



# Acrylamide: do we have a problem?

**Jan A. Delcour**

Laboratory of Food Chemistry  
Katholieke Universiteit Leuven

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# Overview

- Acknowledgements
- Background: Acrylamide in Food
- Acrylamide Contents in Foods
- Exposure to Acrylamide
- Acrylamide Formation in Foods
- Reduction of Acrylamide Formation in Foods
- Toxicology/Epidemiology
- JECFA Approach
- Concluding Comments

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# Acknowledgements

- Dr David R. Lineback  
(University of Maryland)

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# Acrylamide (AA) in Food: Background

- During monitoring of workers exposed to AA (tunnel construction accident in Sweden), AA-hemoglobin adduct observed in control subjects.
- First reported in foods by Swedish National Food Authority and Stockholm University in April, 2002.
- Subsequent studies revealed formation of AA in starch-rich foods heated at 120 °C or above.
- Survey revealed AA in many common foods in Sweden. Rapidly confirmed in several countries.
- AA is considered carcinogenic and genotoxic in animal models.

# AA in Food: Background

- Rapidly became an international issue with meetings, shared information and unprecedented amount of cooperation.
  - FAO/WHO Expert Consultation (June 2002)
  - 2 major meetings in U.S. and an ACS symposium
  - CIAA and EFSA meetings in Europe
  - JECFA Risk Assessment (February 2005)
- A 6<sup>th</sup> Framework EU research project currently in progress, the HEATOX project.
- Additional information on AA in food is available on databases/infobases in the E.U.  
([http://europa.eu.int/comm/food/food/chemicalsafety/contaminants/acryl/database\\_en.htm](http://europa.eu.int/comm/food/food/chemicalsafety/contaminants/acryl/database_en.htm)) and U.S. ([www.acrylamide-food.org](http://www.acrylamide-food.org)).
- FDA and IRMM JRC also maintain databases of analytical values.

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# AA Values in Foods

(Petersen & Tran in "Chemistry and Safety of Acrylamide in Food," p. 70, Springer Science, New York, 2005)

**Table 2. Acrylamide Levels in Foods**

Category	European Data	FDA Data
Breads	12-3200	<10-364
Crispbread	<30-1670	
Crackers and Biscuits	<30-2000	26-620
Cereal	<30-2300	11-1057
Other Grains	<30	
Potato Chips	150-1280	117-2762
Other Salty Snacks	122-416	12-1243
French Fries	85-1104	20-1325
Other Potato Products	<20-12400	
Other Vegetable and Fruit Products	10-<50	<10-70
Prepared Foods	<30-30	
Meats	<30-64	<10-116
Candy and Dessert items	<20-110	<10-909
Cookies		36-432
Coffee and Tea	170-700	37-374
Other Nonalcoholic Beverages	<30	
Alcoholic Beverages	30	
Dairy Products	10-100	<10-43
Baby Food and Formula	40-120	<10-130
Dry Soup Mixes		<10-1184
Gravy and Seasonings		38-54
Miscellaneous	70-200	<10-125

# AA in Snack Products

(from FDA reported analyses)

	<u>µg/kg (ppb)</u>
■ Granola/granola bar	11 - 99
■ Corn/tortilla chips	<10 - 240
■ Crackers	112 - 432
– Butter type	373-425
– Graham	211-647
– Saltine	57-95
■ Cookies	29 - 336
■ Pastry and cake	<12 - 168
■ Peanuts	28 - 92

# AA in Snack Products

(from FDA reported analyses)

	<u>µg/kg (ppb)</u>
■ Cheese snacks	57 - 193
■ Popcorn	97 - 352
■ Pretzels	97 - 342
■ Roasted almonds	236 - 457
■ Tortilla chips	117 - 184
■ Potato chips	17 - 2510
■ Almonds	236 - 457

