Furan: Mechanisms of Formation and Levels in Food

Don S. Forsyth, Adam Becalski, Valerie Casey, Steve Seaman,Karen Pepper and Samuel Ben Rejeb, Food Research Division, Bureau of Chemical Safety, Food Directorate, Health Canada

Background

- Late March, 2004- Health Canada informed of US FDA investigation of furan in canned and bottled food commodities
- Furan has been shown to be carcinogenic in mice and rats, classified as “possibly carcinogenic to humans” (Group 2B) by IARC in 1995
- Although furan is used in industrial processes the likely source was considered to be formation during food processing
- April, 2004- Health Canada commenced method development for study of mechanism(s) of formation and survey of Canadian food products

Furans in Foods

- Furan derivatives have been reported in a wide variety of foods and are a significant flavour and odour component in coffee, cocoa, and various cooked meat products

- Furan has been found in coffee, canned beef, sodium caseinate, soy and rapeseed protein and caramel

Possible Mechanisms of Formation

- Thermal degradation of carbohydrates (Maillard reaction)
- Thermal oxidation of lipid
- Decomposition of ascorbic acid or its derivatives

Effect of Canned Beef Formulation and Processing Time on Furan Levels (Persson and von Sydow 1974)

Formulation	Processing Time (min at 121°C)	Furan (ng/g)
79.3% beef, 20% H_2O, 0.7% NaCl	15	930
	30	750
	45	760
	60	960
	75	870
66.3% beef, 13% fat, 20% H_2O, 0.7% NaCl	30	3700
74.3% beef, 5% carbohydrate, 20% H_2O, 0.7% NaCl	30	670
61.3% beef, 13% fat, 5% carbohydrate, 20% H_2O, 0.7% NaCl	15	2800
	30	3900
	45	3700
	60	980
	75	1400

Analytical Methods

Two methods were used:

1. Static Headspace Analysis
   - Mechanism(s) of formation and food survey

2. MicroExtraction Technique (MET)- A SPME related method developed at Health Canada
   - Food survey

Both methods are based on isotope dilution (d_4-furan) gas chromatography-mass spectrometry

Mechanism of Formation Studies

- 10 mg of test compound was added to a 1.5 mL vial containing 0.5 mL water
- Vials were heated 30 min at 118 ± 1°C
- Cooled to 4°C
- D_4-furan added

Formation of furan from ascorbic acid and derivatives

Reagents	Furan (ng/g)[a]	SD
Ascorbic acid	35	11.9
Ascorbic acid + Fe^{+3}	38	9.6
Sodium ascorbate	3.4	0.7
Sodium ascorbate + Fe^{+3}	29	8.5
Dehydroascorbic acid	338	44.5
Dehydroascorbic acid + Fe^{+3}	381	99
Isoascorbic acid	379	101
Sodium isoascorbate	15	0.8
Sodium isoascorbate + Fe^{+3}	144	3.7
Ascorbyl palmitate	6.8	0.7
Ascorbyl palmitate + Fe^{+3}	4.3	0.4

[a]Concentration of furan in 0.5 mL of reaction mixture
Reagent – 10 mg
Fe^{+3} – 100 µg
Each value is an average of 4 experiments

