

# Acrylamide in Food

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식품공학과

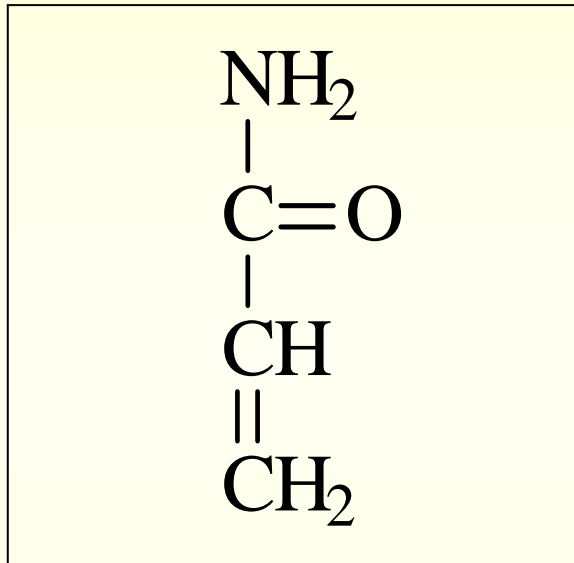
# Brief History

- 2002. April. 24
  - Swedish National Food Administration
  - Stockholm University
  - Acrylamide in fried and oven-baked foods
- Norway
- UK
- Switzerland
- US
- Japan
- Korea

# 식품 중 발암물질

- 식품 중의 발암물질 섭취  
(Generation to Generation)
- 발암물질 제거: 쉬운 방법 없음
- 해결방법: 진행 중

# Acrylamide



**Acrylamide**

- 400,000 tons produced annually
- Over 95% used to produce polyacrylamide
- Water soluble

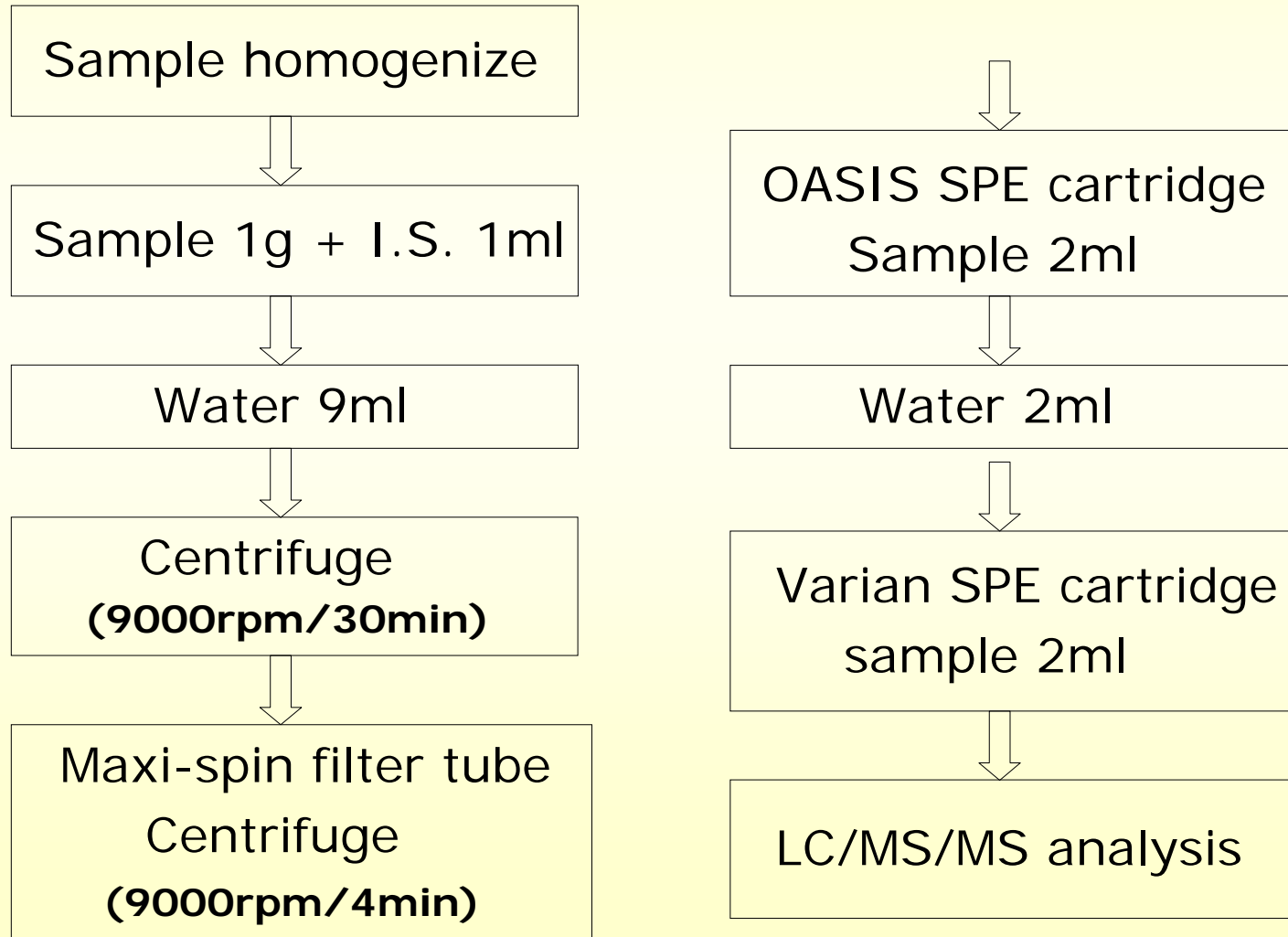
# 연구 분야

(2002 - 2006)

- Formation and Reduction of Acrylamide  
(123 articles)
- Occurrence of Acrylamide and Analytical techniques (112 articles)
- Toxicology (181 articles)