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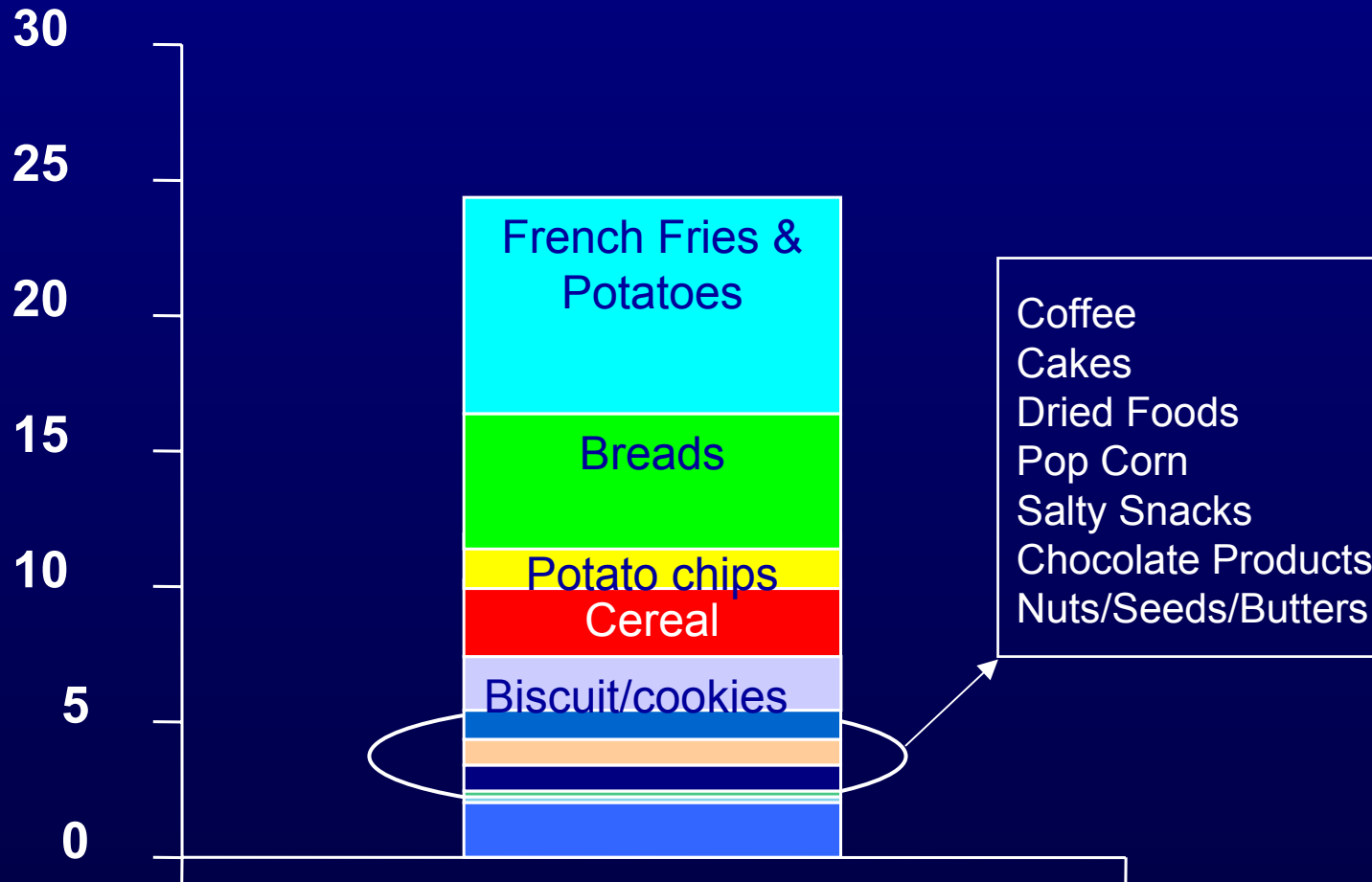
# AA is a Food Problem

US Foods found to contain AA (so far) constitute:

- 38% of calories
- 33% of carbohydrates
- 36% of fiber
- 28% of fat
- 20% of calcium
- 47% of iron
- 25 to 35% of other micronutrients
- 15% of vitamin A
- 34% of vitamin E
- 22 to 44% of B, C and folate vitamins

# Relative Exposure to Acrylamide in U.S. Food

µg/day



## AA exposures estimated in selected exposure assessments (Adapted from Dybing et al., 2004)

Country/source	Daily AA intake ( $\mu\text{g}/\text{kg}\text{-bw}/\text{day}$ ) for mean or higher percentile consumers	
	Mean consumer	Upper percentile consumer
Australia	0.4-0.5 ( $\geq 2$ years)	1.4-1.5 (95 <sup>th</sup> )
Belgium	0.51 (13-18 years)	1.09 (95 <sup>th</sup> )
EC	0.2 - 0.4	
France	0.5 ( $> 15$ years)	1.1 (95 <sup>th</sup> )
Germany	1.1 (15-18 years)	3.4 (95 <sup>th</sup> )
JECFA	1	4
The Netherlands	0.48 (1-97 years)	0.60 (95 <sup>th</sup> )
Norway	0.49 (males) 0.46 (females)	1.01 (90 <sup>th</sup> ) 0.86 (90 <sup>th</sup> )
Sweden	0.45 (18-74 years)	1.03 (95 <sup>th</sup> )
Switzerland	0.28 (16-57 years)	
U.K.	0.3 (19-64 years)	0.6 (97.5 <sup>th</sup> )
U.S.	0.43 ( $> 2$ years)	0.92 (90 <sup>th</sup> )

