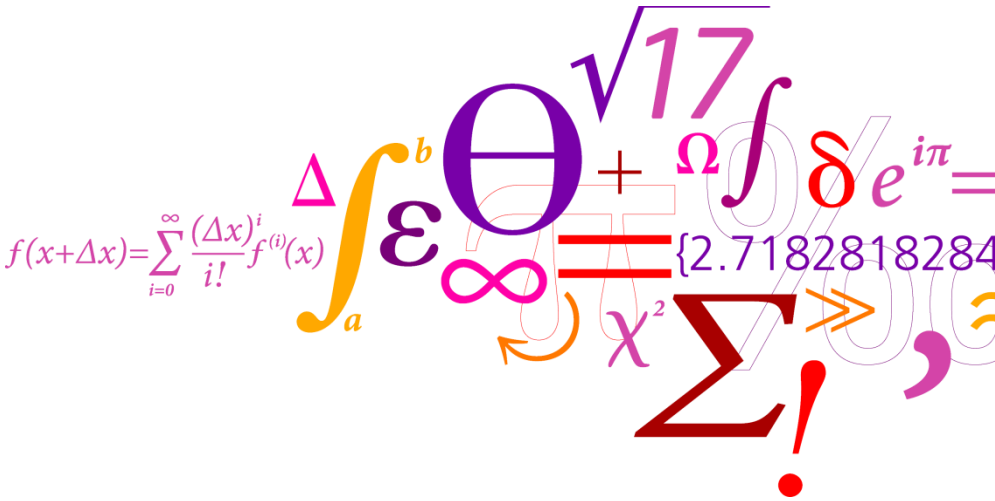
Risk assessment: arsenic

Max Hansen
Senior Advisor
National Food Institute
Technical University of Denmark

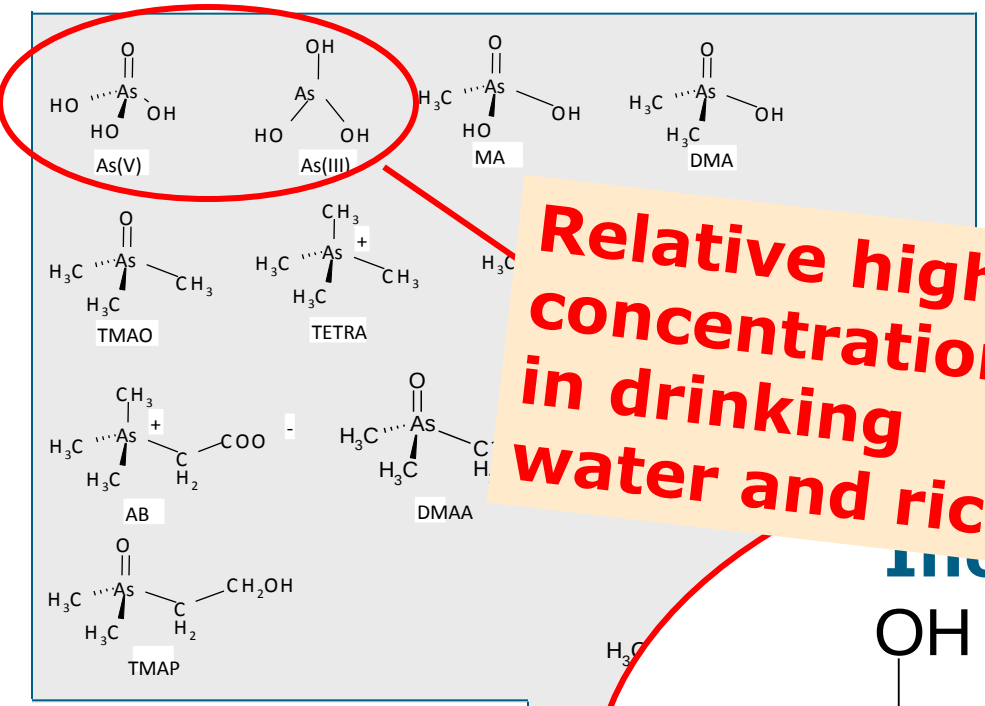


DTU Food
National Food Institute

Agenda

- Arsenic species in food and there toxicity
- Chemical analysis of arsenic
- Danish analysis of inorganic arsenic in rice and rice products
- Implication on regulation
- Analysis and risk assessment/risk management in other countries
- conclusions