# 연구 방법

## ① Sample preparation

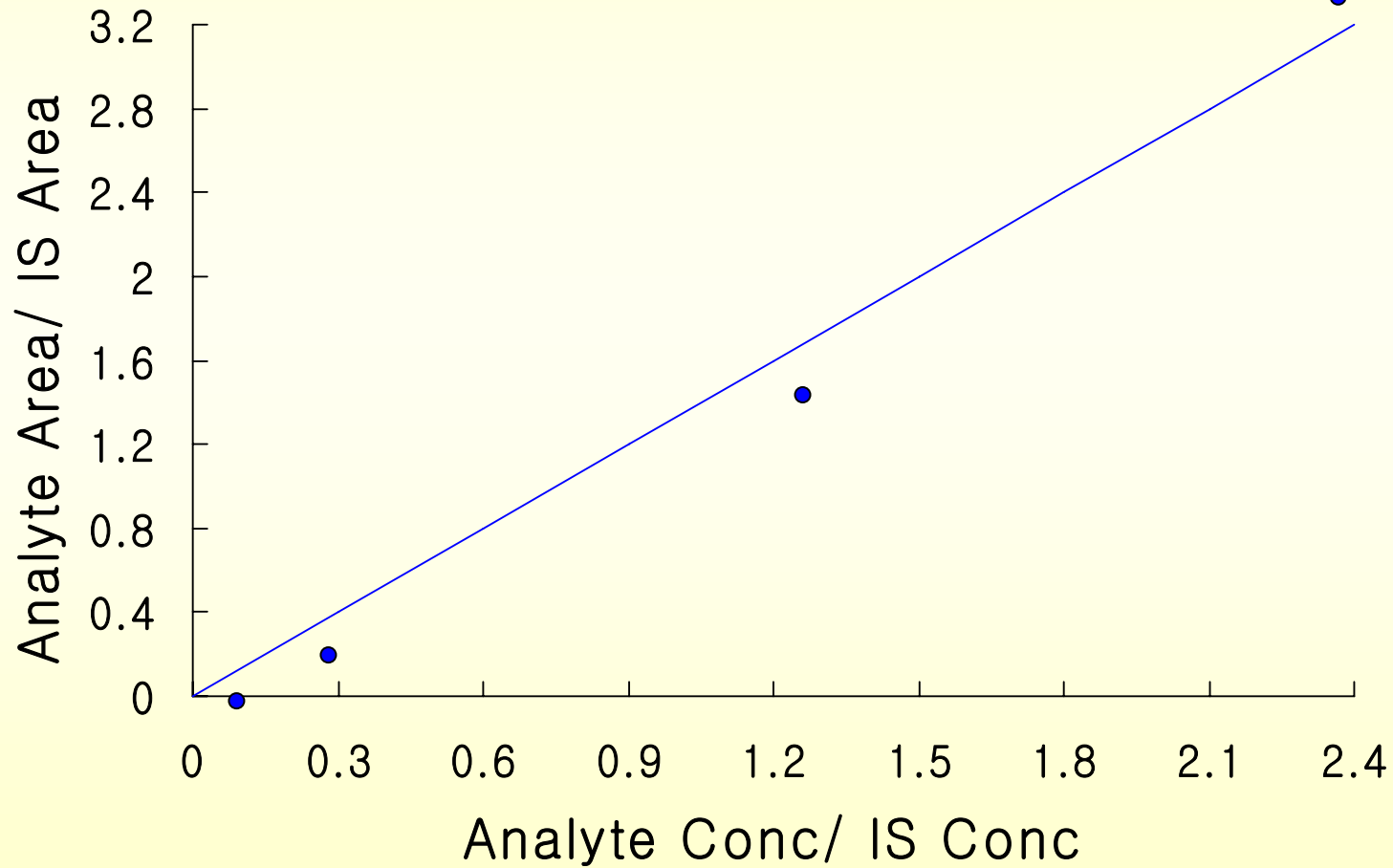


# 연구 방법

## ② LC/MS/MS 조건

- Column : Aqua C18 HPLC column (2×250mm)
- Mobile phase composition: Aqueous 0.1% acetic acid,  
0.5 % methanol
- Column flow rate: 200  $\mu$ l/min
- Acrylamide elution time: 6.5 minutes
- Ionization Mode: Positive ion electrospray
- Collision energy: 19 volts (m/z 27 (80%), m/z 55 (100%)  
and m/z 72 (30%))
- Ions monitored: Acrylamide (m/z 72, 55, 27),  
Internal Standard (75, 58, 29)
- Quantitation: The ratio of peak areas for m/z 55(acrylamide)  
and m/z 58 (internal standard)

# Standard Curve





# Acrylamide Values in Domestic Food

( 2002~2004년 )

Food product	Number of samples	Concentration of Acrylamide (ppb)		
		Minimum	Maximum	
Dairy	butter	5	ND	<10
	cheese	4	<10	<10
	margarine	4	ND	<10
	milk	7	<10	11
	yoghurt	3	<10	<10
Meat/Fish products	bacon	2	<10	<10
	bacon, baked	4	<10	<10
	ham	5	<10	<10
	ham, baked	2	<10	<10
	porkcutlet, frozen	2	<10	<10
	porkcutlet, deep-fried	2	11	22
	sausage	4	<10	<10
tuna, canned	2	<10	<10	

Food product	Number of samples	Concentration of Acrylamide (ppb)		
		Minimum	Maximum	
Grains/ Starches/ Baked products	biscuit	5	11	289
	bread	9	<10	33
	bread, toasted	9	<10	62
	cereal	7	<10	283
	<b>cracker</b>	8	13	459
	donut	2	<10	36
	grain	9	<10	17
	<b>Hardtack (건빵)</b>	8	143	1,081
	popping rice	4	17	66
	porridge	4	<10	<10
	<b>puffed corn</b>	6	75	587
	rice cake	7	<10	<10
	rice, boiled	7	ND	17
scorched rice	4	<10	19	
Fruits/ Vegetables	bean, tofu	4	<10	<10
	bean, tofu, pan cooked	2	<10	<10
	fruit, canned	4	<10	<10
	olive, bottled	2	ND	<10
	<b>olive, black, canned</b>	2	258	681
	potato, raw	5	<10	<10
	vegetable, canned	4	<10	20

Food product	Number of samples	Concentration of Acrylamide (ppb)		
		Minimum	Maximum	
Snack foods	popcorn, not heated	3	≤10	≤10
	popcorn, popped	6	170	397
	potato, french fries, frozen	2	19	37
	potato, french fries, deep-fried	15	141	1896
	potato chip	4	278	1709
	potato snack	8	502	3,277
	snacks, other than potato snack	8	≤10	150
	hot-dog, frozen	2	≤10	11
	hot-dog, microwaved	2	≤10	11
Candy/Sweets	candy	7	≤10	39
	caramel	2	≤10	≤10
	chocolate	8	13	63
Seasonings	bean paste	2	34	60
	bean paste, mixed	4	ND	51
	hot pepper paste	3	≤10	56
	ketchup	4	ND	16
	mustard sauce	2	10	51
	pork cutlet sauce	4	ND	≤10
	sesame oil	4	≤10	51
	mayonnaise	2	ND	ND
	thousand island dressing	2	ND	ND
	fermented soy bean paste products	12	≤10	60

Food product		Number of samples	Concentration of Acrylamide (ppb)	
			Minimum	Maximum
Beverages	carbonated beverage	4	<10	<10
	coffee, brewed	5	<10	11
	<b>coffee, powdered</b>	5	70	1,026
	fruits drinks	5	<10	<10
	tea	7	<10	24
Food products sold on the road	waffle	2	41	53
	hot-dog	2	11	64
	baked squid	2	<10	<10
	dried fish	1		12
	pas (fried sweet potato)	1		57
Homemade foods	boiled down product	5	ND	218
	fried product	9	ND	12
	roasted fish product	2	ND	<10
	seasoned product	2	<10	<10
	soup products	6	ND	<10

\* ND : not detected

식품유형	2006		2002~2004(국내)	2002~2005(FDA)	JECFA
<u>빵류</u>	335	77	36	59	3,436
<u>견과류(감자외)</u>	1,200		1,081	946	7,834
<u>감자 견과류</u>			3,277	829	4,080
<u>캐디류</u>	29		39	909	112
<u>초콜릿류</u>	477		63		
<u>설탕</u>	21		.		
<u>침출차</u>	297		24(tea)	ND	660(green tea, 'roasted')
<u>커피</u>	129		1,026	609	5,399
<u>과실/채소류 음료(prune juice)</u>	625		<10	355	fruits, processed 770
<u>기타음료</u>	<10		<10	60	.
<u>조미식품</u>	300		60	151	1,168
<u>김치·절임식품 (black olive)</u>	51		681	1929	.
<u>땅콩·견과류가공품</u>	262		.	457	1,925
<u>시리얼류</u>	638		283	1,057	1,346
<u>레토르트</u>	144				