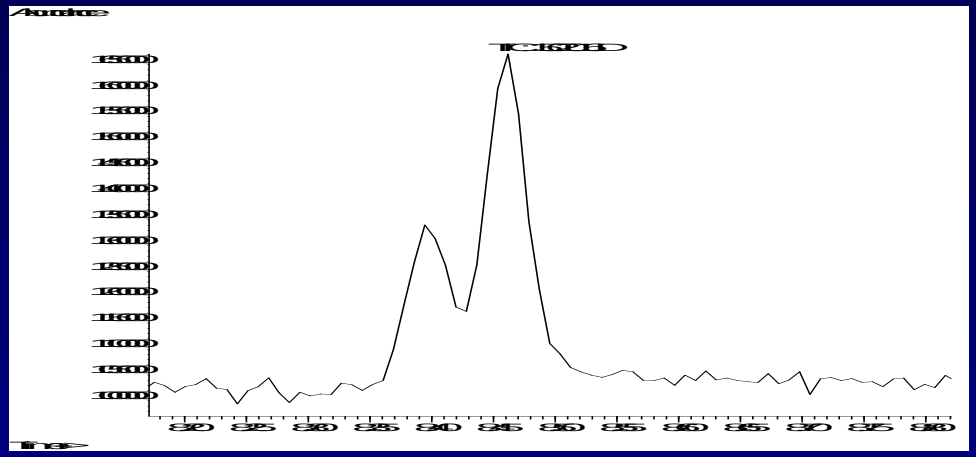
Formation of furan from fatty acids

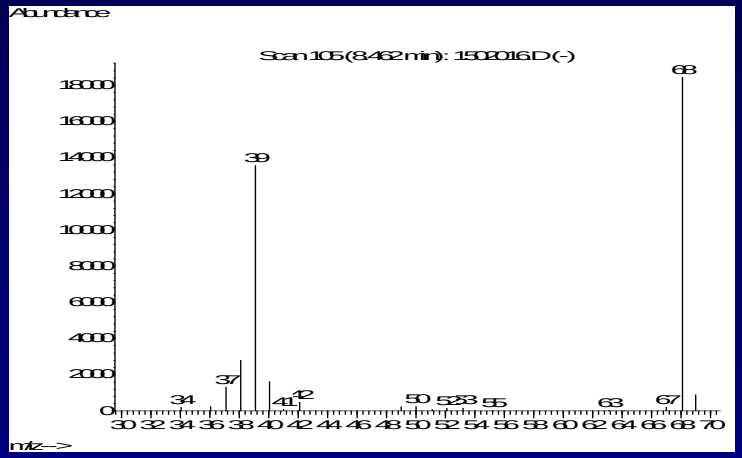
Reagents	Furan (ng/g)[a]	N[b]	SD
Linoleic	125	4	26
Linoleic + Fe^{+3}	498	4	185
Linolenic	625	4	96
Linolenic + Fe^{+3}	985	3	2
Trilinoleate	78	4	16
Trilinoleate + Fe^{+3}	136	4	20
Trilinolenate	570	4	96
Trilinolenate +Fe^{+3}	463	4	4

[a]Concentration of furan in 0.5 mL of reaction mixture
Reagent – 10 mg
Fe^{+3} – 100 µg
[b] number of experiments

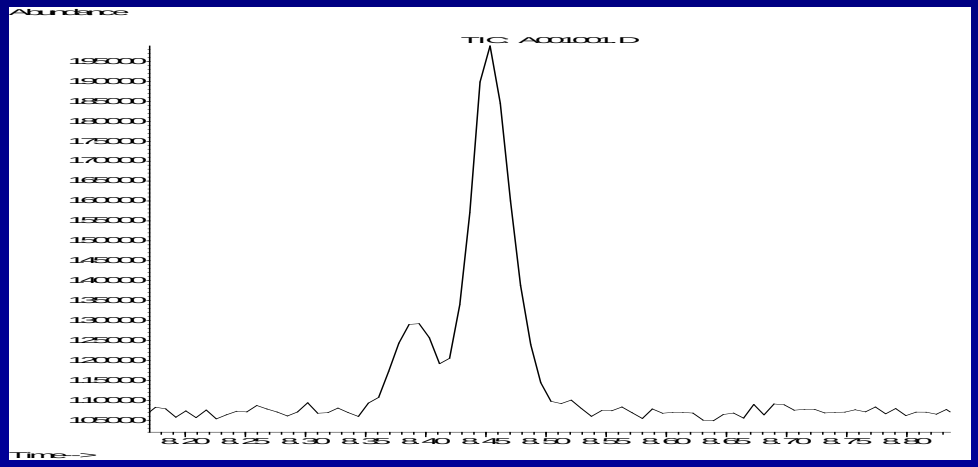
Chromatograms of: a) linolenic acid reaction and b) furan standard (1 ppm native, 0.25 ppm d_4)

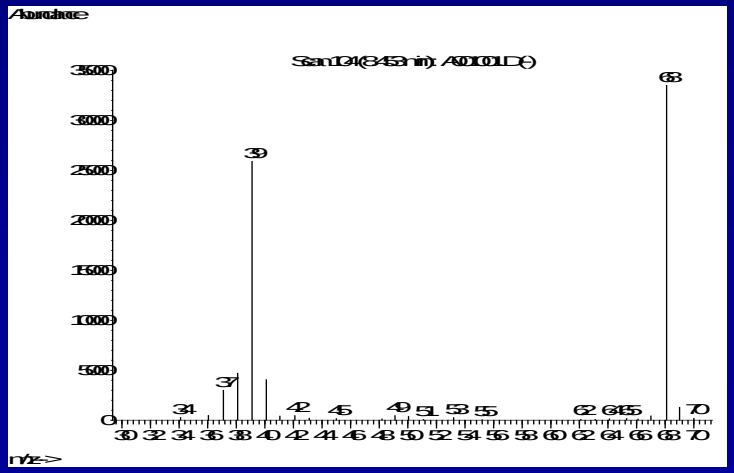
a





b





Conclusions

Two pathways of furan formation were identified in the model systems:

1. Polyunsaturated fatty acids (linoleic, linolenic) via peroxidation and ring closure
2. Decomposition of ascorbic acid derivatives particularly dehydroascorbic acid and isoascorbic acid

Preliminary Survey Results

Furan in Baby Foods

Sample	Furan Concentration (ng/g)	
	MET[a]	Headspace[a]
Beef with Broth	6	6
Banana	7	8
Carrot	54	56
Vegetable and Chicken	18	19
Apple Sauce	5	5
Mixed Vegetable	146	154
Alphabet Beef	62	66
Beef Stroganoff	98	103
Chicken and Stars	25	26

[a]Average of two determinations

Furan in Adult Foods

Sample	Furan Concentration (ng/g)	
	MET[a]	Headspace[a]
Soups	35-117	34-117
Chili	152-227	157-236
Stew	82	83
Bean products	14	14
Canned luncheon meat	7-31	4-28
Coffee, fresh brewed	14-52	14-51

[a]Average of two determinations

Next Steps?

- Further studies on mechanism(s) of formation using model systems and precursor fortified food matrices
- Losses of furan during food processing and cooking
- Further surveys of canned and bottled products
- Participate in round robin method validation study
- Update health risk assessment as new data becomes available


Thank-you !