

Furan: Mechanisms of Formation and Levels in Food

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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



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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 ₂ O, 0.7% NaCl	15	930
	30	750
	45	760
	60	960
	75	870
66.3% beef, 13% fat, 20% H ₂ O, 0.7% NaCl	30	3700
74.3% beef, 5% carbohydrate, 20% H ₂ O, 0.7% NaCl	30	670
61.3% beef, 13% fat, 5% carbohydrate, 20% H ₂ O, 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



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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 $118 \pm 1^\circ\text{C}$
- Cooled to 4°C
- D₄-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

^aConcentration of furan in 0.5 mL of reaction mixture

Reagent – 10 mg

Fe⁺³ – 100 µg

Each value is an average of 4 experiments



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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

^aConcentration of furan in 0.5 mL of reaction mixture
 Reagent – 10 mg
 Fe⁺³ – 100 µg
^b number of experiments

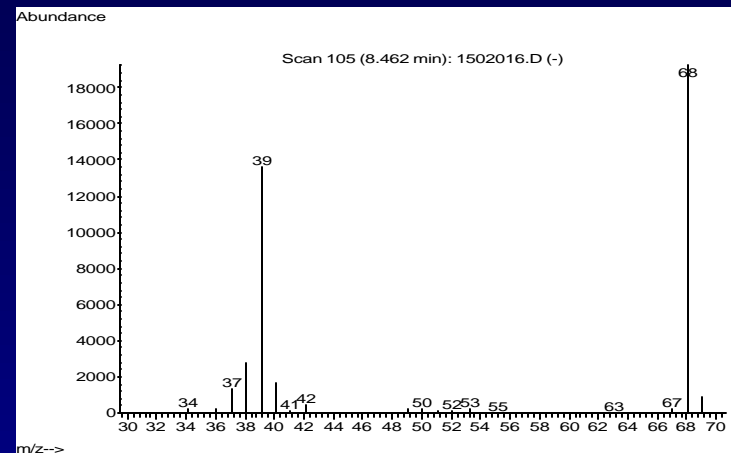
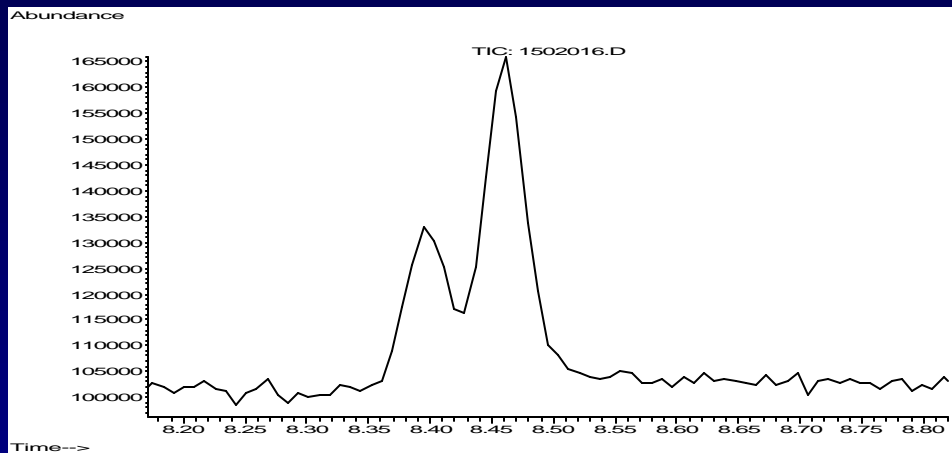


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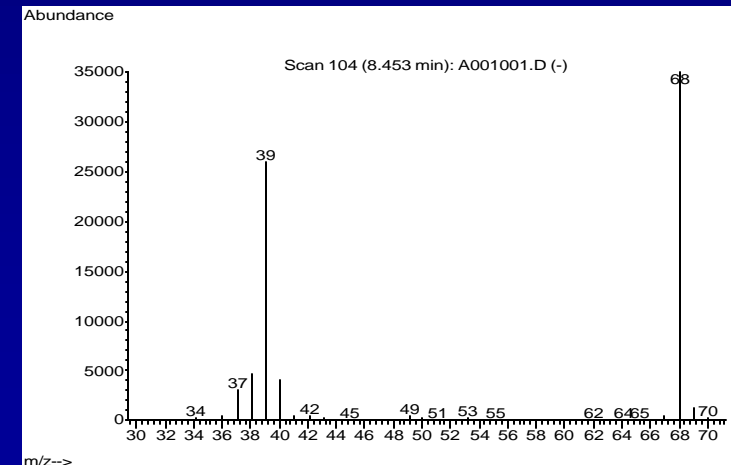
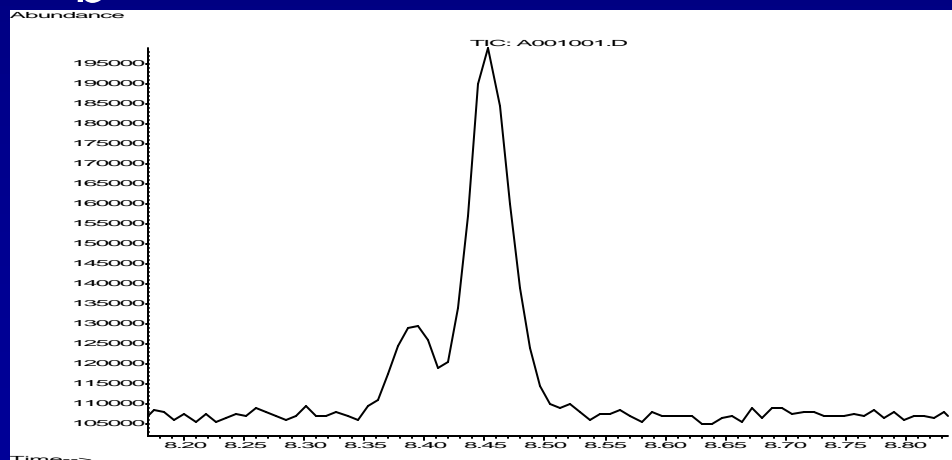
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Chromatograms of: a) linolenic acid reaction and b) furan standard (1 ppm native, 0.25 ppm d₄)

a



b



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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



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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

^aAverage of two determinations



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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

^aAverage of two determinations



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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 !



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