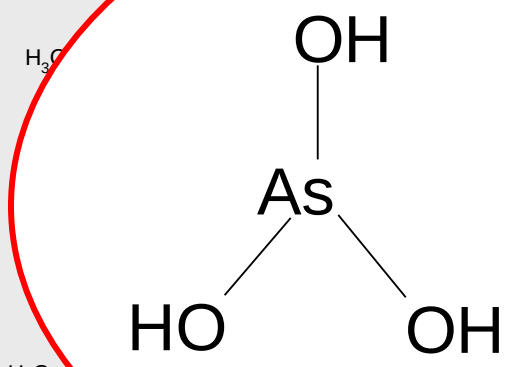
Arsenic compounds in food

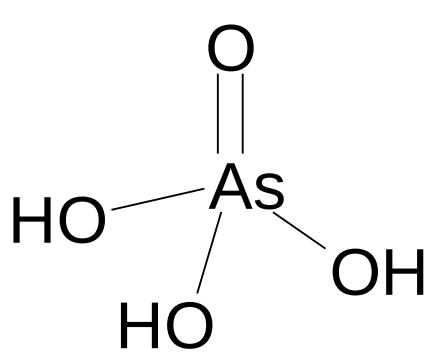


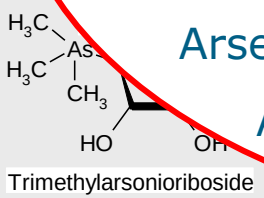
Relative high concentrations in drinking water and rice

High toxicity

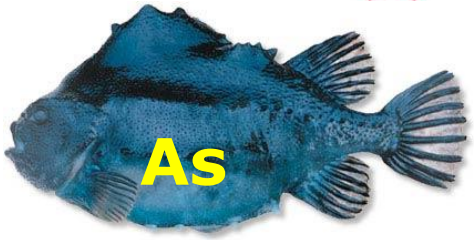
Inorganic arsenic







Arsenic compounds in food



As(V)

As(III)

MA

DMA

TMAO

TETRA

AB

TMAP

Organoarsenic compounds

Methylated species

Very low toxicity

Probably low toxicity

Arsenobetaine

Arsenocholine

Predominant form of arsenic in most seafood and fish

Trimethylarsoniopropionic acid

TMAP

Trimethylarsonioriboside

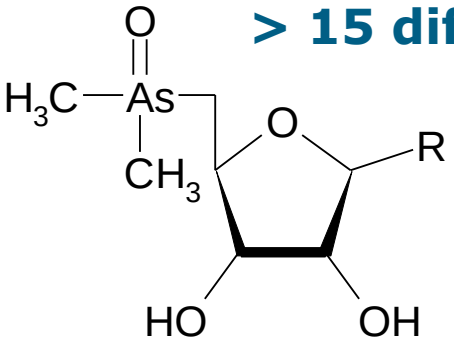
(8)

