part baked bread	5	0.4
		10	0.4
		15	0.4

1.5.7. Cookies

Furan levels in the air whilst baking cookies are given in Table 23.

Table 23. Furan in kitchen air on baking cookies

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.4
	Room blank		0.4
	Cookies	4	0.9
		8	1.3
		12	2.1
		14	0.4
B	Room blank		0.3
	Room blank		0.3
	Cookies	4	0.6
		8	1.2
		12	1.0
		14	1.3
C	Room blank		0.3
	Room blank		0.4
	Cookies	4	0.5
		8	0.9
		12	1.0
		14	0.7
D	Room blank		0.4
	Room blank		0.3
	Cookies	4	
		8	0.3
		12	0.3
		14	0.4

There was evidence of a small increase in furan release to the air as the cookies baked, in particular in sets A, B, and C. The furan increased from the room blank value of 0.3 to 0.4 ng/L to about 1 to 2 ng/L over the cooking and cooling period of 14 minutes. The levels decreased as soon as the oven was turned off and the cookies were removed from the heat. Furan release profiles for the four experiments are shown in Figure 6, and Figure 7 shows the profile of the averaged values for experiments A, B, and C. Here the increase in furan appears to be linear until the baking stops, when it falls away.

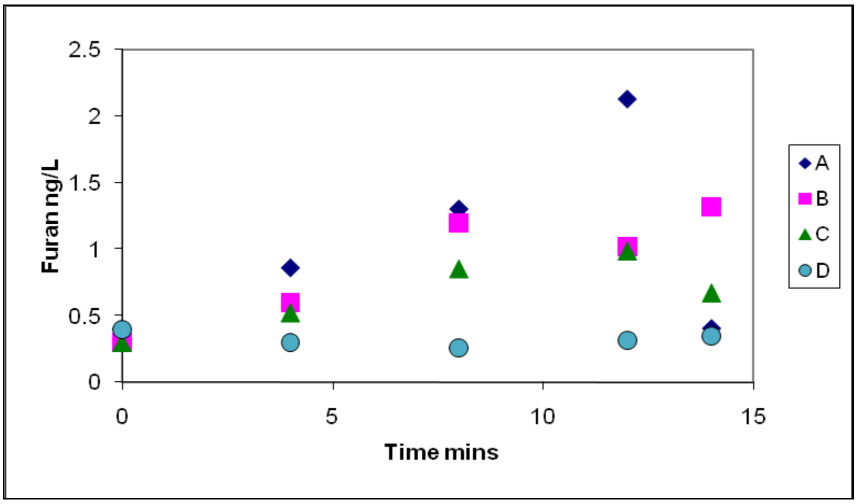


Figure 6 Furan emission profile during cookie baking (4 sets)

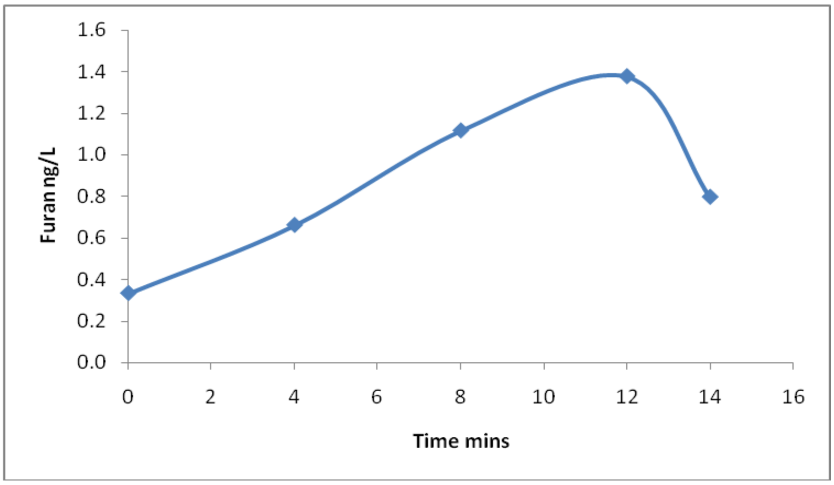


Figure 7 Furan emission profile during cookie baking (3 sets, average profile)

1.5.8. Convenience foods

Results for the atmospheric furan determinations over microwaving convenience foods are given in Table 24. For the bean based meals there was perhaps a very small increase above the room blank values. For the meat based meals there was perhaps a very small increase at 4 to 6 minutes. For the microwaved vegetable pot soup two of three samples showed an increase in furan, to 8 ng/L immediately on removal from the oven after the final heating.

Table 24. Furan in kitchen air on microwave cooking convenience foods

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.2
	Room blank		0.2
	Microwave bean meal taken out/mixed	2.5	0.3
	Microwave bean meal taken out/finished	4.5	0.3
	Microwave bean meal finished + 2 min	6.5	0.2
B	Room blank		0.3
	Room blank		0.2
	Microwave bean meal taken out/mixed	2.5	0.3
	Microwave bean meal taken out/finished	4.5	0.2
	Microwave bean meal finished + 2 min	6.5	0.4
C	Room blank		0.3
	Room blank		0.3
	Microwave bean meal taken out/mixed	2.5	0.3
	Microwave bean meal taken out/finished	4.5	0.2
	Microwave bean meal finished + 2 min	6.5	0.4
D	Room blank		0.3
	Microwave bean meal taken out/mixed	2.5	0.6
	Microwave bean meal taken out/finished	4.5	0.3
	Microwave bean meal finished + 2 min	6.5	0.4
E	Room blank		0.2
	Room blank		0.2
	Microwave bean meal taken out/mixed	2.5	0.5
	Microwave bean meal taken out/finished	4.5	0.4
	Microwave bean meal finished + 2 min	6.5	0.3

Table 24 (continued). Furan in kitchen air on microwave cooking convenience foods

