Rapport 16 – 2013

Trends in Cadmium and Certain Other Metal in Swedish Household Wheat and Rye Flours 1983-2009

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Content

Summary

Wheat flour (sifted), biodynamic wheat flour, wheat bran, and rye flour for household use, have been analysed annually in Sweden for 27 consecutive years 1983-2009. The primary aim of the study was to follow the cadmium content over time in order to detect eventual changes. In addition to Cd, the metals Co, Cr, Cu, Fe, Mn, Ni, Pb, and Zn were also determined. All determinations were made by atomic absorption spectrophotometry with background correction after dry ashing at 450°C. A strict analytical quality control programme was applied throughout the monitoring. The results for Cd in wheat flour, biodynamic wheat flour, wheat bran and rye flour showed no significant change in concentration ($p > 0.05$) over the studied time period. In wheat flour the levels of Cu, Mn and Zn increased significantly over time, whereas in biodynamic wheat flour and wheat bran Fe and Mn showed a decrease ($p < 0.05$). In rye flour the levels of Cu, Fe, Mn, Ni and Zn all decreased significantly over time. The levels of Co, Cr and Pb were generally below the limit of detection, i.e. too low to allow time trend analysis. The mean for Cd in wheat flour was 0.026 mg/kg (range 0.013-0.074, n=144), for biodynamic wheat flour 0.029 mg/kg (range 0.017-0.042, n=23), for wheat bran 0.12 mg/kg (range 0.049-0.25, n=54), and rye flour 0.016 mg/kg (range 0.003-0.044, n=144).The mean for Pb in wheat flour (including biodynamic) over the studied period was <0.013 mg/kg, for wheat bran 0.029 mg/kg (range <0.018-0.12), and rye flour <0.013 mg/kg. The results of the other elements are described in the text and the tables in the report.

Sammanfattning

Mellan 1983 och 2009 undersökte Livsmedelsverket halterna av ett antal metaller i vetemjöl, biodynamiskt vetemjöl, vetekli och rågmjöl avsedda för hushållsbruk. Det främsta syftet var att följa utvecklingen av kadmiuminnehåll för att upptäcka eventuella förändringar över tid. Men även ett antal andra metaller, kobolt (Co), krom (Cr), koppar, (Cu), järn (Fe), mangan (Mn), nickel (Ni), bly (Pb) och zink (Zn), kom att ingå i undersökningen. Alla analyser har gjorts med atomabsorptionsspektrometri med bakgrundskorrektion efter torraskning av proverna vid 450°C. Under undersökningens gång har ett omfattande kvalitetskontrollprogram för analyserna tillämpats. Resultaten för Cd i vetemjöl, biodynamiskt vetemjöl, vetekli och rågmjöl visade ingen signifikant förändring (p>0,05) över tid. I vetemjöl ökade halterna av Cu, Mn och Zn signifikant över tid (p<0,05). I biodynamiskt vetemjöl och i vetekli sjönk halterna av Fe och Mn signifikant. I rågmjöl sjönk halterna av Cu, Fe, Mn, Ni and Zn signifikant över tid. Halterna av Co, Cr och Pb låg generellt under detektionsgränsen, varför ingen tidstrendsanalys kunde göras för dessa metaller. Medelvärdet för Cd i vetemjöl var 0,026 mg/kg (spridning 0,013-0.074, n=144), biodynamiskt vetemjöl 0,029 mg/kg (spridning 0,017-0,042, n=23), vete-kli 0,12 mg/kg (spridning 0,049-0,25, n=54) och i rågmjöl 0,016 mg/kg (spridning 0,003-0,044, n=144). Medelvärdet för Pb i vetemjöl (inklusive biodynamiskt) var <0,013 mg/kg, vetekli 0,029 mg/kg (spridning <0,018-0,12) och i rågmjöl <0,013 mg/kg. Resultaten för övriga metaller beskrivs i rapportens text och tabeller.

Introduction

Cadmium (Cd) is a naturally occurring metal in the environment, including arable soil, and the concentration level can vary considerably between areas depending on the geological conditions. The Cd-level in soil can be increased by, e.g., aerial deposition, Cd-containing phosphate fertilisers and by the use of sewage sludge. It is well established that Cd has adverse health effects, with kidney damage as the primary effect. At higher exposure levels Cd can also cause bone demineralization. Cadmium is also considered carcinogenic to humans [IARC], and furthermore it is suspected of having hormone mimicking properties [Åkesson et al. 2008].