Arsenic compounds in food

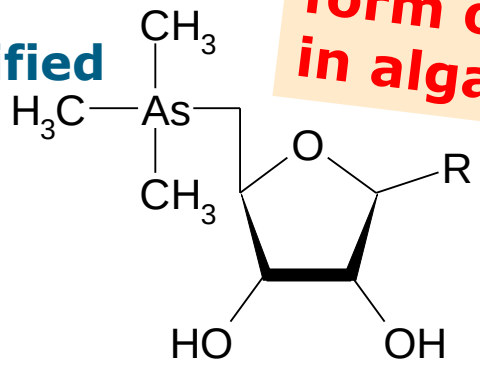
Probably low toxicity

rsenosugars

> 15 different identified

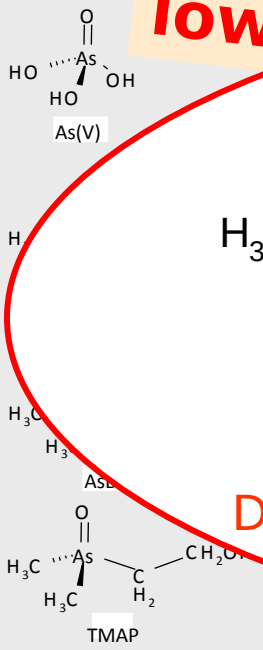


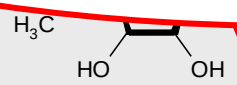
Dimethylarsinoylribosides



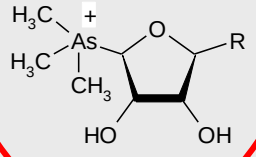
Trimethylarsonioribosides

Predominant form of arsenic in algae



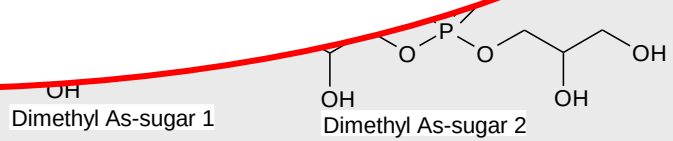


Dimethylarsinoylriboside



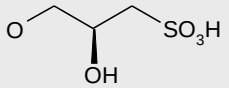
Trimethylarsonioriboside

R = 1,2,3,4,5

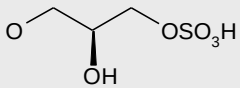


Dimethyl As-sugar 1

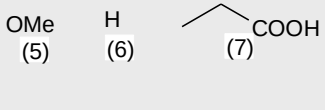
Dimethyl As-sugar 2

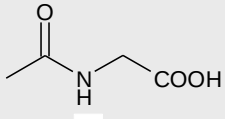


Dimethyl As-sugar 3



Dimethyl As-sugar 4





Arsenic compounds in food

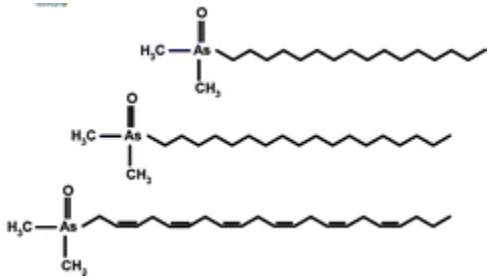