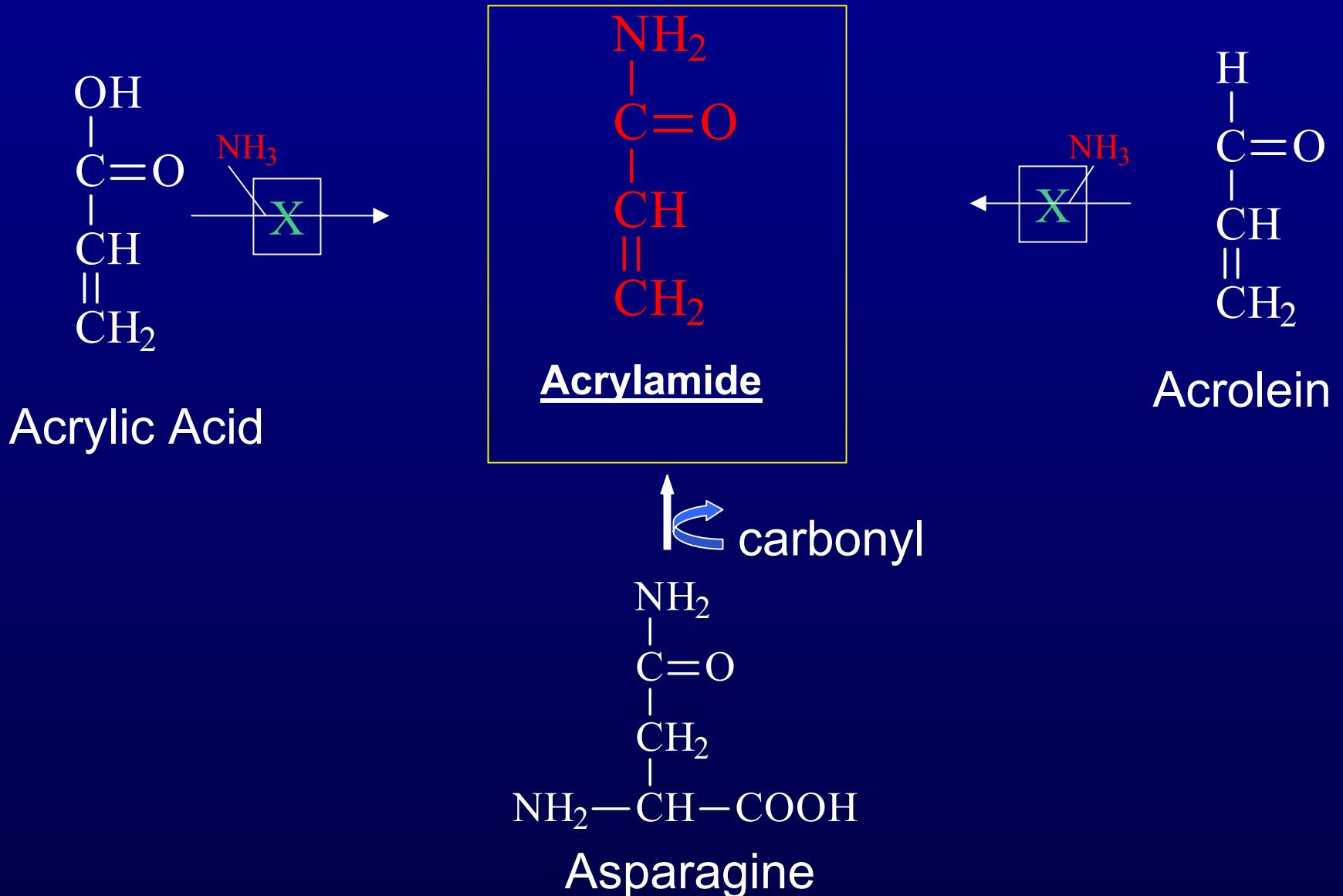
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# AA is formed during:

- Thermal processing
  - High-temperature frying
  - Baking
  - Roasting
  - Grilling
  - Toasting
  - Microwaving
- Favored by low water content

# Studied Mechanisms of AA Formation



# Asparagine in Various Crops

■ Potato	0.5 – 10 mg/g
■ Corn	0.6 – 1
■ Wheat	0.02 – 2
■ Rye	0.2 – 2.8
■ Asparagus	5.4 – 108
■ Cocoa (raw)	30.9
- roasted @ 125C	14.5
- roasted @ 135C	9.4
■ Cheese	40 – 300

Also in peanuts, soybeans, onions, coffee, tomatoes, fruits, etc

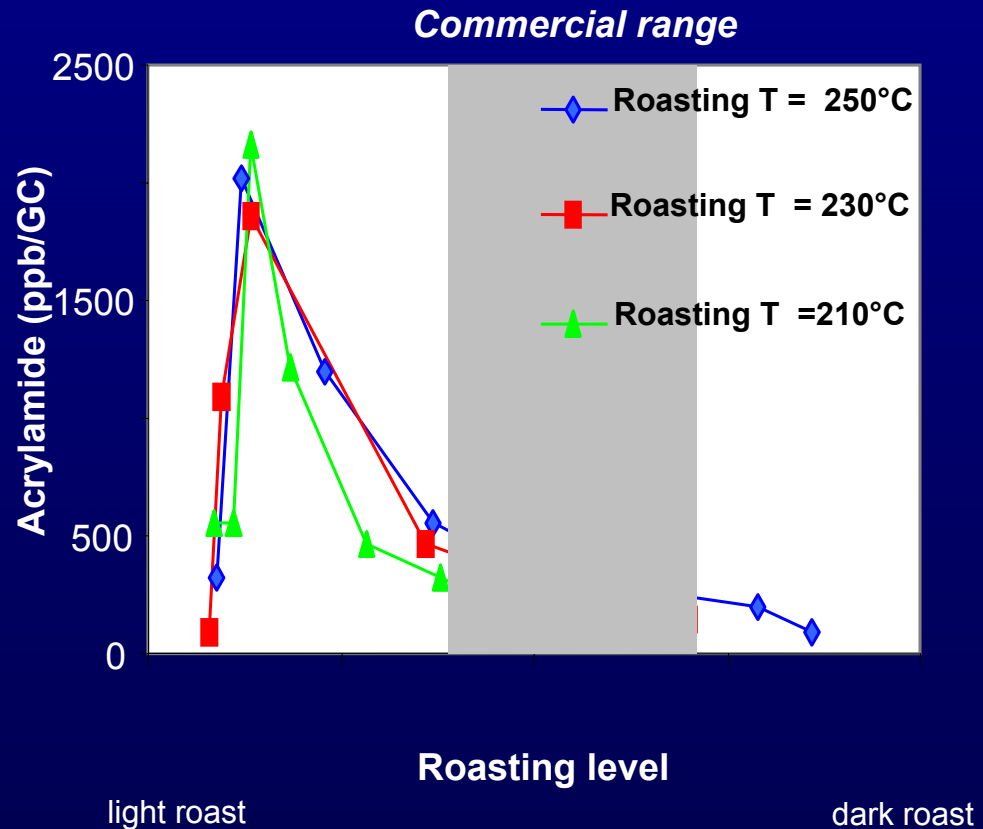
(From Ellin Doyle, Ph.D., Food Research Inst., U. Wisc)