For the non-smoking part of the population, food is the major source of Cd, and wheat (*Triticum aestivum* L.), one of the most consumed foodstuffs in Sweden, is a main contributor. The European Food Safety Authority (EFSA) recently revised, and lowered, the tolerable weekly intake (TWI) from 7 to 2.5 ug/kg body weight in order to ensure a high level of protection of all consumers [EFSA 2009]. Adults in Sweden have an estimated median Cd-intake of approximately 1 µg/kg body weight/week [Sand and Becker 2012], based on data from the Swedish Riksmaten food consumption survey (1997-98). An estimation by EFSA of the Swedish intake of Cd arrived at a median intake (based on occurrence data from different member states) of 1.7 µg/kg body weight [EFSA 2009]. A recent Belgian survey of the intake of Cd in several European countries [Vromman et al. 2010] show an intake level ranging from 0.98-2.33 µg/kg body weight/week. There is thus virtually no margin between the average Cd-intake and the level where harmful effects of Cd may begin to be observed.

It is generally the foods that are consumed in large quantities that have an impact on the dietary exposure, rather than the foodstuffs with the highest levels. It is estimated that 27 per cent of the Cd intake is due to grains and grain products, and at a more detailed level wheat bread and rolls contribute 6.4 per cent [EFSA 2012].

There have been indications that the Cd-level in Swedish arable soil have increased. Two studies [Kjellström et al. 1975. Andersson and Bingefors,1985] on the level of Cd in wheat grain from the same area near Uppsala, Sweden, covering the period 1916–1980 showed that the Cd concentration had increased significantly ($p \leq 0.01$). In calculations from 1992 it was estimated that the Cd-level in arable soil had increased with more than 30 per cent during the 20^{th} century [Andersson 1992]. The main reason for this increase of Cd in the soil is thought to be the extensive use of phosphate fertilizers, which, depending on the source, may contain considerable amounts of Cd.

In 1993 the sale of mineral fertilisers with a Cd-content of more than 100 mg/kg P was prohibited in Sweden. During the period 1995-2010 a progressive tax, which increased with the Cd-content, was imposed on fertilisers with a Cd-content over 5 mg/kg P [KemI 2011]. It is assumed that this has contributed to the extensive use of mineral fertilisers with a low Cd-content.

In a survey of trace elements in Swedish wheat grain sampled between 1967 and 2003 it was found that the Cd-level, after reaching a peak during the 1970-ies have decreased from approximately 0.08 to 0.04 mg/kg. It was assumed that this reduction was mainly due to the use of phosphate fertilizers with low Cd-levels, but that a large decrease in atmospheric deposition of Cd has also played a role [Kirchmann et al. 2009].

Cadmium in food and the diet has been on the agenda at the National Food Agency (NFA) since its establishment in 1972, and wheat has always attracted a large interest. In 1983 it was decided to start a programme to monitor the level in household wheat flour (sifted) from the major producers in order to detect if any change (increase) would occur. Wheat bran, biodynamic wheat flour and rye flour were also included in the programme. In parallel to Cd, a gradually increasing number of other metals were also analysed, and in 1987 the study comprised Cobalt (Co), Chromium (Cr), Copper (Cu), Iron (Fe), Manganese (Mn), Nickel (Ni), Lead (Pb) and Zinc (Zn).

In a separate project in 1985, household wheat flour from 24 Swedish mills (48 samples) were analysed for their content of Cd, Pb, Zn, Cu, Fe and Mn [Andersson et al. 1987]. These results give a broader geographical coverage and comprise a good complement to the results presented here.

In 2001 the results from 1983 to 1997 on Cd and other metals in wheat and rye flour for household use were published [Jorhem et al. 2001]. The results for wheat indicated an increase in the Cd-level during the 1st half and a decrease during the 2nd half of the study. The levels of Co, Cr, Ni (in wheat flour) and Pb were generally too low for a statistical evaluation. In wheat flour Cu, Mn and Zn increased significantly, whereas in wheat bran only Zn showed a significant increase. In rye flour Fe, Mn and Zn decreased significantly during the period. That study is now complemented with results from 1998 to 2009. This means that this report presents an unbroken series of analytical data for 27 consecutive years for a number of metals in flour.