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.2
	Room blank		0.2
	Microwave meat meal taken out/mixed	4	0.3
	Microwave meat meal taken out/finished	6	0.6
	Microwave meat meal finished + 2 min	8	0.2
B	Room blank		0.3
	Room blank		0.2
	Microwave meat meal taken out/mixed	4	0.4
	Microwave meat meal taken out/finished	6	0.3
	Microwave meat meal finished + 2 min	8	0.3
C	Room blank		0.2
	Room blank		0.3
	Microwave meat meal taken out/mixed	4	0.3
	Microwave meat meal taken out/finished	6	1.1
	Microwave meat meal finished + 2 min	8	0.3
D	Room blank		0.2
	Room blank		0.3
	Microwave meat meal taken out/mixed	4	0.8
	Microwave meat meal taken out/finished	6	0.3
	Microwave meat meal finished + 2 min	8	0.3
A	Room blank		1.7
	Microwave veg pot soup out/mixed	1	5.3
	Microwave veg pot soup	2	8.4
	Microwave veg pot soup taken out, stirred	4	2.4
B	Room blank		0.7
	Microwave veg pot soup	1	1.0
	Microwave veg pot soup	2	8.6
	Microwave veg pot soup taken out, stirred	4	1.6
C	Room blank		1.0
	Microwave veg pot soup	1	1.5
	Microwave veg pot soup	2	0.9
	Microwave veg pot soup taken out, stirred	4	0.4

1.5.9. Infant foods

Results for the atmospheric furan determinations over heating infant foods are given in Table 25. Only two lasagne samples were heated in a saucepan as this was not a procedure recommended on the cans and jars. Both samples showed evidence of furan release after 5 minutes. Furan levels in the microwaved samples appeared to elevate air furan levels slightly when removed from the oven, giving an average air level over four minutes of 2.3 ng/L.

Table 25. Furan in kitchen air on microwave cooking infant foods

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		1.3
B	Lasagne (saucepan cooked)	2	1.3
		5	7.4
C	Room blank		0.5
D	Lasagne (saucepan cooked)	2	0.9
		5	2.1
A	Room blank		0.8
	Lasagne	1	11.7
	Lasagne stirred, replaced	2	1.7
	Lasagne taken out stirred	4	0.9
B	Room blank		1.2
	Lasagne	1	1.0
	Lasagne stirred, replaced	2	1.7
	Lasagne taken out stirred	4	1.0
A	Room blank		0.9
	Beans and bacon	1	5.1
	Beans and bacon stirred, replaced	2	1.8
	Beans and bacon taken out stirred	4	1.1
B	Room blank		0.6
	Beans and bacon	1	1.6
	Beans and bacon stirred, replaced	2	1.7
	Beans and bacon taken out stirred	4	0.8
C	Room blank		0.6
	Beans and bacon	1	3.0
	Beans and bacon stirred, replaced	2	2.0
	Beans and bacon taken out stirred	4	1.4
D	Room blank		1.5
	Beans and bacon	1	2.2
	Beans and bacon stirred, replaced	2	1.0
	Beans and bacon taken out stirred	4	1.8

1.5.10. Tomato soup

Results for the furan determinations in the air over heated tomato soup in a saucepan or microwave oven are given in Table 26. Two of three saucepan warmed samples produced a small increase in atmospheric furan. There was no pattern of increase in the microwaved samples although in most cases were elevated slightly above the blank values.

Table 26. Furan in kitchen air on cooking soup

Set	Sampling	Method	Time mins	Furan ng/litre
A	Room blank			3.9
	Tomato soup	saucepan	2	2.5
		saucepan	5	5.7
B	Room blank			1.5
	Tomato soup	saucepan	2	2.7
		saucepan	5	4.7
C	Room blank			1.0
	Tomato soup	saucepan	2	1.4
		saucepan	5	1.1
	Room blank			1.0
A	Tomato soup, lid taken off, stirred	microwave	2	6.9
	Tomato soup, door open after cycle	microwave	5	2.5
	Tomato soup 2 min later	microwave	7	1.6
B	Room blank			1.2
	Tomato soup, lid taken off, stirred	microwave	2	2.1
	Tomato soup, door open after cycle	microwave	5	3.2
	Tomato soup 2 min later	microwave	7	1.4
C	Room blank			1.8
	Tomato soup, lid taken off, stirred	microwave	2	1.9
	Tomato soup, door open after cycle	microwave	4	1.3
	Tomato soup 2 min later	microwave	6	0.6
D	Room blank			0.6
	Tomato soup, lid taken off, stirred	microwave	2	0.5
	Tomato soup, door open after cycle	microwave	4	0.7
	Tomato soup 2 min later	microwave	6	0.6
E	Room blank	microwave		0.5
	Tomato soup, lid taken off, stirred	microwave	2	0.5
	Tomato soup, door open after cycle	microwave	4	1.4
	Tomato soup 2 min later	microwave	6	1.1

1.5.11. Pizzas

Results for the furan determinations on the air on heating pizzas are given in Tables 27 and 28.

Table 27. Furan in kitchen air on oven cooking chilled pizza

Set	Sampling	Time mins	Furan ng/litre
A	Room blank	0	0.4
	Room blank	0	0.4
	Pizza chilled	4	1.8
	Pizza chilled	8	1.2
	Pizza chilled out of oven	12	0.8
	Pizza chilled out of oven +2	14	0.8
B	Room blank	0	0.2
	Room blank	0	0.2
	Pizza chilled	4	1.4
	Pizza chilled	8	0.4
	Pizza chilled out of oven	12	0.7
	Pizza chilled out of oven +2	14	0.6
C	Room blank	0	0.2
	Room blank	0	0.3
	Pizza chilled	4	4.9
	Pizza chilled	8	2.7
	Pizza chilled out of oven	12	1.0
	Pizza chilled out of oven +2	14	0.9
D	Room blank		0.2
	Room blank		0.2
	Pizza chilled	4	1.2
	Pizza chilled	8	2.6
	Pizza chilled out of oven	12	0.7
	Pizza chilled out of oven +2	14	0.4
E	Room blank		0.4
	Room blank		0.2
	Pizza chilled	5	0.3
	Pizza chilled	10	0.5
	Pizza chilled out of oven	12	0.6
	Pizza chilled out of oven +2	15	0.5
	Room blank		0.2
	Room blank		0.2
F	Pizza chilled	5	0.6
	Pizza chilled	10	0.7
	Pizza chilled out of oven	12	2.0
	Pizza chilled out of oven +2	15	0.8