# AA Formation in Coffee

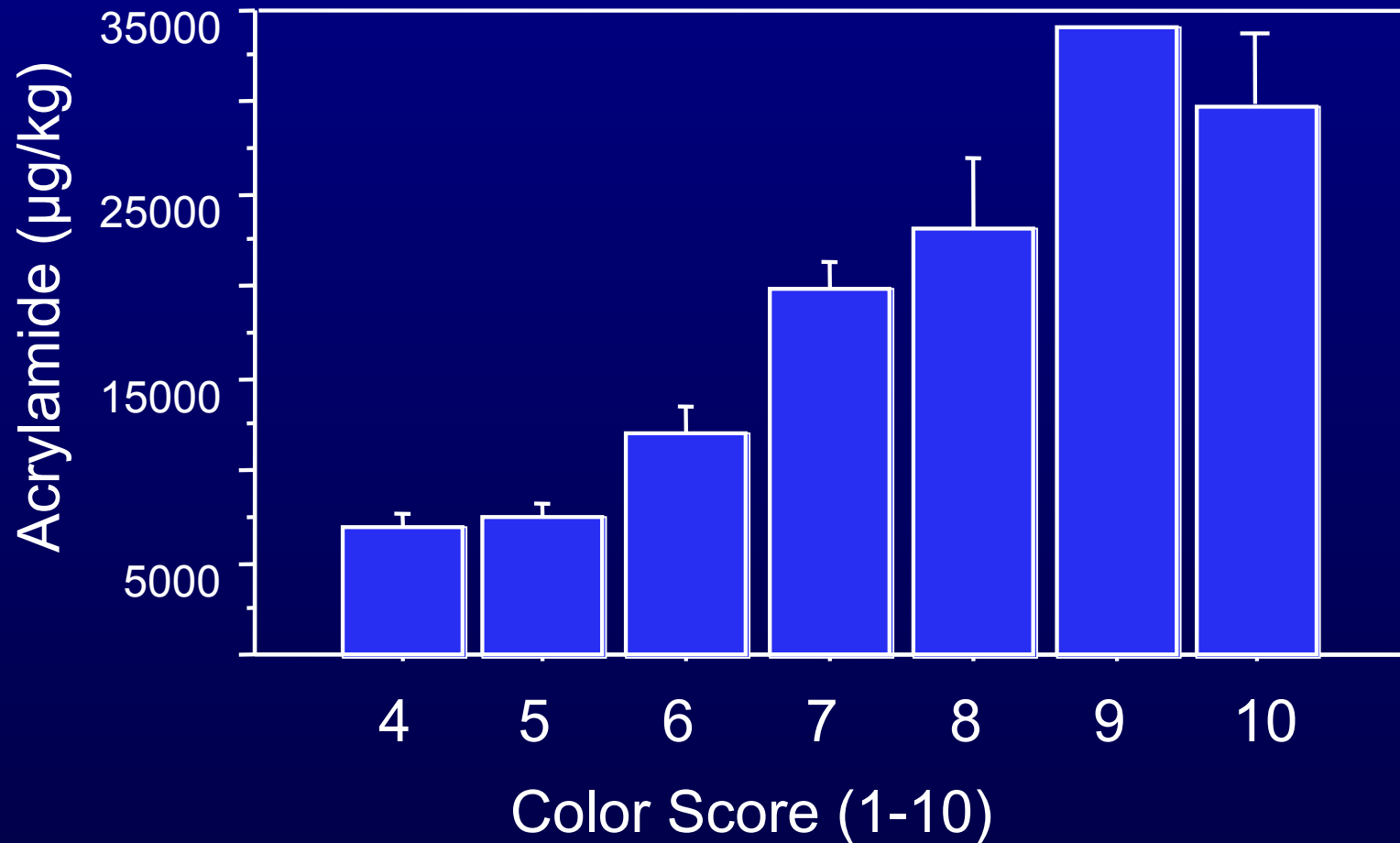
(Stadler, EU Stakeholder Mtg., Oct/2003)

- AA is formed at the beginning of the coffee bean roasting; at higher (darker) roast, level is decreased
- Totally different from what is known about other foodstuffs.
- No options to decrease levels in coffee; roasting step cannot be fundamentally changed.

## Acrylamide in coffee



# Chip Color and AA Concentration



# Summary – AA Formation

- Asparagine and reducing sugars (glucose/fructose) are the major AA precursors in food.
- In potato systems, reducing sugars appear to limit AA formation.
- In cereal systems, asparagine appears to limit AA formation.
- AA formation is temperature critical and occurs well below temperatures at which food is commonly cooked.
- The chemical pathway leading to AA is a low yield (~0.1% in both models and food samples) pathway.
- It will probably not be possible to cook food without forming at least some AA.