In general, mills use regionally produced grain for their products. But there is a certain mobility of grain between regions, e.g., when there is regional shortage. In years when the shortage is severe, it may also be necessary to complement with imported grain. After 1997 the milling industry has gone through considerable changes, which includes the closing down of mills and shifting, and centralizing production to fewer, and larger, production sites. A result of this is that household flour has become not just regionally but more widely distributed, which makes it very difficult to trace their origin. Put together, the mobility of both grain and flour on the market has made it virtually impossible to maintain the sampling strategy which was followed up to 2000. The two producers providing household flour to this study were, at the time of the previous publication, covering the years 1983-1997 estimated to have a market share of circa 85 per cent. The one producer remaining after 2000 estimates its current market share to 45-50 per cent.

In 2008 a report from the NFA discussed the likelihood of a decrease in the nutritional content of plant food available on the market [Mattisson et al. 2008]. The report was initiated by debates in the public media. The results from this study may provide significant metal data regarding this issue.

Over the years the requirements for analytical quality assurance, as well as analytical quality control, has gradually increased. Today the analytical method used in this study is accredited, certified reference materials are analysed regularly and participation in relevant proficiency testing programmes are more or less mandatory. This means that a strictly enforced analytical quality control programme today is in place. Since the method used has remained unchanged during the whole study period (1983-2009) it can be assumed that results for the whole study period are comparable.

Experimental

Sampling

Samples have been collected both in retail shops and mills. Wheat and rye flour: From 1983 to 2000 two samples in packages of 1-2 kg each were collected annually from retail shops in Gothenburg, Malmö and Uppsala. From 2001-2009 four wheat samples were collected annually from the mills in Malmö and Uppsala. From 2001-2009 four rye samples were collected annually from the mill in Malmö (from different batches). Biodynamic wheat flour: One sample was collected annually from a mill in the Lake Mälaren region. This mill receives wheat from contracted producers in the middle and southern parts of Sweden. Contracted producers may change over time.

Wheat bran: Two samples of 0.5 kg each were collected annually from Uppsala and Malmö up to the year 2000. From 2001 to 2009 both samples were collected from the Malmö mill. The wheat bran is divided into two types; Wheat bran, for which the product specification states an ash content between 3.75-5.25 per cent, and Kruska wheat bran, with a specified ash content between 5.50-7.00 per cent.

Analytical Method

The samples were analysed by atomic absorption spectrophotometry (AAS) after dry-ashing in platinum crucibles at 450° C, and dissolution of the ash in 0.1 MHNO_3 [Jorhem 2000]. The metals Cd, Co, Cr, Ni, and Pb were determined by graphite furnace AAS, using the method of standard addition. Copper, Fe, Mn and Zn were determined by flame – AAS. All determinations were made with background correction. Analytical (chemical) blank determinations were made regularly together with the samples. The average concentration of a large number of blanks (>20) was deducted from the recorded result before the metal level was calculated. Matrix modifiers were not used. The moisture content was determined on separate samples by oven drying at 80°C to constant weight. The ash content was determined after ashing at 450°C.

Analytical quality control

Duplicate analysis was regularly performed for control of repeatability standard deviation. Two different reference materials were analyzed together with the samples:

1) An in-house reference material (IRM) consisting of whole-meal wheat flour. This is primarily used for long term control of the analytical process.

2) A certified reference material (CRM), Wheat Flour No. 1567 and 1567a, from the National Institute for Standards and Technology (NIST), USA[1]. Since 1998 the laboratory has regularly participated in proficiency tests (PT). It was not, however, possible to find PTs that covered all the metals in this study.

The standard deviation (SD) for the mean of the blanks was used to calculate the limit of detection (LOD), which is defined as 3 times the SD for the mean blank. The LOD is presented when relevant, i.e., when results are close to, or below the LOD.

The measurement uncertainty (u) for the different metals is the combined sum of the uncertainties of the precision (SD) and the trueness (bias) estimated during the method validation. The expanded measurement uncertainty (U) is then estimated by multiplying u with a coverage factor of 2, which corresponds to a confidence level of 95 per cent. The results are presented in table 1.

Table 1. The relative expanded measurement uncertainty (U%) range for the concentration range (mg/kg) of the different metals encountered in this survey.