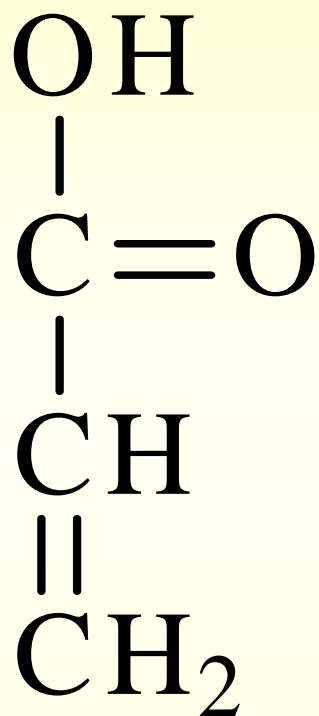
# Mechanisms

## ➤ **Substrates**

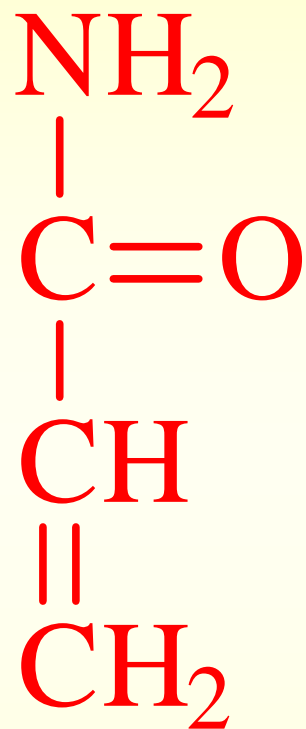
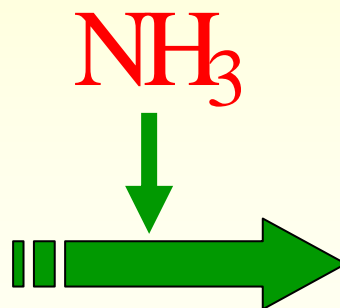
- Starch
- Sugars
- Amino acids
- Oil/Fat
- Degradation products

## ➤ **Potential mechanisms**

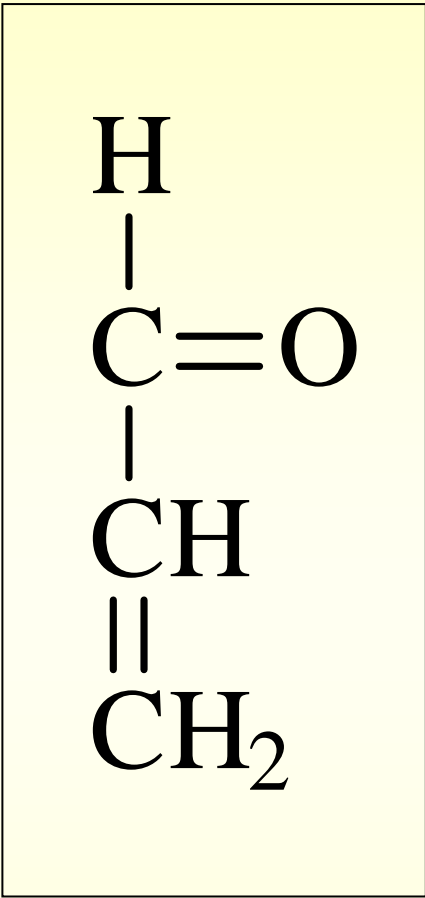
- Maillard reaction products
- Oil/fat pyrolysis products
- Oxidation products
- Free radical reactions



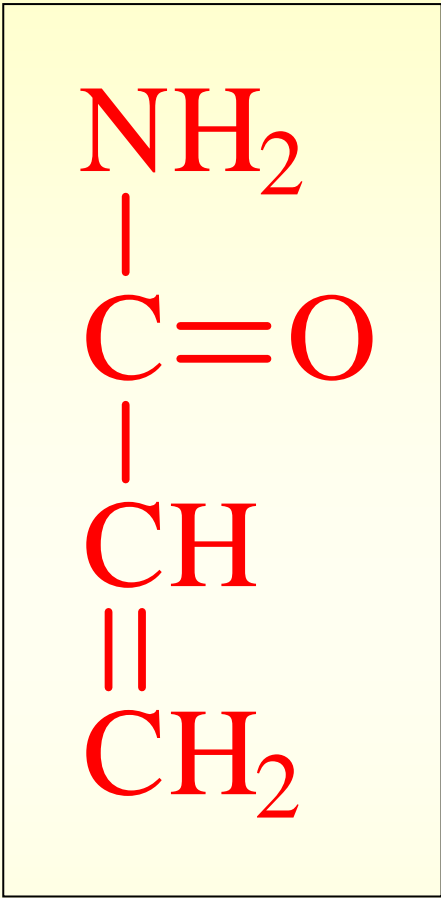
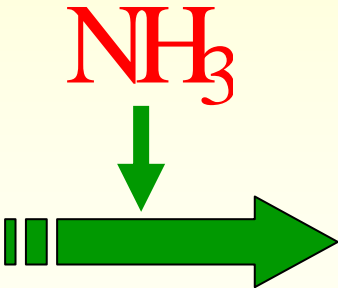
**Acrylic Acid**



**Acrylamide**

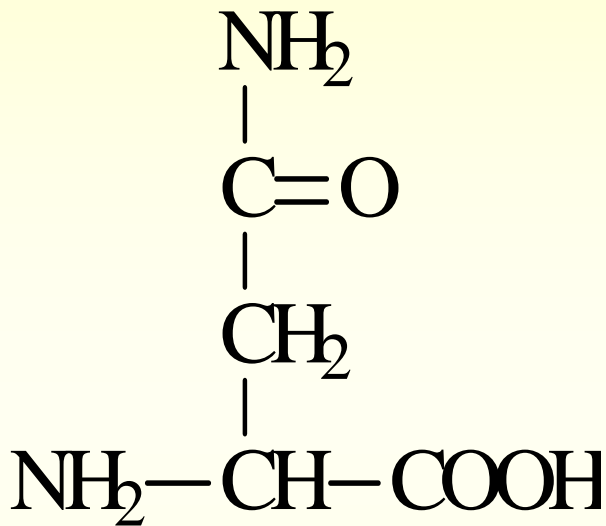


**Acrolein**



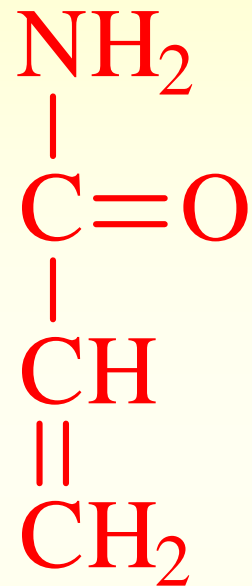
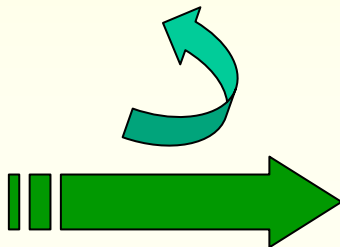
**Acrylamide**