Table 27. Furan in kitchen air on oven cooking chilled pizza

Set	Sampling	Time mins	Furan ng/litre
G	Room blank		0.2
	Room blank		0.2
	Pizza chilled	4	1.0
	Pizza chilled	8	0.4
	Pizza chilled out of oven	12	0.6
	Pizza chilled out of oven +2	15	0.7
H	Room blank		0.2
	Room blank		0.2
	Pizza chilled	4	0.5
	Pizza chilled	8	0.4
	Pizza chilled out of oven	12	0.8
	Pizza chilled out of oven +2	17	0.6

Most of the chilled pizza set (Table 27) released furan to the atmosphere with one measurement at about 5 ng/L, however the release profiles, shown in Figure 8 are variable. An averaged profile (Figure 9) does show formation and loss. The temperature of the oven (set to 220ºC) appeared to vary considerably between batches but measurements inside the oven were made with an infra-red thermometer that was not calibrated for monitoring through the glass oven door.

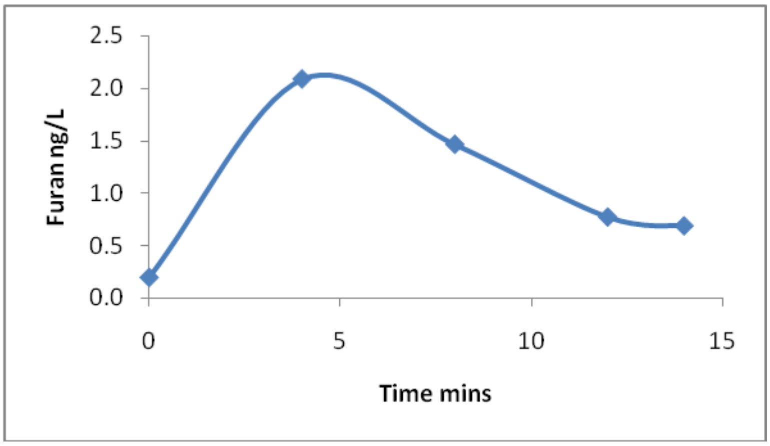


Figure 8 Furan emission profile during chilled pizza baking (5 sets)

For the frozen pizzas (Table 28) 3 of the 4 air sets show an increase to about 1 to 1.5 ng/L at the point when the pizzas was removed from the oven. This effect differs from that observed for the chilled pizzas where the higher levels were recorded earlier. The furan emission profiles (Figure 10) were reasonably consistent for these 3 sets.

Table 28. Furan in kitchen air on oven cooking frozen pizza

Set	Sampling	Time mins	Furan ng/litre
A	Room blank	0	0.4
	Room blank	0	0.3
	Pizza frozen	5	0.6
	Pizza frozen	15	0.4
	Pizza frozen taken out	25	1.1
	Pizza frozen	27	0.4
B	Room blank		0.2
	Room blank		0.3
	Pizza frozen	5	0.3
	Pizza frozen		
	Pizza frozen taken out	25	0.9
	Pizza frozen	27	0.4
C	Room blank		0.4
	Room blank		0.3
	Pizza frozen	5	0.4
	Pizza frozen	15	0.4
	Pizza frozen taken out	25	1.6
	Pizza frozen	30	0.6
D	Room blank		0.2
	Room blank		0.2
	Pizza frozen	5	0.2
	Pizza frozen	15	0.2
	Pizza frozen taken out	25	0.3
	Pizza frozen	30	0.3

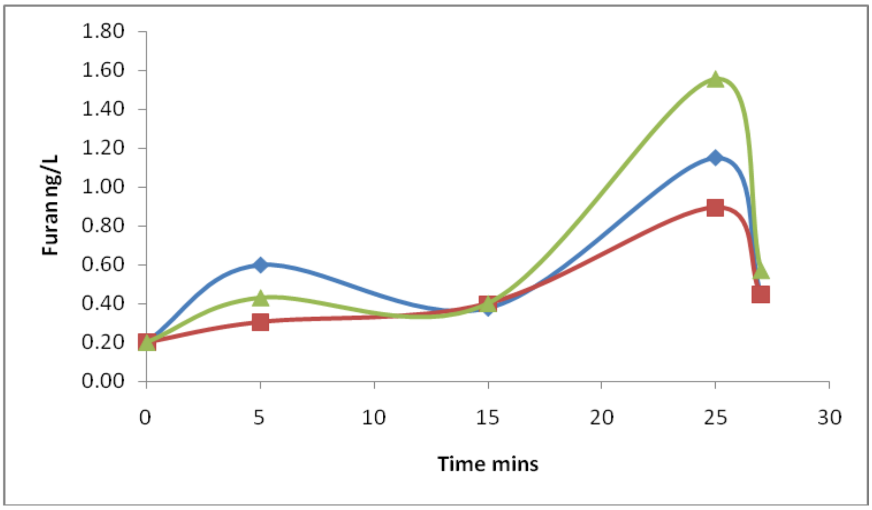


Figure 10 Furan emission profile during frozen pizza baking (3 sets)

1.5.12. Breaded chicken pieces

Results for the furan determinations on the air on heating breaded chicken pieces are given in Table 29. All four sets show some increase in the kitchen air furan content up to the time when the pieces were removed from the oven, although the maximum levels vary from 0.6 to 2.7 ng/L. The furan emission profile is shown in Figure 11. Five minutes after taking the pieces from the oven (20 mins) the furan had not decreased to the room blank level.