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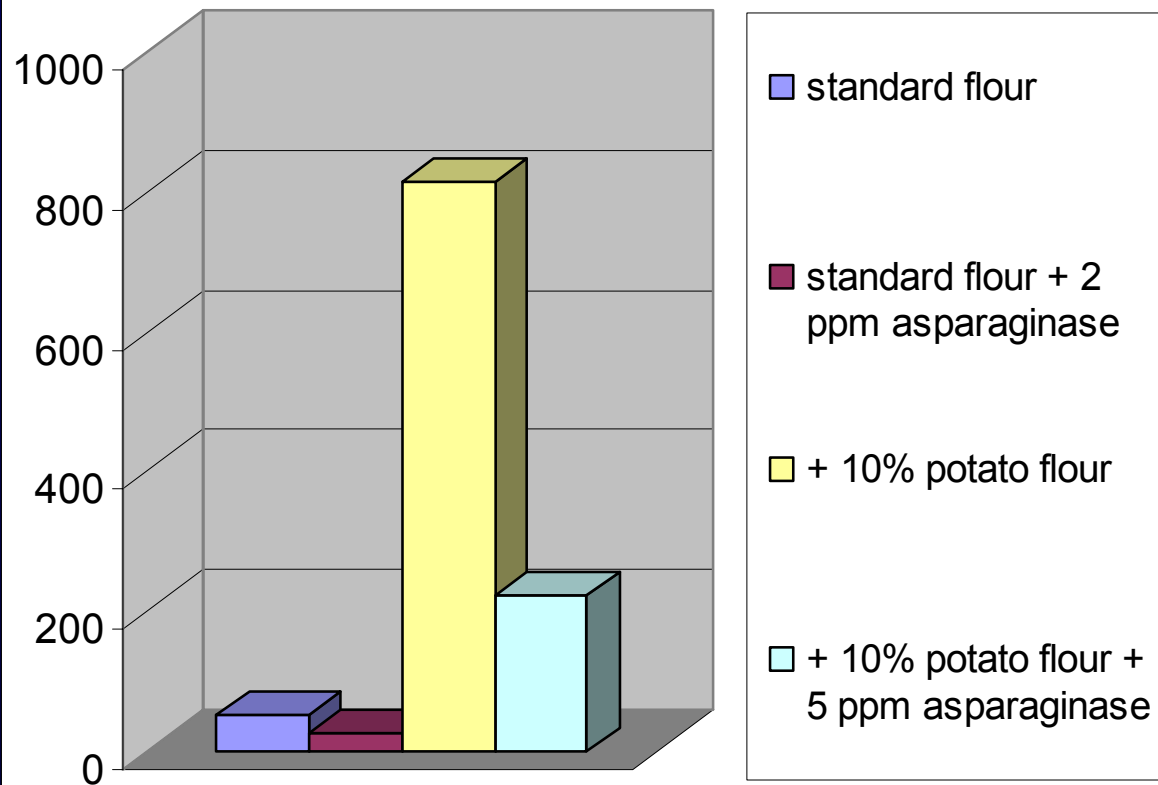
# Approaches to Reducing AA

- Remove reactants
- Disrupt reaction
- Remove AA after formation

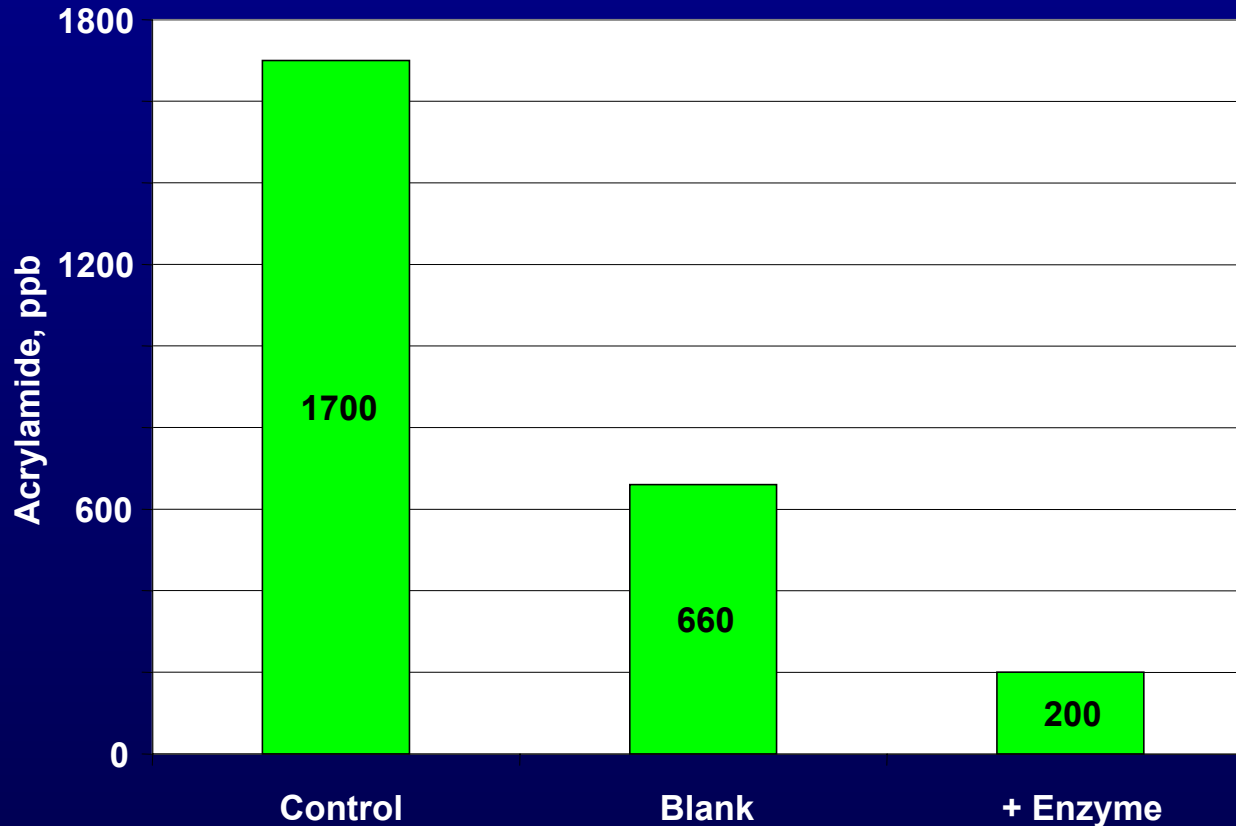
# Changes in Processing/Formulation

- Ingredients
- Processing conditions
- Equipment
- Definition of texturization and texture characteristics of food products with minimization of AA in mind