Metal	**Concentration range**	**U%**
Cd	0.013-0.25	26-22
Cu	1.2-16	35-7
Fe	7.5-176	13-8
Mn	3.8-132	8-5
Ni	0.04-1.3	59-35
Pb	0.02-0.12	74-25
Zn	5.1-104	4-4

[1]NIST uses the trademark Standard Reference Material (SRM) for CRMs.

Results

Results of the analytical quality control

The analytical results
The results from the analysis of CRMs, and participation in PTs, indicate that the analytical results found in this study are reliable (allowing for measurement uncertainty) see Tables 2 & 3. Certain metals, e.g. Cr and Ni, are difficult to analyse at the low concentrations found in cereals, primarily due to contamination which is seen in the blanks. This leads to high LODs. Other metals, e.g. Cd and Co are less affected by contamination which consequently leads to lower LODs.

Estimation of time-trends
In order to enable comparison between the whole-meal flour IRM and the CRM wheat flour 1567 and 1567a, the results were recalculated as percent recovery. Linear regression analysis (at $p<0.05$) of the combined recoveries indicated a significant time change only for Zn (increasing). This significance is an effect of the very small variations in the recoveries and has no major effect on the analytic-cal results.

The CRMs 1567 and 1567a, wheat flour were evaluated using the zeta-score [NMKL Procedure No. 9]. The results were satisfactory with zeta-scores $|\zeta| \leq 2$. See Table 2.

The PT-results, covering various vegetable foodstuffs and concentration levels, had z-scores in the range -1.5 to +1.6. A z-score within the range ±2 is considered acceptable. See Table 3.

Table 2. Results from CRM NIST 1567 (1983-1989) and 1567a (1990-2009) wheat flour (mg/kg dry weight).

Metal	Year	n	Found mean	SD	Certified level	95% CI	Zeta-score
Cd	1983-1989	5	0.033	0.005	0.032	0.007	0.1
	1990-2009	20	0.026	0.005	0.026	0.002	0.0
Co	1990-2009	18	0.014	0.004	(0.006)[1]		
Cu	1983-1989	5	2.9	0.9	2.0	0.3	1.0
	1990-2009	20	2.0	0.5	2.1	0.2	-0.2
Fe	1983-1989	5	16.8	2.7	18.3	1.0	-0.6
	1990-2009	20	14.4	2.1	14.1	0.5	0.1
Mn	1983-1989	5	8.7	0.7	8.5	0.5	0.2
	1990-2009	20	9.8	0.5	9.4	0.9	0.6
Ni	1983-1989	3	0.10	0.03	(0.18)[1]		
Pb	1990-2009	20	0.015	0.005	(<0.020)[1]		
Zn	1983-1989	5	10.1	1.1	10.6	1.0	-0.4
	1990-2009	20	11.8	0.5	11.6	0.4	0.4

[1] The levels in brackets are indicative, not certified.

Table 3. Results from participation in vegetable based PT programmes 1998-2006.

	Test material	Provider	Year	Found result mg/kg	Assigned value mg/kg	Target б	z-score
Cd	Vegetable powder	FAPAS[1]	1998	0.660	0.684	0.116	-0.2
	Sun flour seeds	FAPAS	2001	0.612	0.711	0.120	-0.8
	Vegetable purée	FAPAS	2006	0.059	0.0551	0.012	+0.3
	Vegetable purée	FAPAS	2006	0.056	0.0677	0.015	-0.8
Fe	Breakfast cereals	FAPAS	1998	142	127	9.8	+1.6
	Breakfast cereals	FAPAS	1999	300	295	20.2	+0.3
	Bread powder	FAPAS	2003	22.0	23.1	6.1	-0.5
Pb	Vegetable powder	FAPAS	1998	2.60	2.249	0.319	+1.1
	Sun flour seeds	FAPAS	2001	0.105	0.124	0.027	-0.7
	Vegetable purée	FAPAS	2006	0.129	0.121	0.027	+0.3
	Vegetable purée	FAPAS	2006	0.090	0.098	0.022	-0.4
Zn	Breakfast cereals	FAPAS	1998	1.99	2.51	0.35	-1.5
	Breakfast cereals	FAPAS	1999	27.5	26.9	2.61	+0.2
	Bread powder	FAPAS	2003	10.4	10.3	1.2	+0.1

[1] FAPAS proficiency test Program, Sand Hutton, York, UK. www.fapas.com

Analytical Results

It was recently discovered that in 1987 the producer of biodynamic wheat flour introduced some changes in the grinding equipment that had an impact on several metals. The results for biodynamic wheat flour 1983-1986 were therefore not included in this study.