Table 29. Furan in kitchen air on oven cooking breaded chicken pieces

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		0.4
	Room blank		0.2
	Breaded chicken pieces	5	0.4
	Breaded chicken pieces	10	0.6
	Breaded chicken pieces taken out	15	0.5
	Breaded chicken pieces out 5 mins	20	0.6
B	Room blank		0.4
	Room blank		0.3
	Breaded chicken pieces	5	0.5
	Breaded chicken pieces	10	0.7
	Breaded chicken pieces taken out	15	1.6
	Breaded chicken pieces out 5 mins	20	0.9
C	Room blank		0.2
	Room blank		0.4
	Breaded chicken pieces	5	0.2
	Breaded chicken pieces	10	0.6
	Breaded chicken pieces taken out	15	0.6
	Breaded chicken pieces out 5 mins	20	0.9
D	Room blank		0.6
	Room blank		0.3
	Breaded chicken pieces	5	1.1
	Breaded chicken pieces taken out	15	2.7
	Breaded chicken pieces out 5 mins	20	0.8

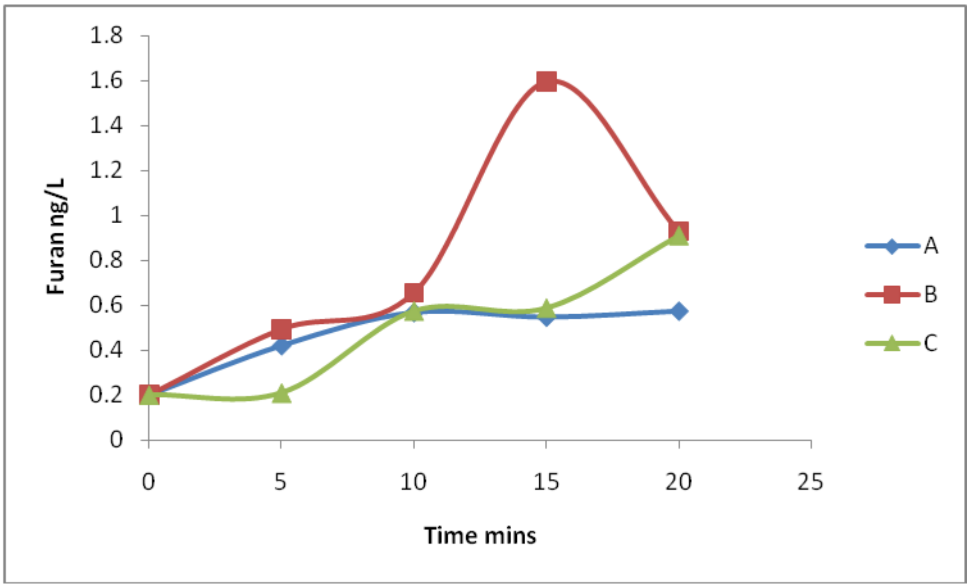


Figure 11 Furan emission profile during cooking frozen breaded chicken pieces (3 sets)

1.5.13. Breaded vegetable pieces

Results for the furan determinations on breaded vegetable product are given in Table 30. The furan in air increased with cooking for all sets, with set A for some reason having unusually high levels, possibly related to the (unexplained) high final temperature. When the furan release profiles were plotted for the remaining three sets (Figure 12), it was clear that furan was released in increasing quantity, up to 3 ng/L, until the product was removed from the oven, thereafter it decreased, not reaching the room blank level in set C only 5 mins after removal from the oven.