# Effects of asparaginase on AA formation in crusts of batard breads (in ppb)



# AA reduction with asparaginase in French fries



**Lab made French fries**

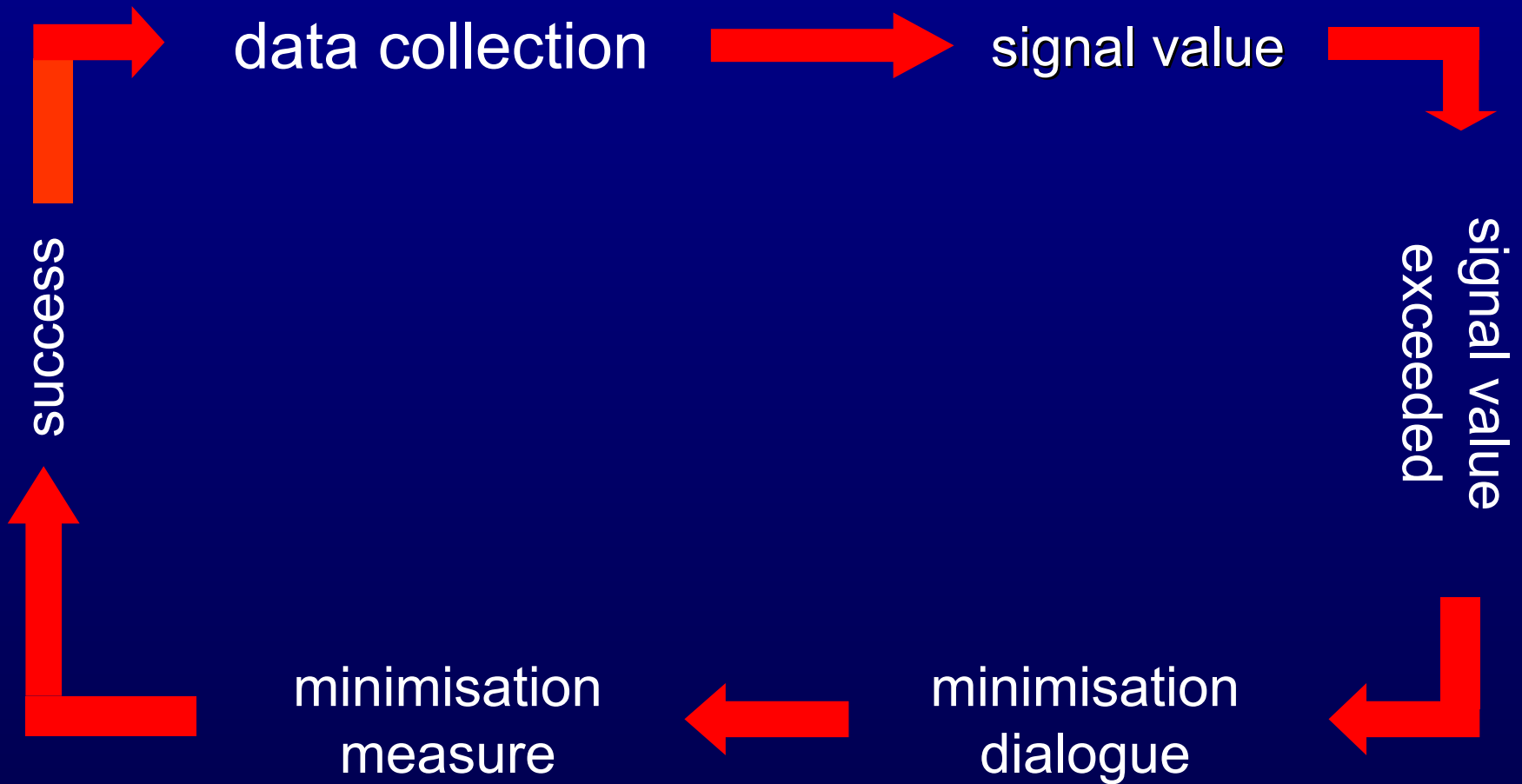
# AA Reduction in Cracker Products

- Wheat cracker and potato cracker
- Use of asparaginase reduced AA by at least 70% in both products.
- Replace ammonium hydrogen carbonate by sodium hydrogen carbonate (baking agent) and replace reducing sugars by sucrose - ~80% less AA in wheat cracker
- Decreasing free asparagine & reducing sugars in ingredients and a lower baking temperature ~50% reduction in potato cracker  
(Vass et al. 2004. Czech. J. Food Sci. 22:19-21)

# German Minimization Concept

- Data concerning foods tested are compiled to form food product groups
- In individual product groups, those products that count among the 10% of foods with the highest contamination are identified.
- The lowest level (amount) within this group in turn acts as a “signal level”
- At levels above 1,000  $\mu\text{g}/\text{kg}$  acrylamide, all products should, in principle, be included in the efforts

# Dynamic concept of minimization



# German Minimization Concept:

Signal Values ( $\mu\text{g}/\text{kg}$ )

<u>Product</u>	<u>9/02</u>	<u>1/03</u>	<u>11/03</u>	<u>11/04</u>
Cakes	800	660	575	575
Breakfast cereals	260	260	200	200
Coffee, roasted	370	370	370	370
Potato chips	1000	1000	1000	1000
Crisp bread	610	610	610	610
French fries (prepared)	770	570	570	440

(B. Matthäus, 5<sup>th</sup> Internat Symp Deep-Fat Frying, San Francisco, Feb. 05)

# The CIAA Acrylamide “Toolbox”

(CIAA, 23 Sept. 2005, [www.ciaa.be](http://www.ciaa.be))

- Results of three years of cooperative research and testing.
- Not meant as a prescriptive manual nor formal guidance.
- Brief descriptions of intervention steps evaluated.
- A “living document” with a catalogue of tested concepts at different trial stages.
- For individual manufacturers, including small and medium size enterprises. Can provide useful leads in catering, retail, restaurants and domestic cooking.
- A total of 13 additional parameters, grouped within four major Toolbox compartments.

