Ash content

Wheat bran and kruska wheat bran have a significantly different ash content and are therefore separated in the ash content table. There was, however no significant difference in metal levels between the two, and the metal results were therefore merged into one table.

The mean ash content was 0.53 per cent and 0.67 per cent for wheat and biodynamic wheat flour, respectively. Wheat bran had a mean ash content of 5.0 per cent and kruska wheat bran 6.4 per cent. Rye flour had a mean ash content of 1.6 per cent. See Tables 4 and 5.

Table 4. Ash content in household wheat and rye flours (% fresh weight) on the Swedish market 1983-2009. n.a.= not analysed.

	Wheat flour				**Biodynamic wheat flour**		**Rye flour**			
Year	**n**	**Mean**	**Min**	**Max**	**n**	**Mean**	**n**	**Mean**	**Min**	**Max**
1983	6	0.57	0.50	0.71		n.a.	6	1.76	1.62	1.96
1984	6	0.55	0.52	0.61		n.a.	6	1.72	1.59	1.87
1985	6	0.52	0.48	0.56		n.a.	6	1.65	1.63	1.69
1986	6	0.68	0.65	0.73		n.a.	6	1.65	1.45	1.98
1987	6	0.50	0.41	0.57	1	0.76	6	1.62	1.47	1.78
1988	6	0.52	0.50	0.55	1	0.80	6	1.69	1.60	1.86
1989	6	0.51	0.47	0.55	1	0.82	6	1.61	1.55	1.67
1990	6	0.51	0.46	0.58	1	0.67	6	1.55	1.49	1.71
1991	6	0.52	0.48	0.57	1	0.77	6	1.49	1.36	1.56
1992	6	0.54	0.50	0.57	1	0.59	6	1.63	1.53	1.79
1993	6	0.54	0.51	0.58	1	0.61	6	1.52	1.31	1.71
1994	6	0.51	0.44	0.58	1	0.42	6	1.53	1.40	1.60
1995	6	0.49	0.40	0.62	1	0.64	6	1.60	1.50	1.70
1996	6	0.53	0.49	0.56	1	0.81	6	1.70	1.60	1.90
1997	6	0.54	0.42	0.61	1	0.51	6	1.51	1.25	1.68
1998	6	0.56	0.54	0.58	1	0.80	6	1.61	1.51	1.73
1999	6	0.54	0.50	0.57	1	0.67	6	1.43	1.33	1.54
2000	6	0.50	0.43	0.56	1	0.75	6	1.60	1.44	1.86
2001	4	0.49	0.48	0.50	1	0.56	4	1.55	1.42	1.61
2002	4	0.58	0.56	0.61	1	0.64	4	1.68	1.57	1.90
2003	4	0.56	0.48	0.63	1	0.66	4	1.40	1.29	1.54
2004	4	0.48	0.45	0.50	1	0.79	4	1.38	1.33	1.41
2005	4	0.50	0.49	0.50	1	0.55	4	1.51	1.35	1.66
2006	4	0.53	0.51	0.57	1	0.60	4	1.50	1.38	1.59
2007	4	0.54	0.50	0.56	1	0.69	4	1.32	1.25	1.39
2008	4	0.54	0.51	0.55	1	0.62	4	1.35	1.23	1.43
2009	4	0.52	0.44	0.56	1	0.74	4	1.38	1.34	1.45
Mean		**0.53**	**0.40**	**0.73**		**0.67**		**1.57**	**1.23**	**1.98**
n	**144**				**23**		**144**			

Table 5. Mean ash content in wheat bran and kruska wheat bran (% fresh weight) on the Swedish market 1983-2009.

Year	**n**	**Wheat bran**	**n**	**Kruska wheat bran**
1983	2	4.94		
1984	2	5.35		
1985	1	4.60	1	6.24
1986			2	6.87
1987			2	6.54
1988	1	4.49	1	6.27
1989			2	6.88
1990	1	4.47	1	5.82
1991	1	5.15	1	6.13
1992	1	4.93	1	5.89
1993	1	4.75	1	5.91
1994	1	4.60	1	5.60
1995	1	5,00	1	6,40
1996			2	6.95
1997	1	4.82	1	6.03
1998			2	6.44
1999			2	6.63
2000			2	6.45
2001	2	4.59		
2002	2	4.61		
2003	2	4.66		
2004	2	4.89		
2005	2	4.69		
2006	2	4.49		
2007	2	4.38		
2008	2	4.30		
2009	2	3.99		
Mean		**5.00**		**6.40**
n	**31**		**23**	