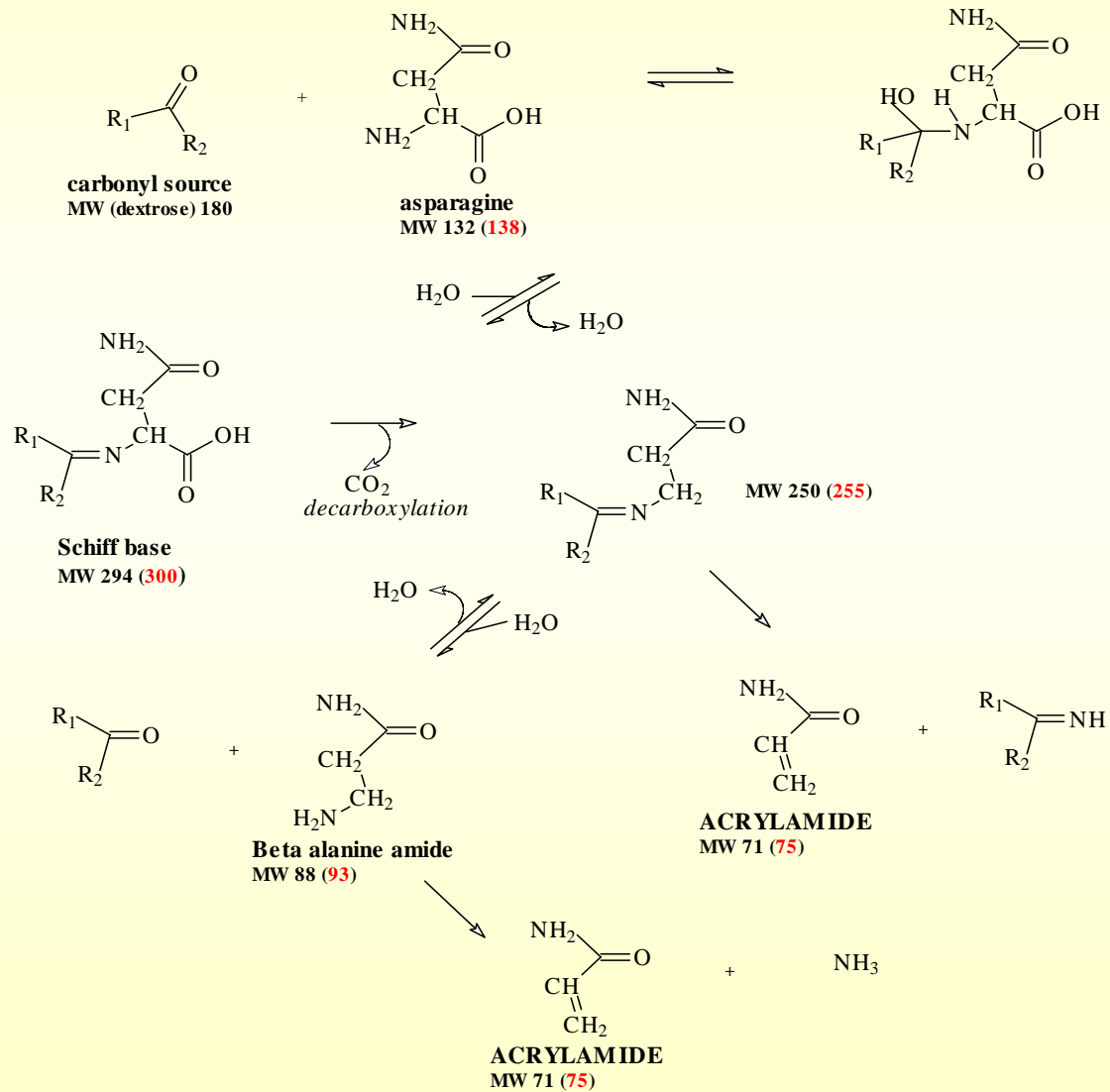
**Asparagine**

carbonyl



**Acrylamide**

# Acrylamide Formation Mechanism



# Approaches to Reducing Acrylamide in Food

- Remove reactants
- Disrupt reaction
- Remove acrylamide after formation

# Concentrations of Sugars and Amino Acids in a Potato Cultivar Used Chipping

sugar		Concn (g/100g)	
glucose		0.1	
fructose		0.08	
sucrose		1.07	
amino acid	Concn (mg/100g)	amino acid	concn (mg/100g)
Ala	4.7	Lys	4.7
Arg	16.4	Met	4.7
<b>Asn</b>	<b>93.9</b>	Phe	4.7
Asp	4.7	Pro	4.7
Gln	28.2	Ser	4.7
Glu	9.4	Thr	18.8
Gly	0	Trp	0
His	7	Tyr	7
Ile	7	Val	9.4
Leu	4.7		

# What Factors Affect Acrylamide Formation?

- Food composition
  - Precursors
  - pH
  - Moisture
  - Other compounds
- Processing conditions
  - Time
  - Temperature
  - Other