Probably low toxicity

Identified in fish

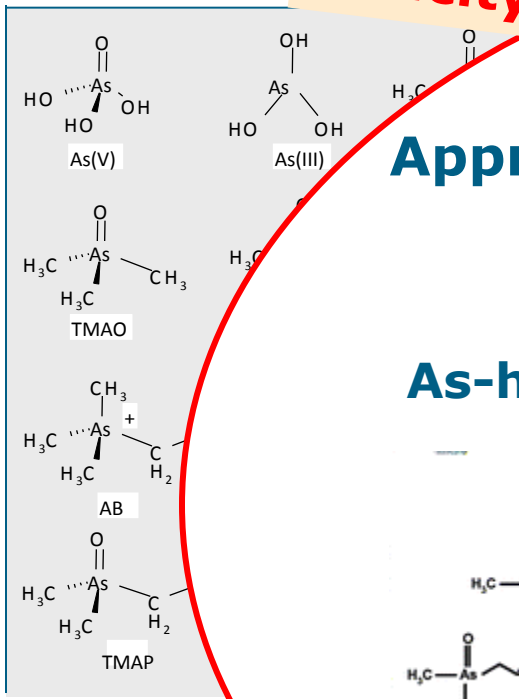
Arsenolipids

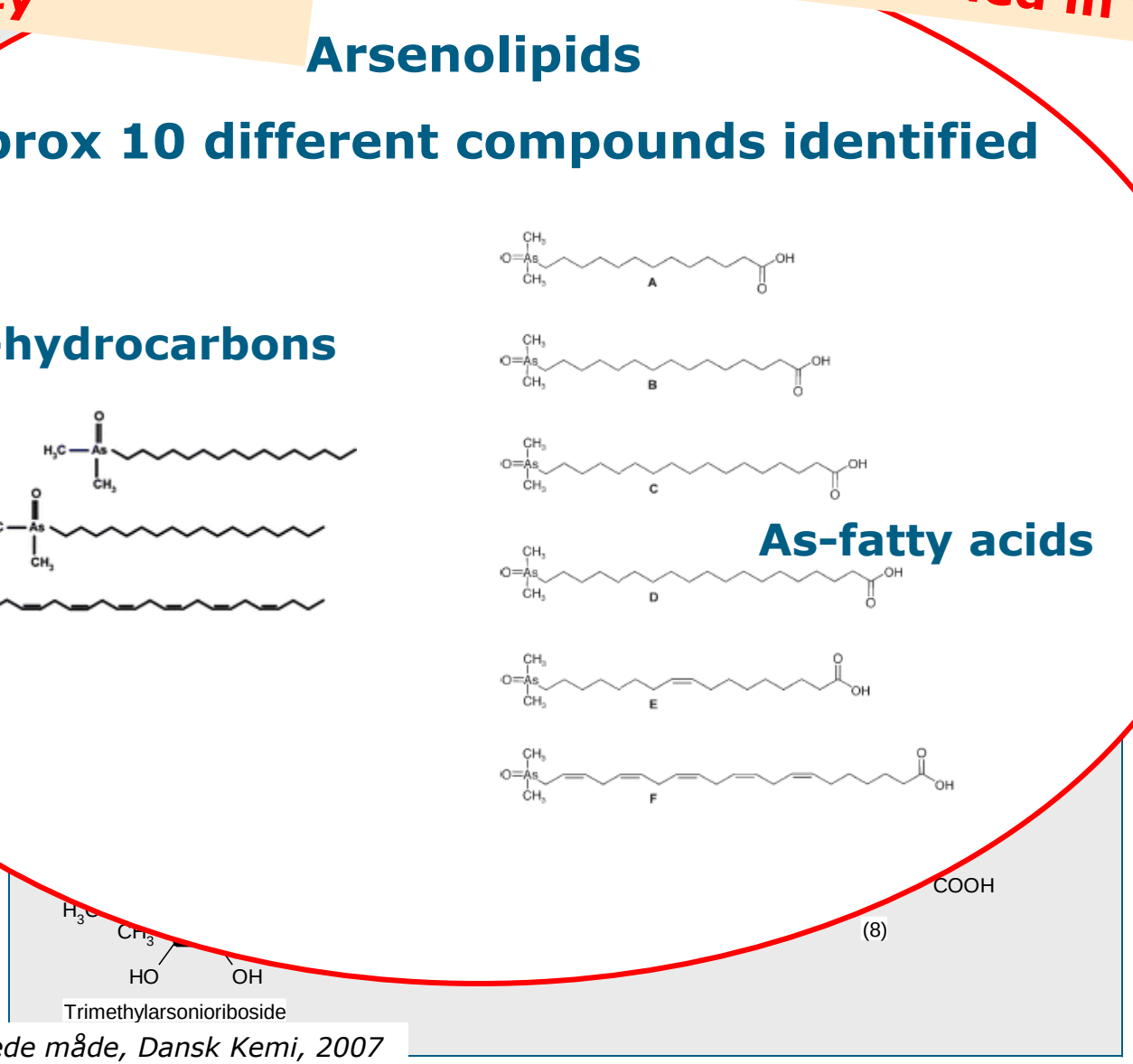
Approx 10 different compounds identified

As-hydrocarbons



As-fatty acids





Sloth et al, Arsen – på den fede måde, Dansk Kemi, 2007

Arsenic compounds in foodstuffs

Plants: May contain high concentrations of inorganic arsenic. In rice 30 – 70 % of total arsenic as inorganic arsenic. Organic compounds like monomethylarsonic acid (MA) and dimethylarsinic acid (DMA) in lower concentrations.

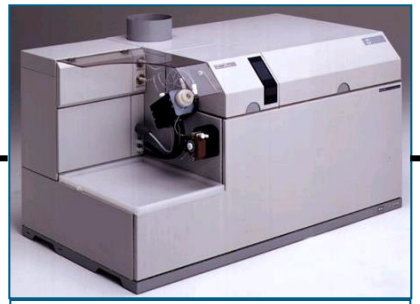
Fish muscle: > 90% af total arsenic is arsenobetaine (AB) + other organoarsnic compounds (DMA, TMAP, TETRA, TMAO, AC). Fatsoluble arsenolipids can contribute up to 30 % in fatty fish. Inorganic arsenic is < 0,1 mg/kg in fish.