Time trend analysis

All time trend analyses are made at a probability level of 5 per cent ($p<0.05$), and all results in the time trend analysis are based on dry weight, in order to eliminate moisture as a confounding factor. Other confounding factors may be due to e.g., different ash content in samples of the same type, since the metal contents can be expected to be related to the ash (i.e. mineral) content, which in turn is related to the grinding and sifting process. If a change in the ash content occurs together with a similar change in trace metal content it is possible that this is due to a change in the milling process, whereas if there is no change in ash, but a change in the content of, e.g., Cd it may be assumed that this is due to changes in the environment or in the agricultural practices/conditions.

In the case of wheat bran the relative difference in ash content between wheat bran and Kruska wheat bran was, on average, 25 per cent. This difference did not result in significantly different metal levels between the groups. Therefore the metals in bran were merged into one table.

The statistically significant time trends found in this survey, for the years 1983-2009, can be used to predict future time trends. The time factors predict the number of years needed to arrive at half or double the current mean level. These predictions are highly sensitive to environmental changes, as well as changes in the agriculture and other production procedures. It is therefore of the outmost importance that the reader see these predictions as indications/possibilities rather than firm, irrevocable, truths.

Time trends could not be calculated for Co, Cr and Pb because of many results below the LOD.

There was no significant time trend for Cd in any of the sample groups, as can be seen in Table 6. In Figures 1-3 all results for Cd in wheat flour, bran and rye flour are shown together with their regression lines. No increase in the Cd-content is indicated. In the previous report [Jorhem et al. 2001] a curved relation to the year of sampling (1983-1997) was noted. Statistical analysis of the results of the samples showed a co-variation with the results of the reference materials. With the additional samples in this study we still have a co-variation with the results of the reference materials. When the effect of the co-variation with the reference materials is taken into account there is still an undulation of the results over time. This indicates that the analytical method is not the cause of this undulation.
However, changes in the environment, as well as a reintroduction of phosphate fertilizers with higher Cd-content, may be the basis for a future increasing trend.

The time trends for the other metals were generally increasing in wheat flour. In biodynamic wheat flour, wheat bran and rye flour metals with a significant time trend all showed a decreasing tendency (Table 6).

Cadmium

Wheat flour: the mean concentration of the 144 samples was 0.026 mg/kg, ranging from 0.013 to 0.074 mg/kg (Table 7). The regression analysis showed no significant change over the 27 year period (Table 6 and Figure 1).

Table 6. Time trends in the metal concentration in wheat and rye flour and wheat bran on the Swedish market 1983-2009. 0 = no significant change, ↗ = significant increase, ↘ = significant decrease. Time factor = number of years to doubling the current (2009) level, or number of years to half the current level.

	Wheat flour (n = 144)		**Biodynamic wheat flour (n = 23)**		**Wheat bran (n = 54)**		**Rye flour (n = 144)**	
Metal	Time trend (p<0.05)	Time factor years	Time trend (p<0.05)	Time factor years	Time trend (p<0.05)	Time factor years	Time trend (p<0.05)	Time factor years
Cd	0		0		0		0	
Cu	↗	>200	0		0		↘	43
Fe	0		↘	13	↘	35	↘	20
Mn	↗	>100	↘	16	↘	34	↘	15
Ni	0		0		0		↘	10
Zn	↗	>100	0		0		↘	31
Ash	↘	>200	0		--		↘	63