# What Factors Affect Acrylamide Formation?

## ➤ Food composition

### - Amino acids

ASN, MET, GLN, ASP, CYS

Other amino acids- LYS

### - Sugars

Fructose > glucose > sucrose

### - pH

pH 8.0 > 5.5 > 3.0

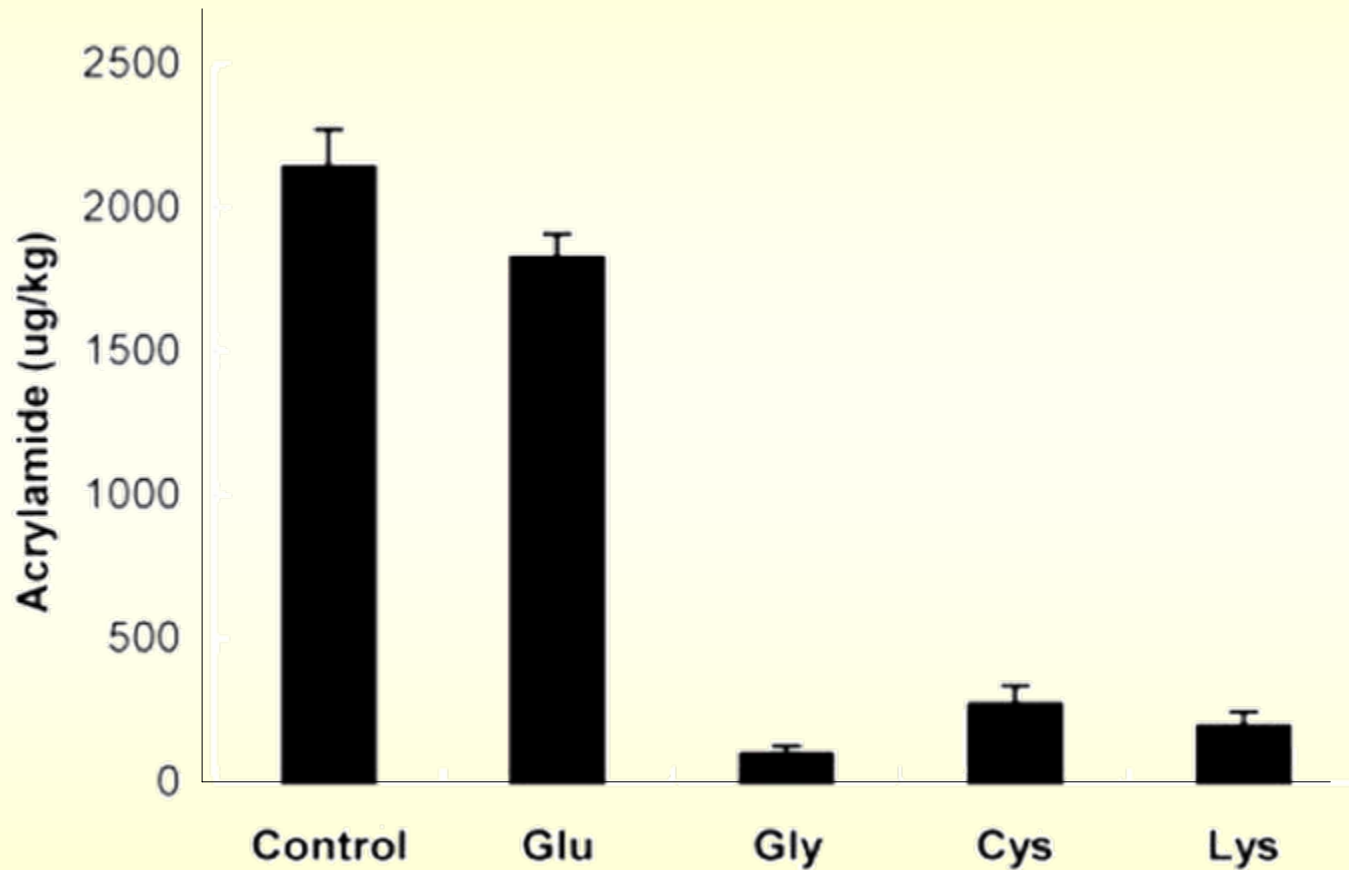
### - Moisture content

Effects unclear