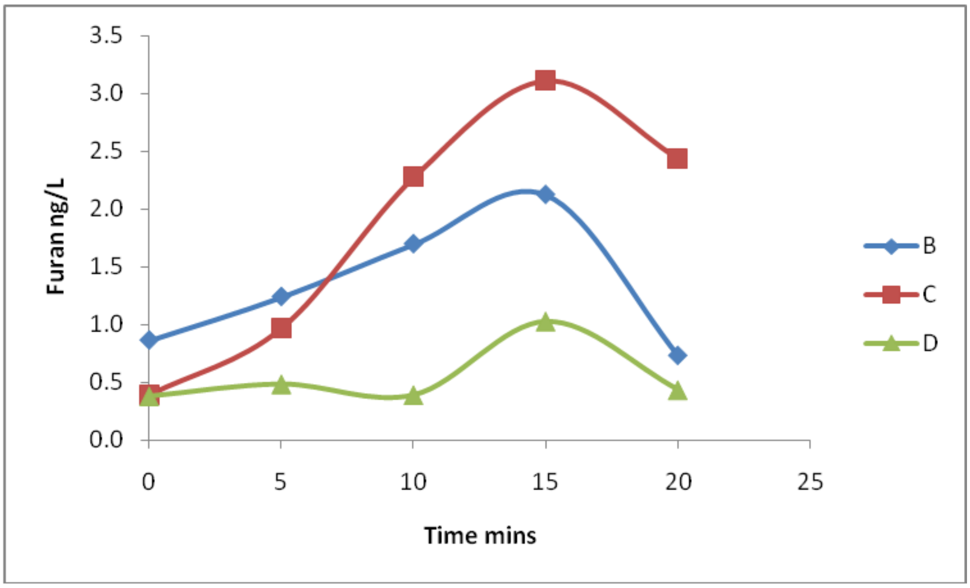
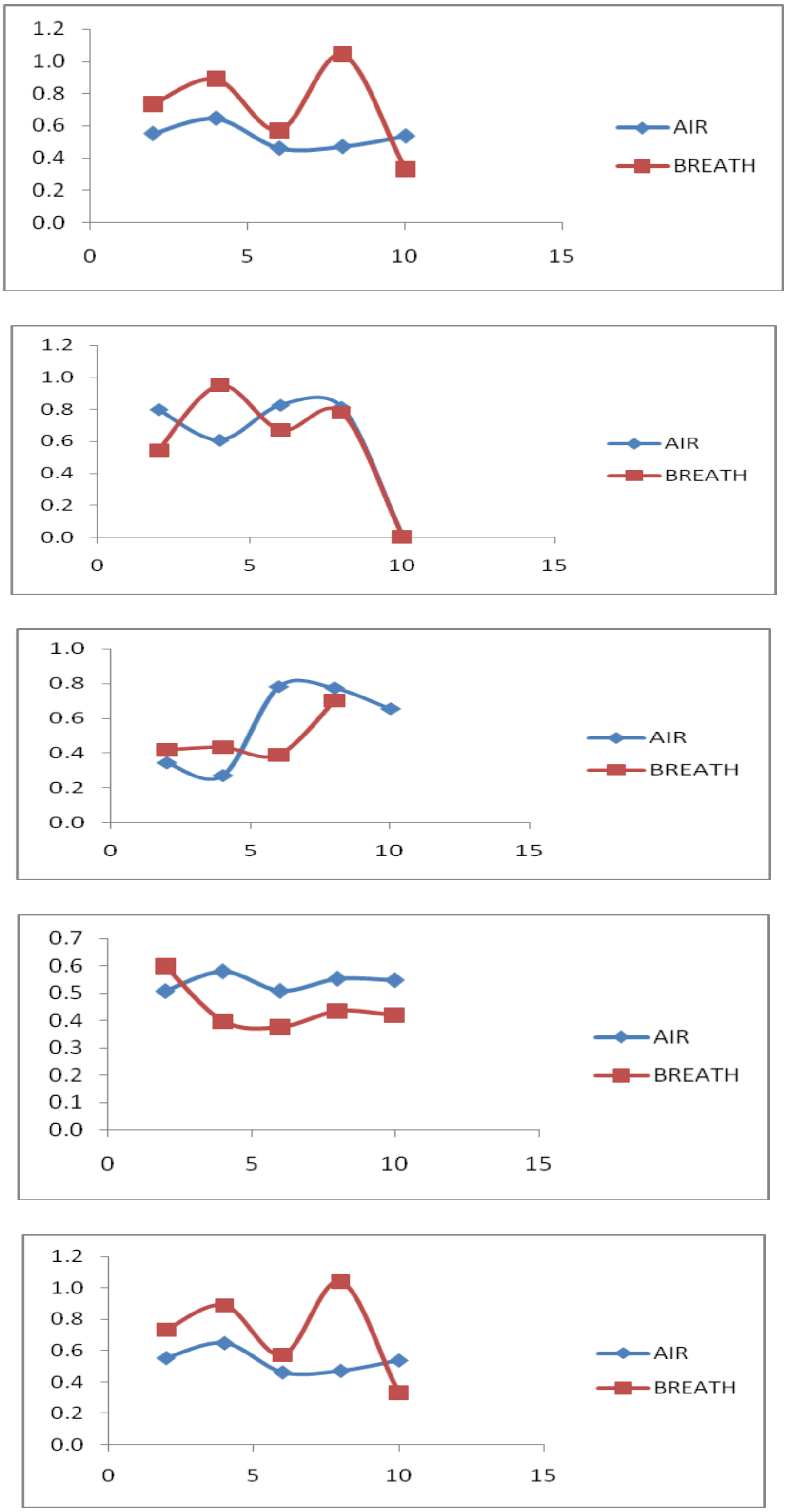


Figure 12 Furan emission profile during cooking frozen breaded vegetable pieces (3 sets)



Vertical axis furan (ng/L). Horizontal axis time (minutes).

Figure 13 Furan in air and breath after cooking frozen breaded fish pieces

Table 30. Furan in kitchen air on oven cooking breaded vegetables

Set	Sampling	Time mins	Furan ng/litre
A	Room blank		1.0
	Room blank		0.7
	Breaded vegetables	5	0.5
	Breaded vegetables	10	8.2
	Breaded vegetables taken out	15	20.6
	Breaded vegetables out 2 mins	17	6.4
B	Room blank		0.4
	Room blank		0.4
	Breaded vegetables	5	1.2
	Breaded vegetables	10	1.7
	Breaded vegetables taken out	15	2.1
	Breaded vegetables out 2 mins	17	0.7
C	Room blank		0.5
	Room blank		0.2
	Breaded vegetables	5	1.0
	Breaded vegetables	10	2.3
	Breaded vegetables taken out	15	3.1
	Breaded vegetables out 2 mins	17	2.4
D	Room blank		0.0
	Room blank		0.4
	Breaded vegetables	5	0.5
	Breaded vegetables	10	0.4
	Breaded vegetables taken out	15	1.0
	Breaded vegetables	17	0.4

1.5.14. Breaded fish pieces

Results for the furan kitchen air determinations during cooking of breaded fish are given in Table 31.

Table 31. Furan in kitchen air on oven cooking breaded fish pieces

Set	Sampling	Method	Time mins	Furan ng/litre
A	Room blank			0.3
	Room blank			1.7
	Oven air during cooking	oven door opened	5	8.9
	Oven air during cooking	oven door opened	10	24.8
	Oven air during cooking	oven door opened	15	165.4
	Breaded fish pieces taken out		20	26.5
	Kitchen air after cooking		22	3.4
B	Room blank			0.9
	Room blank			0.3
	Oven air during cooking	oven door opened	5	3.6
	Oven air during cooking	oven door opened	10	21.4
	Oven air during cooking	oven door opened	15	125.9
	Breaded fish pieces taken out		20	92.9
	Kitchen air after cooking		22	8.4
C	Room blank			0.4
	Room blank			0.4
	Oven air during cooking	oven door opened	5	4.1
	Oven air during cooking	oven door opened	10	2.2
	Oven air during cooking	oven door opened	15	43.3
	Breaded fish pieces taken out		20	71.7
	Kitchen air after cooking		22	3.6
D	Room blank			0.1
	Room blank			0.2
	Kitchen air during cooking	oven door closed	5	8.6
	Kitchen air during cooking		10	11.2
	Kitchen air during cooking		15	12.3
	Breaded fish pieces taken out	oven door opened	20	0.5
	Kitchen air after cooking		22	0.1
	Breath blank			0.3
	Breath at 20 mins		20	0.5
	Breath at 22 mins		22	0.9