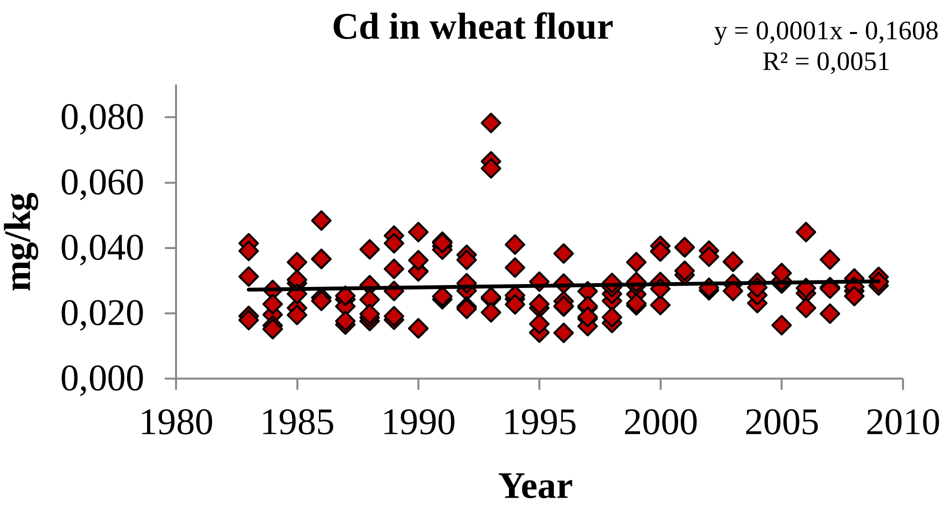

Figure 1. The regression line for Cd in wheat flour 1983-2009.

Biodynamic wheat flour: The mean Cd level was 0.029 mg/kg for the 23 samples (Table 7). The results did not change in a statistically significant way (Table 6).

Wheat bran: The mean concentration of the 54 samples was 0.12 mg/kg, ranging from 0.049 to 0.25 mg/kg (Table 7). No significant time dependent change was indicated (Table 6 and Figure 2).

Rye flour: The mean concentration of the 144 rye samples was 0.016 mg/kg, ranging from 0.003 to 0.044 mg/kg (Table 7). The regression analysis showed no significant change over time (Table 6 and Figure 3).

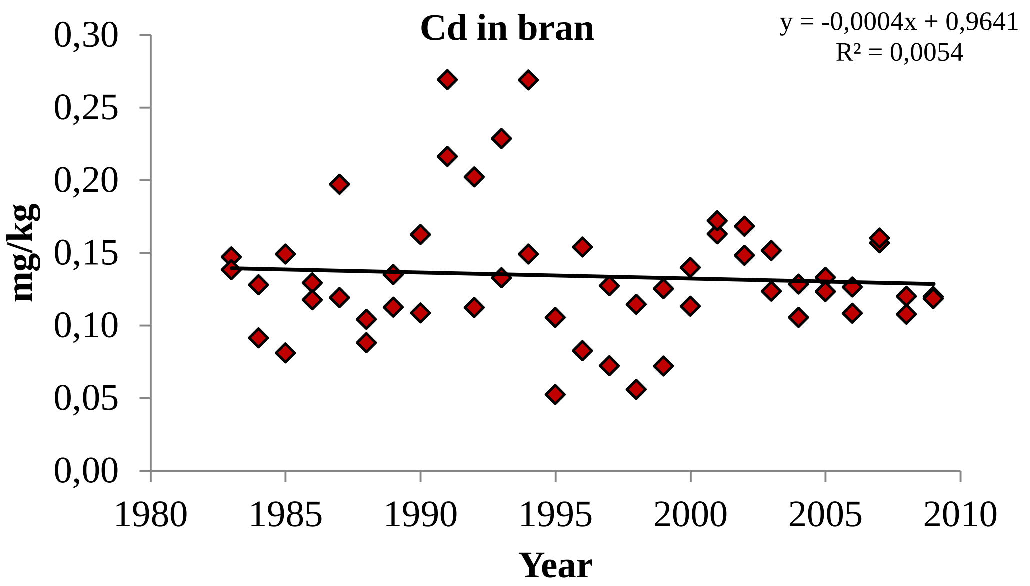

Figure 2. The regression line for Cd in wheat bran and Kruska wheat bran 1983 – 2009.