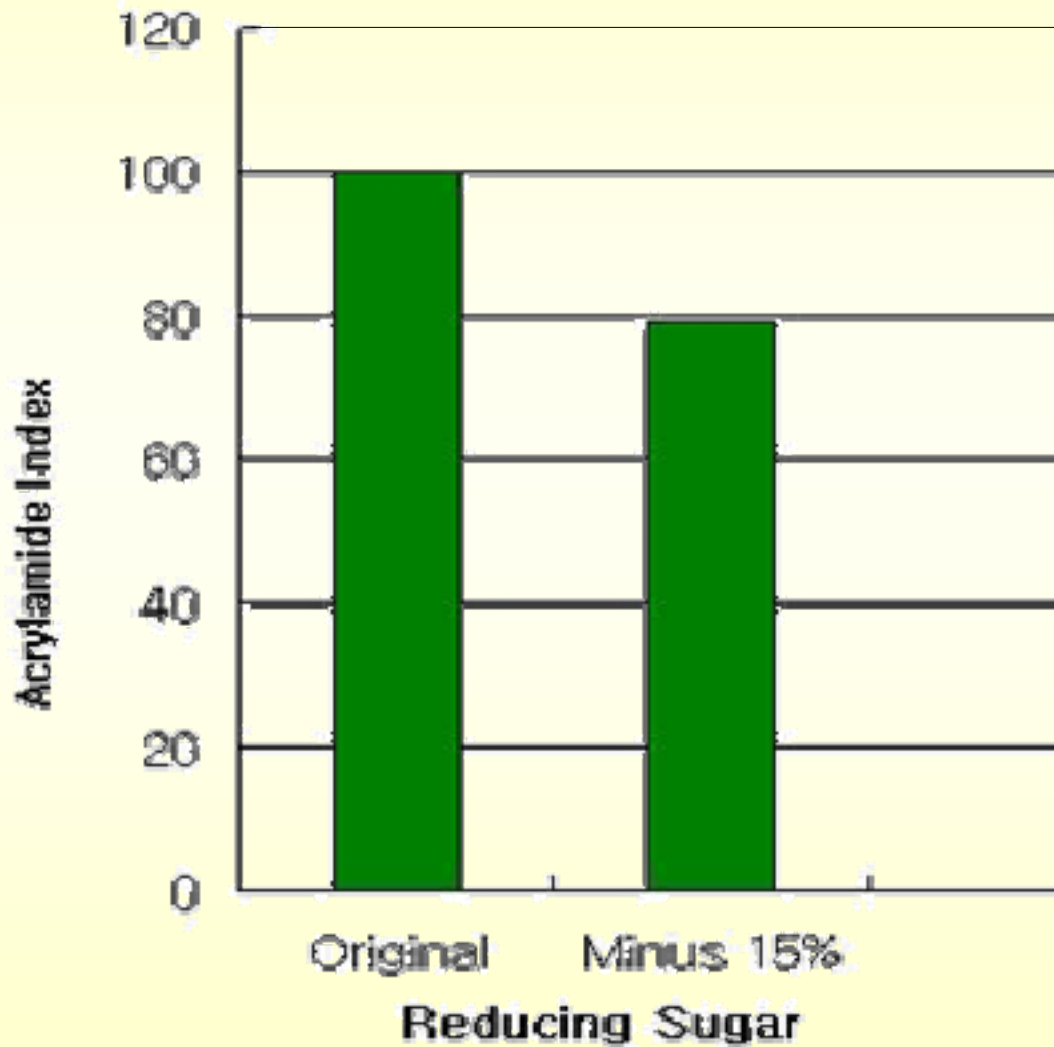
### - Others

< 2003, FDA >

# Effects of Amino Acids



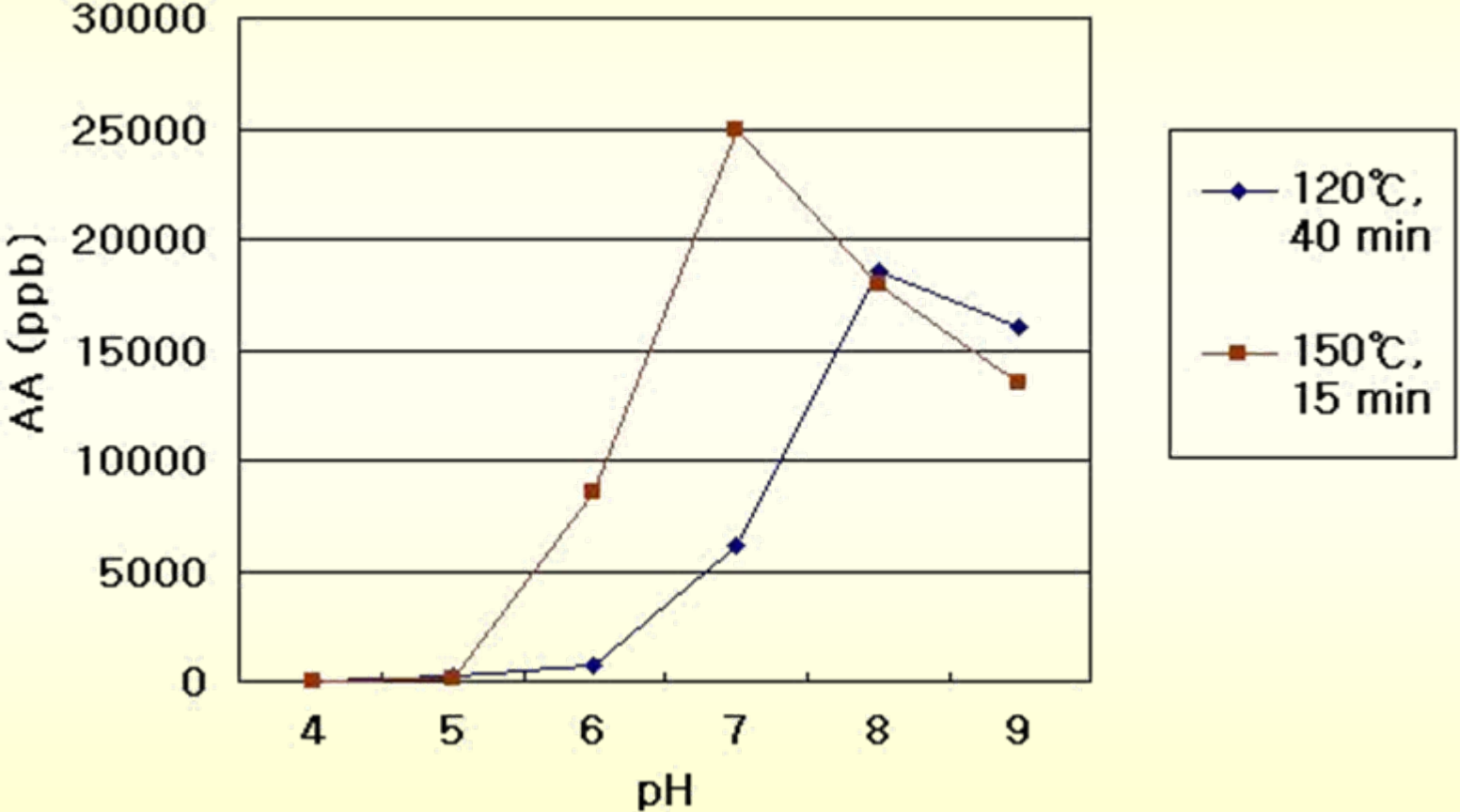
# Sugar Control



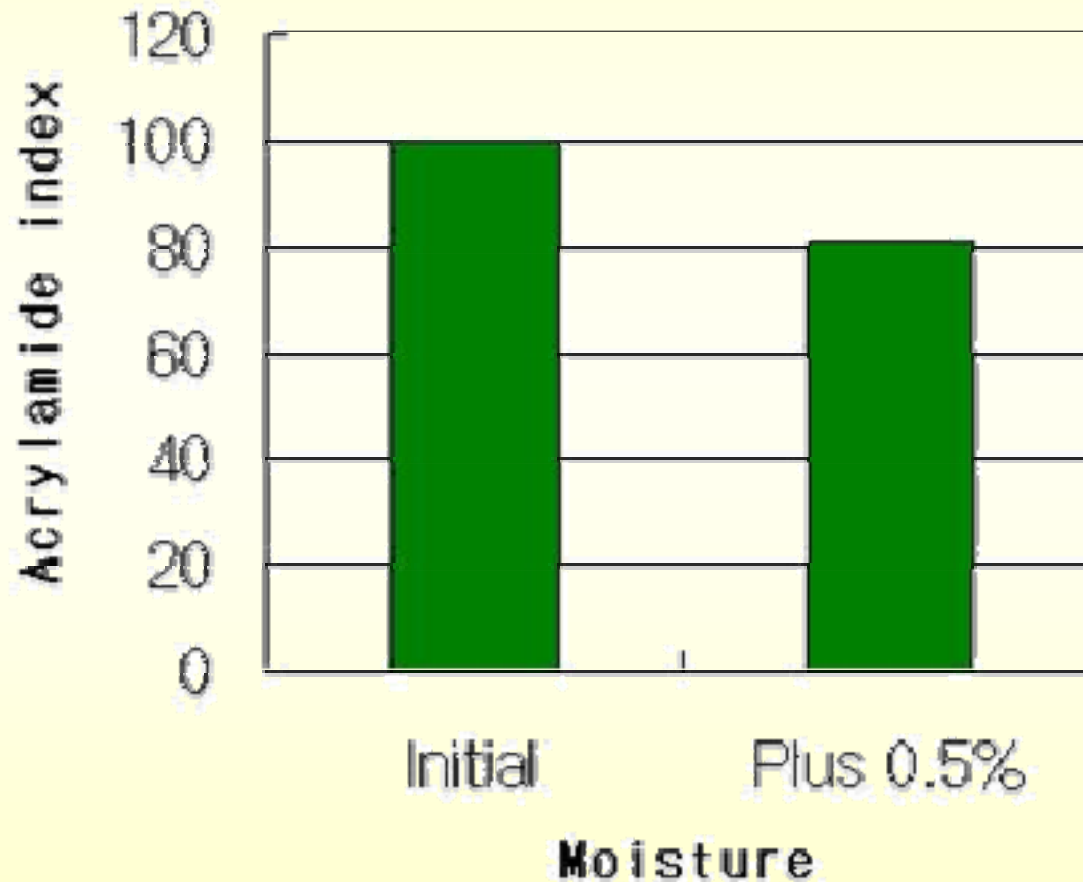
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# Effect of pH on Acrylamide Formation