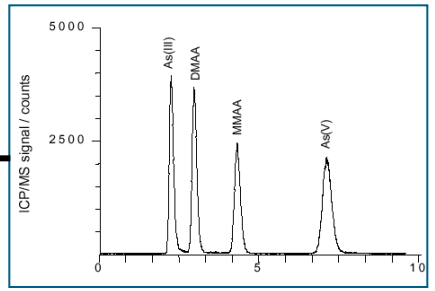
Shellfish: Primarily AB + sometime arsenic sugars (from seaweed) + DMA and other organoarsenic compounds. Shrimps can have low concentrations of inorganic arsenic despite high concentrations of total arsenic.

Seaweed: Primarily arsenosugars (> 15 different compounds) + other organoAs compounds. Inorganic arsenic is normally low but can be very high (>50 mg/kg) in few species (Saragassum typer, e.g. Hijiki).

Analysis of arsenic: HPLC-ICPMS

Analysis for total arsenic is not relevant in risk assessment!!!





HPLC

Sample introduction

Column

Separation

ICPMS

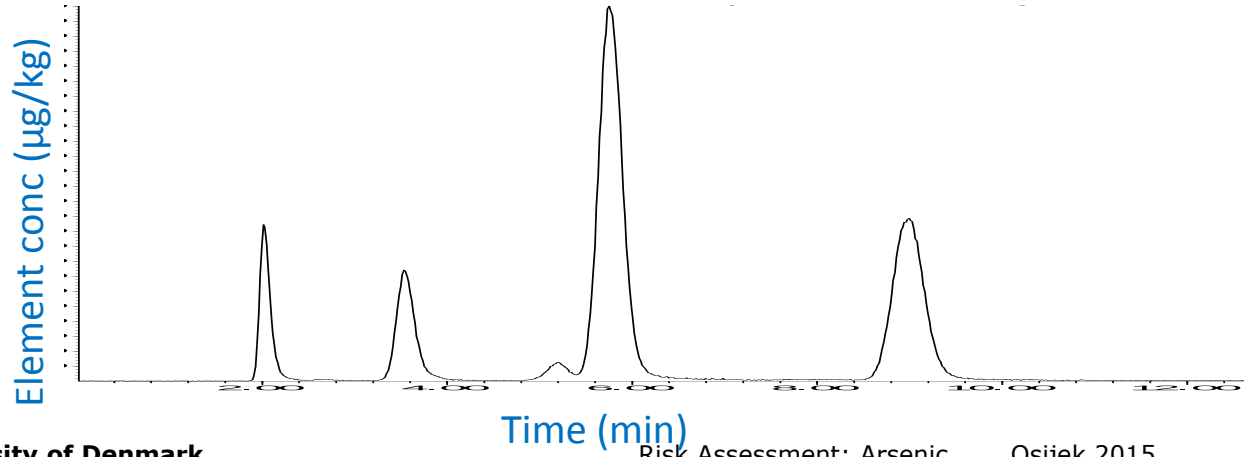
Element specific detection

Result

Chromatogram

Output:

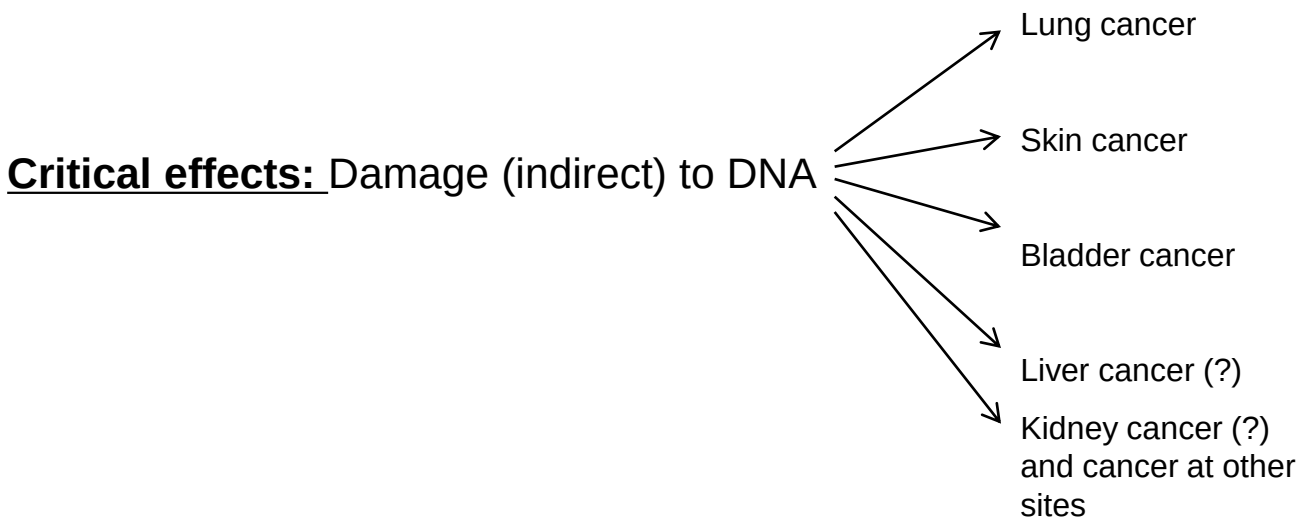
Arsenic specific chromatogram



CEN method for iAs in food

- Project expected to start in 2012; projectleader DTU Food in Denmark
- Selective determination of **iAs in foodstuffs of marine and plant origin**
- Method based on extraction with dilute acid and determination of **iAs by HPLC-ICPMS** (anion-exchange chromatography)
- Method concept will be discussed in the CEN expert group CEN TC275/WG10 on trace elements and their species (Secretariat at DIN, Germany)
- trial in 2013
- Technical approval by end of 2013
- Formal approval by EU MS in 2014
- Final European standard published in 2015

Toxicity of inorganic arsenic



IARC (WHO) (2004): Group 1 carcinogenic to humans.

Sufficient evidence of carcinogenicity in humans.

Toxicity of inorganic arsenic

EFSA (2009): $BMDL_{01}$ 0.3 - 8 µg/kg bw/day (lowest value for lung cancer)
$BMDL_{01}$ is the dose which will increase the **lifetime** incidence of cancer with 1% (some uncertainties has been included in the value)
The $BMDL_{01}$ is based on human epidemiological studies on drinking water

$BMDL_{01}$ cannot be considered as a health based intake threshold!!

JECFA (FAO/WHO) (2010): $BMDL_{0.5}$ 3.0 – 5.0 µg/kg bw/day (lung cancer, average **11.5 year** follow up)
Based on the same study as EFSA but corrected for intake from other sources than drinking water.

Danish investigations

3 studies have been performed:

1. Total and inorganic arsenic in rice
2. Total and inorganic arsenic in rice cakes
3. Total and inorganic arsenic in rice based babyfood

Inorganic arsenic in rice

A total of 65 samples of ordinary white rice, paraboiled rice and rice for rice pudding and 19 samples of brown rice

Inorganic arsenic content:

White rice: 89 ± 37 µg/kg

Brown rice: 189 ± 100 µg/kg

Difference between white and brown rice were stastistical significant

No difference between different types of white rice and no difference between rice from different countries

Consumption of rice

Age Years	Body weight kg	Rice for pudding			Rice in convenience food		Boiled rice		
		Mean consumption (ready to eat) Grams	Mean consumtion dryweight g/kg bw/day	95 percentil dry weight g/kg bw/day	Mean consumption (ready to eat) Grams	95 percentil dry weitht g/kg bw/day	Mean consumption (ready to eat) grams	Mean consumtion dryweight g/kg bw/day	95 percentil dry weitht g/kg bw/day
4 – 75	60	6	0.033	0.22	1	-	15	0.083	0.350
4 – 6	19	9	0.16	0.099	0	-	11	0.061	0.233
7 - 11	29	8	0.091	0.065	1	-	16	0.089	0.339
12 - 17	45	6	0.044	0.027	1	-	20	0.111	0.456
15-18	53.5	5	0.031	0.023	0	-	19	0.106	0.439
19-24	60	2	0.011	0.013	2	-	14		0.350
25-34	60	6	0.033	0.022	1	-	19	0.078	0.372
35-44	60	7	0.039	0.022	1	-	20	0.106	0.417
45-54	60	5	0.028	0.018	1	-	16	0.111	0.350
55-64	60	6	0.033	0.021	0	-	10	0.089	0.278
65-75	60	9	0.05	0.031	0	-	8	0.056	0.222