Table 31 (continued). Furan in kitchen air on oven cooking breaded fish pieces

Set	Sampling	Method	Time mins	Furan ng/litre
A	Room blank			0.3
	Room blank			0.2
	Kitchen air after cooking	oven door closed	2	0.6
	Kitchen air after cooking	during cooking	4	0.6
	Kitchen air after cooking		6	0.5
	Kitchen air after cooking		8	0.5
	Kitchen air after cooking		10	0.5
	Breath blank			0.4
	Breath sample after cooking		2	0.7
	Breath sample after cooking		4	0.9
	Breath sample after cooking		6	0.6
	Breath sample after cooking		8	1.0
	Breath sample after cooking		10	0.3
B	Room blank			0.4
	Room blank			0.3
	Kitchen air during cooking	oven door closed	5	0.6
	Kitchen air during cooking		10	0.6
	Kitchen air during cooking		15	0.7
	Breaded fish pieces taken out	oven door opened	20	0.9
	Kitchen air after cooking		25	0.6
C	Room blank			0.4
	Room blank			0.5
	Kitchen air after cooking	oven door closed	2	0.8
	Kitchen air after cooking	during cooking	4	0.6
	Kitchen air after cooking		6	0.8
	Kitchen air after cooking		8	0.8
	Kitchen air after cooking		10	0.0
	Breath blank			0.3
	Breath blank			0.4
	Breath sample after cooking		2	0.5
	Breath sample after cooking		4	1.0
	Breath sample after cooking		6	0.7
	Breath sample after cooking		8	0.8
	Breath sample after cooking		10	0.0

Table 31 (continued). Furan in kitchen air on oven cooking breaded fish pieces

Set	Sampling	Method	Time mins	Furan ng/litre
D	Room blank			0.1
	Room blank			0.3
	Kitchen air after cooking		2	0.3
	Kitchen air after cooking		4	0.3
	Kitchen air after cooking		6	0.8
	Kitchen air after cooking		8	0.8
	Kitchen air after cooking		10	0.7
	Breath blank			0.4
	Breath blank			0.2
	Breath sample after cooking		2	0.4
	Breath sample after cooking		4	0.4
	Breath sample after cooking		6	0.4
	Breath sample after cooking		8	0.7
E	Room blank			0.3
	Room blank			0.2
	Kitchen air after cooking		2	0.5
	Kitchen air after cooking		4	0.6
	Kitchen air after cooking		6	0.5
	Kitchen air after cooking		8	0.6
	Kitchen air after cooking		10	0.5
	Breath blank			0.3
	Breath blank			0.3
	Breath sample after cooking		2	0.6
	Breath sample after cooking		4	0.4
	Breath sample after cooking		6	0.4
	Breath sample after cooking		8	0.4
	Breath sample after cooking		10	0.4
F	Room blank			0.3
	Room blank			0.2
	Kitchen air after cooking		2	0.6
	Kitchen air after cooking		4	0.6
	Kitchen air after cooking		6	0.5
	Kitchen air after cooking		8	0.5
	Kitchen air after cooking		10	0.5
	Breath blank			
	Breath blank			0.4
	Breath sample after cooking		2	0.7
	Breath sample after cooking		4	0.9
	Breath sample after cooking		6	0.6
	Breath sample after cooking		8	1.0
	Breath sample after cooking		10	0.3

For three initial experiments the oven door was opened to turn the fish pieces (this procedure was specified on the packet for some similar breaded fish products but not this one). Air samples were taken from a breathing position directly above the door as it was opened. These experiments produced high levels of furan in the air samples (40 to 129 ng/L), and showed that the furan in the oven was rapidly replenished between sampling.

In a single experiment where the oven door remained closed the furan level reached 11 to 12 ng/L towards the end of the cooking. This was comparatively high but much lower than expected from the previous data. From this experiment two exhaled breath samples were taken after the cooking process. They contained slightly more furan than the room and breath blanks taken before cooking.

This furan exhalation experiment was followed up by measuring furan in the kitchen air and in breath at one minute intervals following the cooking of breaded fish pieces. The results are shown in Figure 13 where it can be seen that the kitchen air and exhaled breath usually contained very similar levels of furan, between 0.4 and 1 ng/L. The levels in the kitchen air did not decrease over 10 minutes but some of the breath samples show a decrease.

1.5.15. Potato chips (fries).

Results for the furan air determinations on various procedures for cooking fried potato products (microwave chips, oven chips and freshly prepared chips) are given in Table 32. On this occasion the microwave chips were prepared in a vacant office (5 x 4 x 4 m), empty except for carpeting and furniture) which had a higher furan background than the kitchen. Microwave cooking did not increase the furan levels in the office air.

Table 32. Furan in kitchen air on oven cooking potato products

Sample	Set	Method	Sampling	Time mins	Furan ng/L
Microwave chips	A	microwave	Room blank		0.9
			Kitchen air, chips opened, shaken	2	1.5
			Kitchen air chips finished, out of oven	3	1.1
	B	microwave	Room blank		1.3
			Kitchen air, chips opened, shaken	2	0.8
			Kitchen air chips finished, out of oven	3	0.8
	C	microwave	Room blank		0.8
			Kitchen air, chips opened, shaken	2	0.9
			Kitchen air chips finished, out of oven	3	1.0
	D	microwave	Room blank		0.9
			Kitchen air, chips opened, shaken	2	0.8
			Kitchen air chips finished, out of oven	3	1.1
	E	microwave	Room blank		0.6
			Kitchen air, chips opened, shaken	2	0.5
			Kitchen air chips finished, out of oven	3	0.9
	F	microwave	Room blank		0.7
			Kitchen air, chips opened, shaken	2	0.8
			Kitchen air chips finished, out of oven	3	0.8