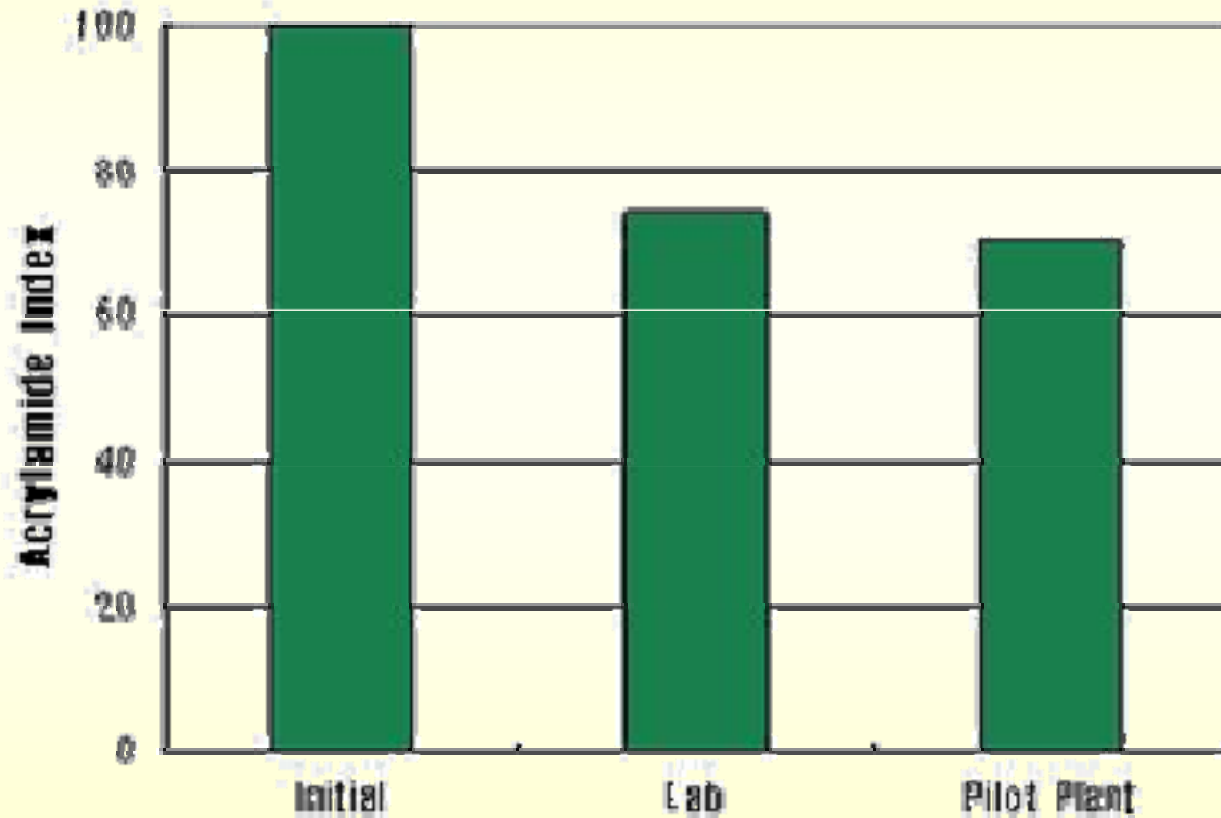


# Moisture Control



< P & G, personal communication >

# Asparaginase



< P & G, personal communication >

# What Factors Affect Acrylamide Formation?

## ➤ Processing Conditions

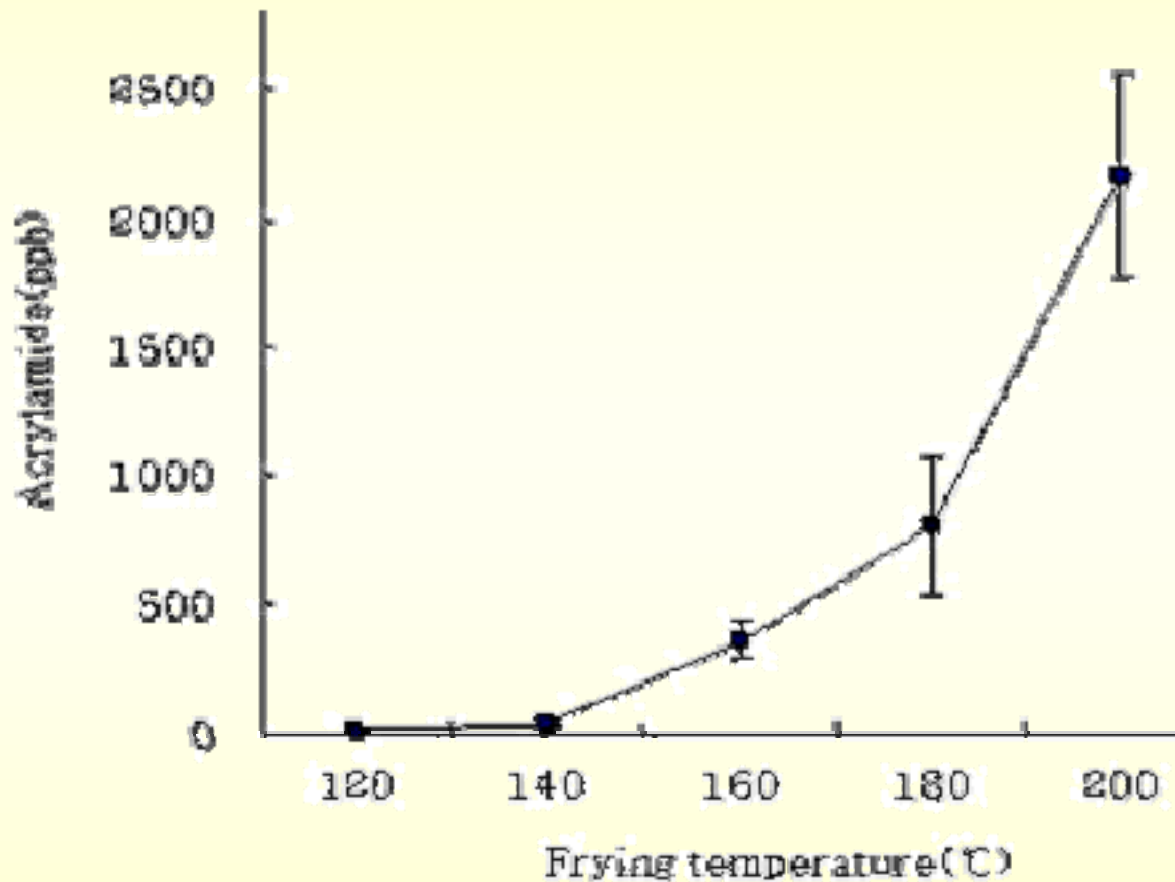
- Temperature
- Time

# Effect of Temperature

## In food

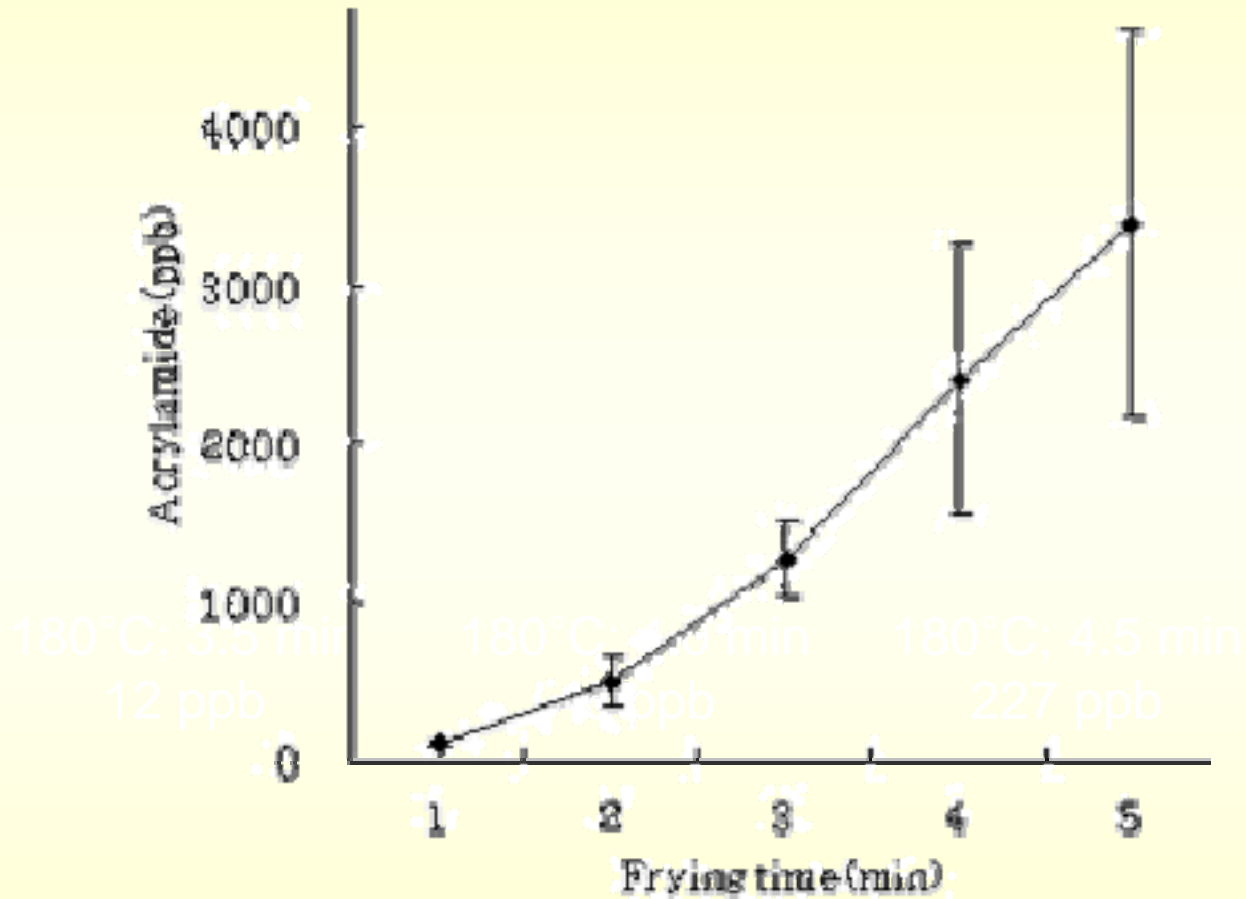
- Boiling and retorting produce little to no acrylamide
- Frying and baking result in modest to high levels
- Acrylamide levels increase with cooking/processing temperature