# The CIAA Acrylamide “Toolbox”

- Agronomical
  - Sugars
  - Asparagine
- Recipe
  - Ammonium bicarbonate
  - pH
  - Minor ingredients
  - Dilution
  - Rework

# The CIAA Acrylamide “Toolbox”

- Processing
  - Fermentation
  - Thermal input
  - Pre-treatment (e.g. washing, blanching, milling)
- Final preparation
  - Colour endpoint
  - Texture/Flavour
  - Storage/shelf-life/Consumer preparation

## Toolbox Compartment

Category	Agronomical	Recipe	Processing	Final Prep.
Potato Products	 Sugar	 	 Thermal input Pre-treatment	 Color endpoint
Bread/Biscuits/ Bakery Wares	 Asparagine	 $NH_4HCO_3$	 Fermentation Moisture	 Color endpoint
Breakfast Cereals	 Asparagine	 	 	 
Coffee	 	 	 Dark roasting	 Storage

 : Low or no impact  
  : High impact

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# Toxicology of AA

- Carcinogenic in animal (rodent) studies
- Classified by IARC as category 2A “Probably carcinogenic to humans”
- Metabolized to glycidamide; forms DNA adducts
- Genotoxic in a range of assays
- Acutely neurotoxic
- Three human cohort studies (1986, 1989, 1999)
  - No evidence of causal relationship between workplace exposure and cancer incidence.
  - One mention of nonsignificant increase in risk of pancreatic cancer.

# NTP CERHR Report

(Natl. Toxicol Pgm, Cntr for Eval of Risks to Human Reprod)

- Considering the low level of estimated exposure to AA derived from a variety of sources, the Panel expressed **negligible concern for adverse reproductive and developmental effects** for exposures in the general population.
- The Panel expressed **minimal concern for AA induced heritable effects** in the general population. Recognizes that dose-response information of these effects is limited.

# Human Epidemiological Studies

- 538 Controls; 987 large bowel, bladder and kidney cancer cases - Most “high-AA” foods included in questionnaire –  
**No positive association between dietary exposure and risks** (US & Sweden, Mucci et al., 2003)
- A group of coordinated case-control studies (hospital based) –  
**No positive association between intake of fried/baked potatoes and incidence of cancer of oral cavity, throat, larynx, large bowel, breast, ovary** (Pelucchi et al., Italy and Switzerland, 2003).
- Reanalyzed and confirmed (Pelucchi et al., 2005) –  
**No consistent association between intake of acrylamide and the risk of breast, oral cavity/pharynx, esophageal, colorectal, laryngeal, ovarian, and prostate cancer.**

# Human Epidemiological Studies

- Mucci (published in 2004)- re-analysed data from Swedish case-control study and **renal cell cancer** –  
**No increased risk due to AA intake.**
- A prospective study of 61,467 women in Swedish Mammography Cohort (1987-2003). Mucci et al (2005) –  
**No evidence that dietary intake of acrylamide associated with cancers of the colon or rectum.**
- Mucci et al (2005) intake of dietary AA among 43,404 Swedish –  
**No evidence of association between amount consumed and risk of breast cancer.**

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# JECFA Risk Assessment Approach

- Margin Of Exposure (MOE) = Margin of Safety
- MOE is ratio of the toxicity estimate (BMDL – benchmark dose lower confidence limit) generated from animal studies to estimated exposure.
- The higher the exposure, the lower MOE.
- MOE indicates the level of concern to assist risk managers in setting priorities for implementing measures to protect public health.

# MOE for AA (JECFA)

- Using national averages: Intake of acrylamide for general population = 1  $\mu\text{g}/\text{kg}$  bw/day; high consumers = 4  $\mu\text{g}/\text{kg}$  bw/day.
- BMDL for induction of mammary tumors in rats = 300  $\mu\text{g}/\text{kg}$  bw/day. Thus: MOE is 300 for general population and 75 for high consumers.
- For polycyclic aromatic hydrocarbons (PAHs) calculated MOEs were 25,000 for average and 10,000 for high intakes.

# JECFA Conclusions

- For PAHs (MOEs of 25,000 average, 10,000 high): JECFA concluded that the estimated intakes of PAHs from foods were of low concern for human health.
- For acrylamide (MOEs of 300 average, 75 high). JECFA considered these margins to be low for a substance that causes cancer in animals.
- JECFA considered that these MOEs for AA in food may indicate a human health concern, i.e., the intake of AA from certain foods may be a human health concern.

# JECFA Recommendations

- Re-evaluate AA when results of ongoing carcinogenicity and long-term neurotoxicity studies become available.
- Continue appropriate efforts to reduce AA concentrations in food.
- Occurrence data on AA in foods as consumed in developing countries would be useful.