Table 32. Furan in kitchen air on oven cooking potato products

Sample	Set	Method	Sampling	Time mins	Furan ng/L
Oven chips	A	oven	Room blank	0	0.5
			Room blank	0	0.2
			Kitchen air	5	1.2
			Kitchen air	10	1.7
			Oven chips taken out	15	2.9
			Kitchen air chips out 2 mins	17	1.7
	B	oven	Room blank	0	0.3
			Room blank	0	0.3
			Kitchen air	5	0.4
			Kitchen air	10	0.6
			Oven chips taken out	15	
			Kitchen air chips out 2 mins	17	1.4
	C	oven	Room blank	0	0.3
			Room blank	0	0.3
			Kitchen air	5	19.8
			Kitchen air	10	2.5
			Oven chips taken out	15	3.4
			Kitchen air chips out 2 mins	17	4.7
	D	oven	Room blank	0	0.3
			Room blank	0	0.2
			Kitchen air	5	0.8
			Kitchen air	10	1.1
			Oven chips taken out	15	2.5
			Kitchen air chips out 2 mins	17	1.5

Table 32. Furan in kitchen air on oven cooking potato products

Sample	Set	Method	Sampling	Time mins	Furan ng/L
Fresh potatoes	A	fryer	Room blank		0.3
			Room blank		0.4
			Kitchen air	3	10.9
			Kitchen air chips shaken	6	34.3
			Kitchen air chips out	9	20.1
			Kitchen air 2 mins after	11	4.0
	B	fryer	Room blank		0.2
			Room blank		0.2
			Kitchen air	3	3.9
			Kitchen air chips shaken	6	7.3
			Kitchen air chips out	9	6.5
			Kitchen air 2 mins after	11	7.7
	C	fryer	Room blank		0.8
			Room blank		0.6
			Kitchen air	3	15.3
			Kitchen air chips shaken	6	21.4
			Kitchen air chips out	9	23.9
			Kitchen air 2 mins after	11	8.1
	D	fryer	Room blank		1.2
			Room blank	3	13.8
			Kitchen air	6	19.3
			Kitchen air chips shaken	9	8.9
			Kitchen air chips out	11	9.0

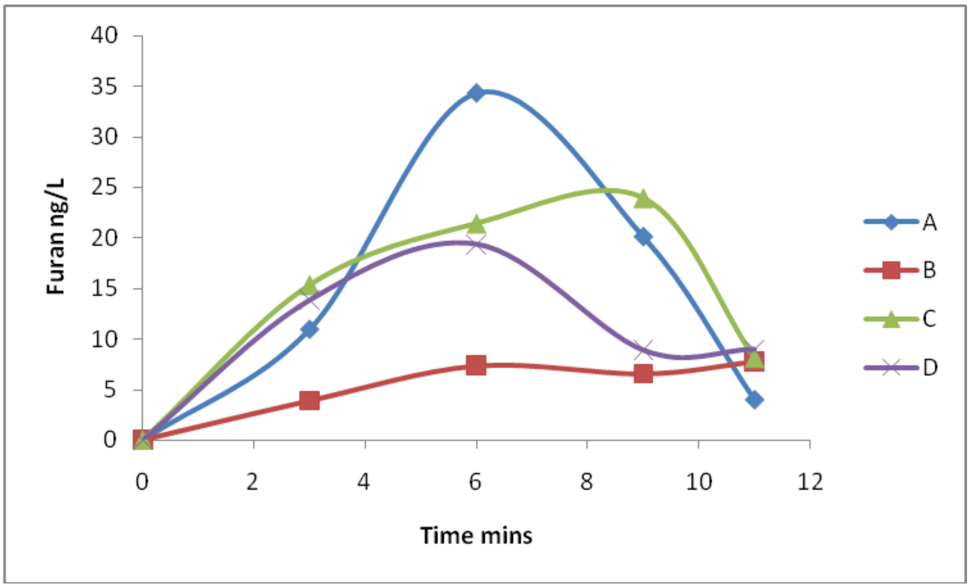


Figure 14 Furan emission profile during frying fresh potatoes (4 sets)

Cooking oven chips released furan up to about 5 ng/L (excluding one very high data point). In two of the sets the atmospheric furan decreased after the chips were removed from the oven but in the other two it did not.

The fresh chips all produced air furan levels of between 5 and 35 ng/L with the levels possibly decreasing before the chips were removed from the fryer.

1.5.16. Summary of air sampling results

The project has shown that furan can be measured in air using appropriate equipment. The system of sampling into inert bags, transferring the sample to a trapping medium and its analysis by thermal desorption gas chromatography-mass spectrometry has been shown to be a useful tool. It has been demonstrated that furan can be determined in the interior air of kitchens when food is cooked, that the levels vary with cooking technique and food product, and that emission profiles can be generated from certain cooking activities.

It has been shown that results are both low and variable for cooking activities of short duration (less than 10 minutes) even when the levels of furan expected to be released were high (the case of coffees). For cooking practices that lasted in excess of 10 minutes (cooking in ovens, frying chipped potatoes) the data were more uniform. This demonstrates that sampling at single points within a room (e.g. near the consumer’s mouth) with static air is a source of considerable variability, whereas when the cooking is prolonged the furan distribution within the air of the room becomes more uniform. Also the oven cooking is more likely to disperse furan better on account of it having a higher heat output which would encourage convection and mixing of the room air.

The data show that the highest furan inhalation would result from the addition of water to a cafetiere, the frying of chipped potatoes in an open chip pan, and baking some foods in an oven.

1.6. EXPOSURE CALCULATIONS

Exposure calculation data are provided in Tables 33 and 34. As the air measurement results were in most cases very variable, these values are a rough estimation only.