# Effect of Temperature



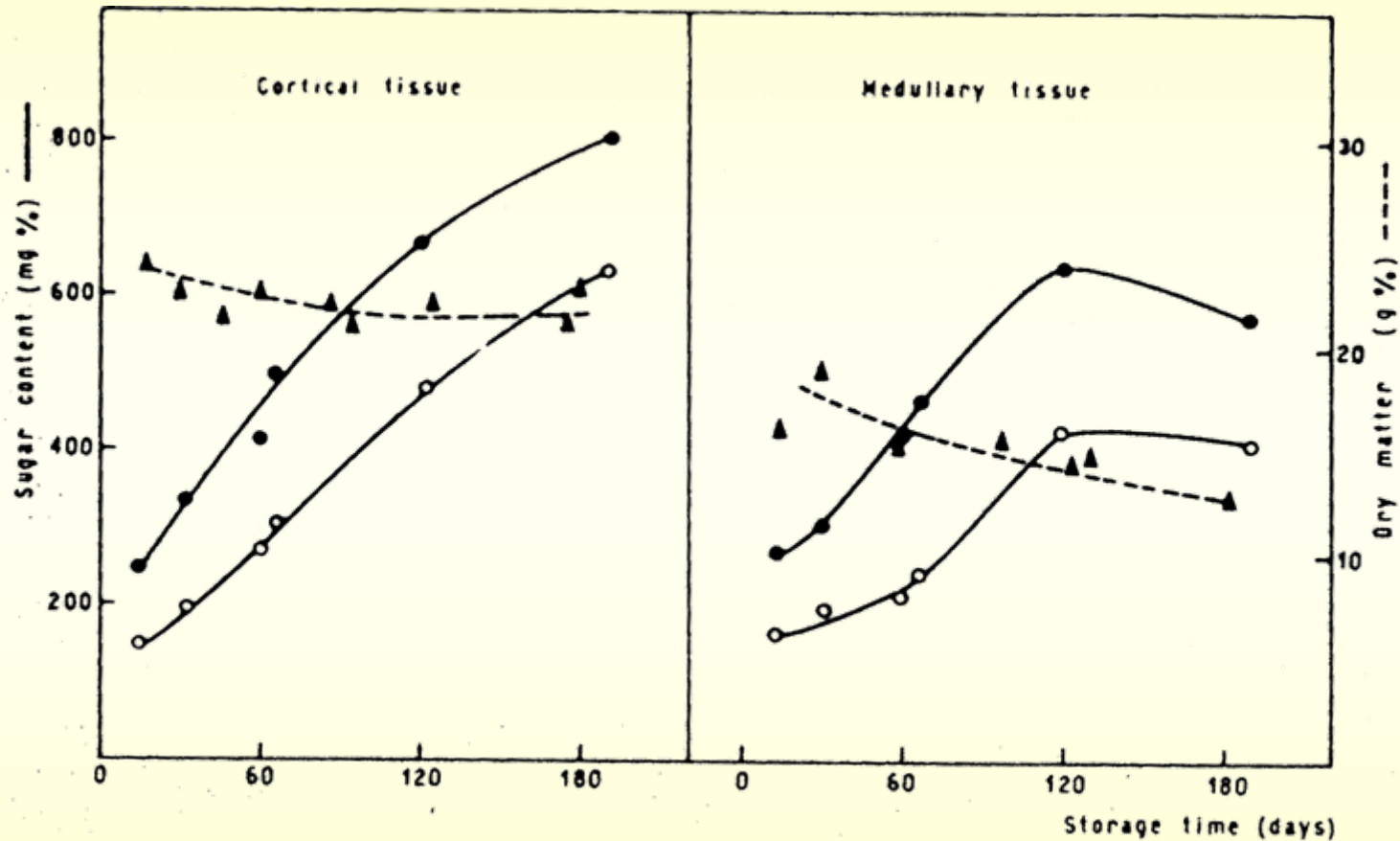
→ Frying temperature-dependent formation of acrylamide

# Effect of Time



→ Acrylamide levels increased with frying time

# Changes in sugars during storage



- (○) reducing sugars
- (●) total soluble sugar
- storage at 3°C



# Remove After Formation

- **Supercritical CO<sub>2</sub>**  
Removes everything,  
but destroys the product
- **UV light**  
No effect,  
several wavelengths including visible

# Toxicology of Acrylamide

- Classified by IARC as category 2A  
→ Probably carcinogenic to humans
- Acutely neurotoxic
- Genotoxic in a range of assays
- Metabolized to glycidamide; forms DNA adducts

# Toxicology of Acrylamide

- Carcinogenic in animal (rodent) studies
- Three human cohort studies; (1986, 1989, 1999)
  - No evidence of a causal relationship between exposure and cancer incidence

# Human epidemiological study

(British Journal of Cancer 2003; 88: 84-89)

## Authors concluded

- No positive association between dietary exposure to acrylamide and risks of bowel, bladder or kidney cancer

# Toxicokinetics of Acrylamide

(Cancer Epidemiology Biomarkers Prev 2006; 15(2):266–71 )

- Toxicokinetics of Acrylamide in Humans after Ingestion of a Defined Dose in a Test Meal to Improve Risk Assessment for Acrylamide Carcinogenicity

# FAO/WHO Expert Consultation

(Rome, June, 2002)

- Estimated average chronic human dietary intake is in the order of  $1\mu\text{g}/\text{kg}$  body weight/day
- NOAEL for acrylamide neuropathy is  $500\mu\text{g}/\text{kg}$  body weight/day
- Generally recommended that exposures be "as low as reasonably achievable (ALARA)"

# 음식 섭취 가이드라인

(consumer advice)

- Choose a variety of grains daily, especially whole grains
- Choose a variety of fruits and vegetables daily
- Choose a diet that is low in saturated fat and cholesterol and moderate in total fat
- Choose a diet moderate in sugars
- Choose and prepare foods with less salt
- Aim for a healthy weight
- Be physically active each day