Intake of inorganic arsenic from rice

Age Years	Body weight kg	Rice for rice pudding		Boiled rice*	
		Mean intake of inorganic arsenic µg/kg bw/day	95 percentile intake of inorganic arsenic µg/kg bw/day	Mean intake of inorganic arsenic µg/kg bw/day	95 percentile intake of inorganic arsenic µg/kg bw/day
4 – 75	60	0.0033	0.022	0.008	0.035
4 – 6	19	0.0159	0.099	0.019	0.073
7 - 11	29	0.0090	0.065	0.018	0.069
12 - 17	45	0.0044	0.027	0.015	0.060
15-18	53.5	0.0031	0.023	0.012	0.049
19-24	60	0.0011	0.013	0.008	0.035
25-34	60	0.0033	0.022	0.011	0.037
35-44	60	0.0039	0.022	0.011	0.042
45-54	60	0.0028	0.018	0.009	0.035
55-64	60	0.0033	0.021	0.006	0.028
65-75	60	0.0050	0.031	0.004	0.022

*Based on information from retailers it was assumed that 10% were brown rice

Intake of inorganic arsenic from rice for small children

Age	Body weight	Consumption white rice	Consumption brown rice	Total rice consumption	Arsenic intake mean	Total rice consumption (95 percentile)	Arsenic intake (95 percentile)
Month		g	g	g/kg bw	µg/kg bw	g	µg/kg bw
5.3 – 8.0	8.49	8.97	1.26	1.19	0.041	46.84	0.19
8.0 - 10.0	9.25	5.43	1.35	0.69	0.027	52.12	0.20
10.0 - 12.0	9.82	4.53	1.19	0.53	0.021	49.82	0.19
12.0 - 24.0	11.34	4.93	1.18	0.48	0.019	48.35	0.15
24.0 - 37.0	13.82	3.74	1.05	0.3	0.013	29.44	0.08

Estimation of risk from intake inorganic arsenic from rice

Calculated $BMDL_{01}$ by EFSA: 0.3 – 8 µg/kg bw

EFSA did not suggest a margin of exposure

Mean intake from rice 0.01 µg/kg bw 95 percentile about 0.04 µg/kg bw

Small children may have mean intake of inorganic arsenic 0.04 µg/kg bw and 95 percentile at 0.2 µg/kg bw

Minor concern for normal rice eaters but some concern for high consumers specially small children

Investigation of rice crackers

19 rice crackers of different brands were analysed:

The concentration of inorganic arsenic was 320 ± 80 µg/kg

Age	Body weight	Consumption Mean	Consumption 95 percentile	Consumption Maximum	Arsenic intake mean	Arsenic intake 95 percentile	Arsenic intake maximum
	g	g	g	g	µg/kg bw	µg/kg bw	µg/kg bw
5.3 – 8.0	8.49	0.14	0.48	11.43	0.01	0.02	0.43
8.0 - 10.0	9.25	0.50	2.86	8.57	0.02	0.10	0.30
10.0 - 12.0	9.82	0.69	4.29	11.82	0.02	0.14	0.39
12.0 - 24.0	11.34	0.87	5.00	8.93	0.02	0.14	0.25
24.0 - 37.0	13.82	0.83	4.86	11.67	0.02	0.11	0.27

Low risk with mean consumption but with the maximum consumption an intake of arsenic at ½ the lower value of the EFSA BMDLo1

Investigation of rice based baby food

Risk assessment performed without specific measurement of inorganic arsenic in the rice. Give the best quantitative estimation

Assumptions:

Mean concentration of inorganic arsenic 110 µg/kg based on the data from the rice study

Consumption of 30 g rice from rice based baby food per day for 1 month

Weight of the baby is set to 9 kg

0.3 µg/kg bw/day is used as $bmdl_{01}$ for development of lung cancer

lineary dose response relationship and no thresshold for the effect

Based on these assumption it was calculated that the intake would give 12 extra lung cancer cases per million persons

Concluions

Minor health concern for adults with a moderate consumption of rice

Some health concern for children with a high consumption of rice (95 percentile)

Minor health concern for children with a mean consumption of rice crackers

Some health concern for children with a high consumption of rice cracckers

Some health concern for children with a high consumption of baby food over a shorter time span

Acknowledgement

Jens Jørgen Sloth
Sisse Fagt
Dorthe Licht Cederberg
Birgitte Herbst