Table 33. Consumer exposure to furan from food

Sample	Cooking method	Furan ug/kg	Edible portion grams	Intake ug/portion
Coffee	Cup brewed with hot water	2	220	0.4
Coffee	Cafetiere brewed with hot water	28	220	6.1
Coffee	Percolated	41	40	1.6
Coffee	Percolated, home	31	40	1.2
Coffee espresso	Bean to cup machine	188	45	8.5
Coffee latte	Bean to cup machine	217	220	47.8
Coffee regular	Bean to cup machine	226	250	56.5
Coffee espresso	Vending machine	36	190	6.9
Coffee regular	Vending machine	43	90	3.9
White bread	Toasted	299	130	38.9
White bread	Toasted home	3	130	0.4
Wholemeal bread	Toasted	150	150	22.5
Wholemeal bread	Toasted home	5	150	0.8

Bread part-baked	Baked	8	150	1.2
Cookies	Baked from mixture	7	150	1.1
Bean based convenience meal	Microwaved	2	400	0.8
Meal based convenience meal	Microwaved	5	400	2.0
Soup based convenience meal	Microwaved	2	340	0.7
Infant food vegetable	Microwaved	15	180	2.7
Infant food meat	Microwaved	17	120	2.0
Tomato soup	Saucepan heated	26	400	10.4
Tomato soup	Microwaved	32	400	12.8
Pizza chilled	Baked	3	300	0.9
Pizza frozen	Baked	19	300	5.7
Breaded chicken	Oven cooked	7	300	2.1
Breaded vegetables	Oven cooked	6	150	0.9
Breaded fish	Oven cooked	5	200	1.0
Chips part cooked, frozen	Microwaved	2	100	0.2
Chips frozen	Oven cooked	2	500	1.0
Chips from fresh potatoes	Fried	12	500	6.0

Dietary intake has been calculated from a multiplication of the furan concentration by the edible portion size and is expressed as quantity of furan per food portion. The figures do not reflect daily intake but refer to the furan obtained from the portion size. The portion sizes have been obtained variously from the pack size, the quantity left after cooking, and an assumption of what a reasonable portion would be.

Table 34. Consumer exposure to furan from air during food cooking

Sample	Cooking method	Air Furan ng/L	Exposure Time mins	Air Inhaled L	Furan Inhaled ng
Coffee instant	In cup with hot water	0.6	5	25	15
Coffee powder	Cafetiere	8.0	10	50	400
Coffee powder	Percolated	3.0	6	30	90
Coffee powder	Percolated, home	0.6	6	30	18
Coffee 5 types	Vending machines	2.0	10	50	100
White bread	Toasted	5.0	6	30	150
White bread	Toasted home	0.8	6	30	24
Wholemeal bread	Toasted	1.6	6	30	48
Wholemeal bread	Toasted home	0.5	6	30	15
Bread part-baked	Baked	0.6	15	75	45
Cookies	Baked from mixture	0.3	15	75	23
Bean convenience meal	Microwaved	0.3	7	35	11
Meal convenience meal	Microwaved	0.4	8	40	16
Soup convenience meal	Microwaved	2.9	4	20	58
Infant food vegetable	Microwaved	2.5	4	20	50
Infant food meat	Microwaved	1.7	4	20	34
Tomato soup	Saucepan heated	2.1	5	25	53
Tomato soup	Microwaved	1.6	6	30	48

Pizza chilled	Baked	0.8	12	60	48
Pizza frozen	Baked	0.5	30	150	75
Breaded chicken	Oven cooked	0.7	20	100	70
Breaded vegetables	Oven cooked	3.1	20	100	310
Breaded fish	Oven cooked	0.9	22	110	99
Chips part cooked, frozen	Microwaved	0.9	3	15	14
Chips frozen	Oven cooked	2.1	17	85	179
Chips from fresh potatoes	Fried	9.5	11	55	523

Inhalation intake has been calculated from an approximated breathing rate and volume. Furan levels in the air could be calculated in one of two ways from basic data. Where the furan release profiles were very different for repeated cooking experiments the average of all the furan concentrations regardless of sampling time was used to give a figure for the furan content of the air. For calculation purposes this was treated as being constant throughout the exposure period. The exposure period used was the time between the first and last air samplings.

Where the furan release profiles for repeated cooking experiments were reasonably similar the furan levels at individual time points could in theory be calculated from the furan emission profile charts the quantity of furan, equivalent to the area under the graph corresponded to the area under the graph. This could be calculated by determining the area under each line-segment in the graph using the formula =(B2+B1)/2*(A2-A1) where Excel column A contained the furan level and Excel column B the time point. The formula above when entered into the C column will contain the area under the curve for the interval between consecutive samples in the graph, the sum of which is the total area under the curve. To include all segments of the curve it would be necessary in some cases to predict when the furan would decrease to blank level and add an extrapolated point for calculation purposes. However this approach was not possible as the furan did not reach the baseline level during the sampling periods, and so for consistency the average furan level approach was used.

Respiration is quite complex. In simple terms the respiratory minute volume (or minute ventilation, or flow of gas) is the volume of air which can be inhaled (inhaled minute volume) or exhaled (exhaled minute volume) from a person's lungs in one minute (Elert 2001; Seeley, Stephens and Tate 1999). Minute volume is calculated by taking the tidal volume and multiplying it by the respiratory rate (the number of breaths per minute). A normal minute volume would be 5–8 litres. An average human breathes 0.5 litres between 9 and 20 times per minute. Assuming cooking to be relatively non energetic, the breathing rate would be likely to be about 0.5 litres 10 times per minute = 5 litres per minute. Thus the calculation was made by multiplying the average furan content of the air over the exposure (cooking) period assuming an inhalation rate of 5 L/min. However it is not simple to include the exhalation data without a much more detailed study of the exhalation of furan.

The limited and unplanned studies of exhalation of furan carried out here were considered necessary in order to estimate exhalation for calculation of exposure.

Exhalation experiments indicate that furan is exhaled over at least 5 minutes after drinking coffee, and that the pre-consumption level in breath is not reached within 10 minutes. Furan levels in breath collected after cooking breaded fish in an oven mostly remained similar to the level in the inhaled air. The levels of furan *inhaled* were calculated to be up to about 10 ng/L , equivalent to 3 ug/hour. In a study of furan in the *exhaled* breath of smokers the exhalation rate was 1 ug/hour (Conkle et al. 1975). Thus there are only early and speculative data on exhalation and the net intake from breathing cannot be calculated without the accumulation of considerably more data.

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