# JECFA Comments on Reduction of Risk

- National food safety authorities should urge relevant food industries to work towards improving food preparation technologies that lower significantly the AA content in critical foods (French fries, potato chips, coffee, pastries, sweet cookies, breads, rolls, toasts).

# JECFA Comments on Reduction of Risk

- National food safety authorities should encourage industry and researchers to communicate the data obtained and the techniques/ technologies developed in an open and transparent manner enabling use by other producers and consumers.

# JECFA Comments on Reduction of Risk

- National authorities should develop guidance directed at lowering AA content in home-cooked foods and reducing intake of foods high in AA as part of nutritional guidance for an overall healthy diet.
- Messages should be communicated in a simple manner, combined with suggestions on how to lower or prevent other unwanted substances formed during home-cooking

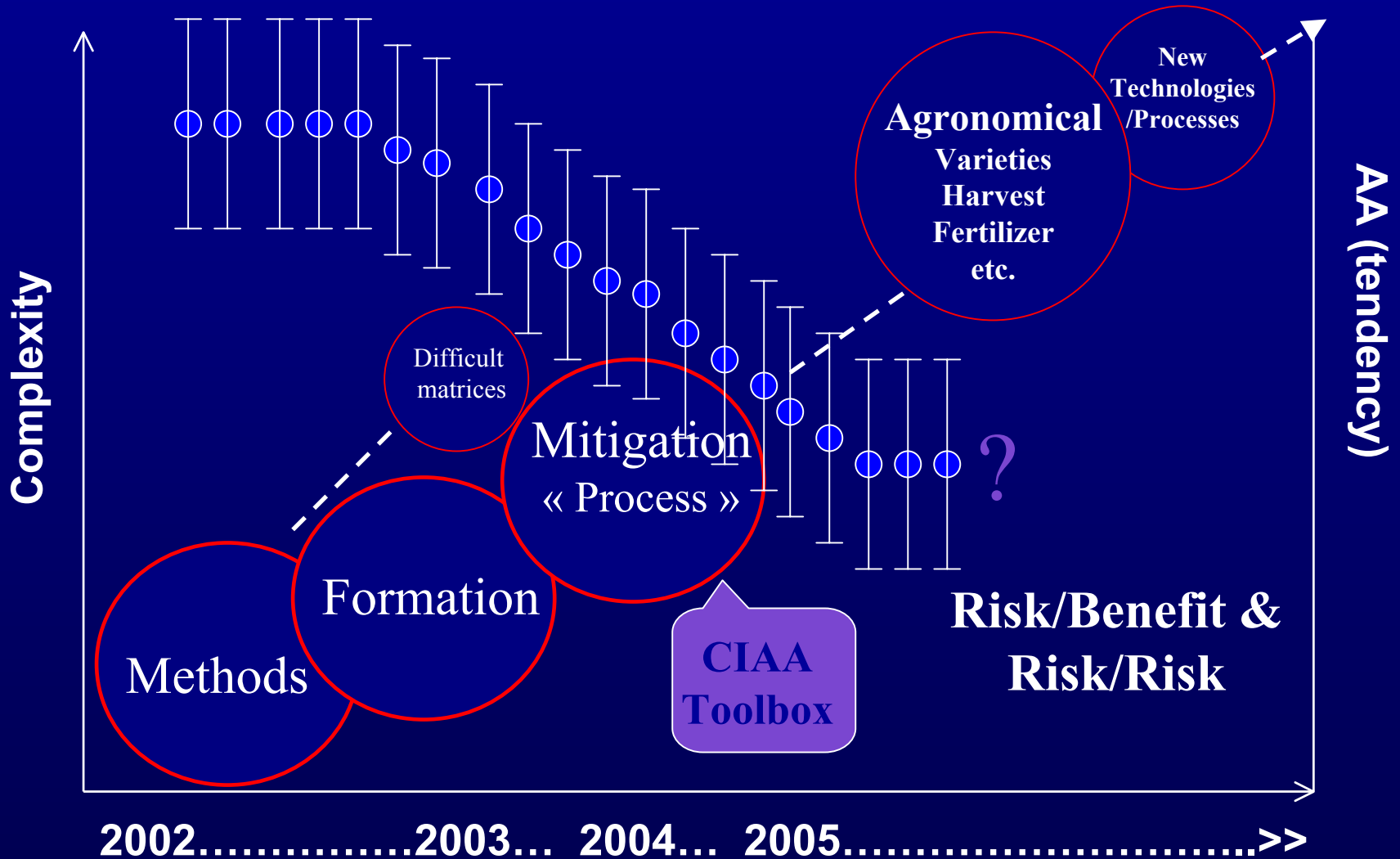
# JECFA Comments on Reduction of Risk

- Authorities and industries should ensure that methods (methodologies) used to reduce AA in food do not increase or introduce microbiological and chemical hazards.  
(Noted time-temperature provisions and pathogens)
- The latest information available on AA reinforces general advice on healthy eating.  
(National authorities should continue such advice)

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# Roadmap (via R. Stadler)



ppm

# Comments

- The notion of “carcinogens” in food is not new (e.g., cooked meat). Humans have eaten these foods for millennia.
- Food safety = balancing desirable and undesirable attributes with emphasis on a positive balance toward desirable attributes and safety.
- Scientific uncertainty now that AA in foods presents a health risk.
- The JECFA risk assessment raises a concern (a “flag”) - to be further addressed.

# Comments

- Significant progress has been made.
- Unprecedented cooperation of all stakeholders.
- Industry commitment to investigate all possible avenues for reduction.
- Maintain current momentum in the research and proactive exchange through established channels.