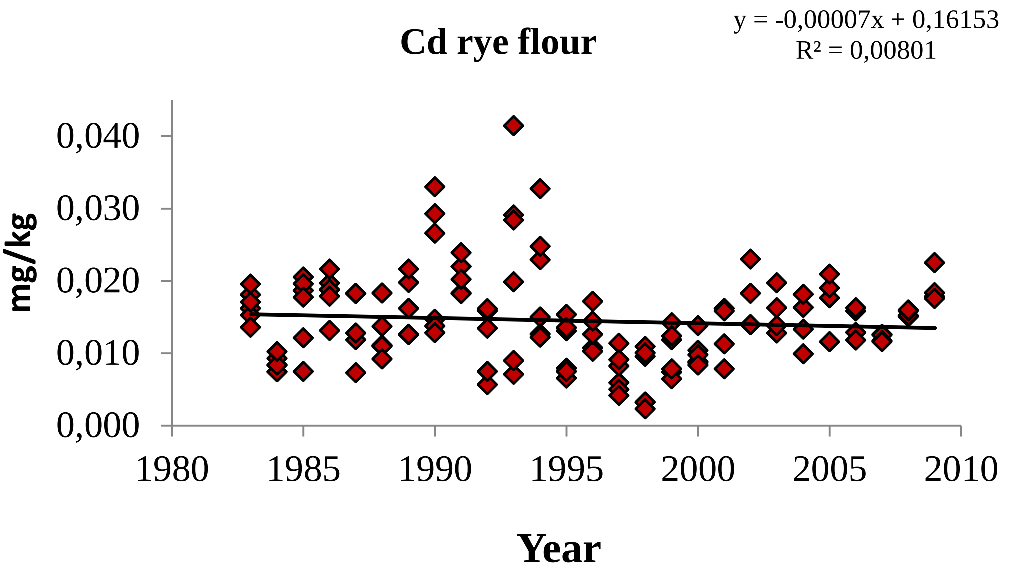

Figure 3. The regression line for Cd in rye flour 1983-2009.

Table 7. Cd-levels, in mg/kg fresh weight, in household wheat and rye flour wheat bran on the Swedish market 1983-2009.

	Wheat flour				Biodynamic wheat flour		Wheat bran				Rye flour			
Year	**n**	**Mean**	**Min**	**Max**	**n**	**Result[1]**	**n**	**Mean**	**Min**	**Max**	**n**	**Mean**	**Min**	**Max**
1983	6	0.025	0.016	0.037			2	0.13	0.13	0.13	6	0.019	0.015	0.022
1984	6	0.018	0.014	0.025			2	0.10	0.09	0.12	6	0.009	0.008	0.011
1985	6	0.025	0.018	0.033			2	0.11	0.08	0.14	6	0.017	0.008	0.022
1986	6	0.030	0.022	0.045			2	0.12	0.11	0.12	6	0.020	0.014	0.023
1987	6	0.020	0.015	0.023	1	0.036	2	0.15	0.11	0.18	6	0.016	0.008	0.020
1988	6	0.023	0.016	0.036	1	0.025	2	0.09	0.08	0.10	6	0.014	0.010	0.020
1989	6	0.027	0.016	0.039	1	0.022	2	0.11	0.10	0.12	6	0.018	0.014	0.024
1990	6	0.027	0.014	0.041	1	0.031	2	0.13	0.10	0.15	6	0.024	0.014	0.036
1991	6	0.032	0.022	0.038	1	0.042	2	0.23	0.20	0.25	6	0.023	0.020	0.026
1992	6	0.027	0.020	0.035	1	0.031	2	0.15	0.11	0.19	6	0.013	0.006	0.017
1993	6	0.044	0.019	0.074	1	0.038	2	0.17	0.13	0.22	6	0.024	0.008	0.044
1994	6	0.027	0.021	0.038	1	0.026	2	0.20	0.14	0.25	6	0.021	0.013	0.035
1995	6	0.018	0.013	0.028	1	0.017	2	0.07	0.05	0.10	6	0.011	0.007	0.017
1996	6	0.023	0.013	0.036	1	0.042	2	0.11	0.08	0.14	6	0.014	0.011	0.019
1997	6	0.019	0.015	0.024	1	0.022	2	0.09	0.07	0.12	6	0.008	0.005	0.013
1998	6	0.022	0.016	0.027	1	0.033	2	0.08	0.05	0.11	6	0.007	0.003	0.012
1999	6	0.025	0.021	0.033	1	0.021	2	0.09	0.07	0.12	6	0.011	0.007	0.016
2000	6	0.030	0.021	0.037	1	0.021	2	0.12	0.11	0.13	6	0.011	0.009	0.016
2001	4	0.033	0.029	0.037	1	0.024	2	0.16	0.15	0.16	4	0.014	0.008	0.018
2002	4	0.030	0.025	0.036	1	0.037	2	0.15	0.14	0.16	4	0.019	0.015	0.025
2003	4	0.029	0.025	0.033	1	0.020	2	0.13	0.12	0.14	4	0.017	0.014	0.021
2004	4	0.024	0.021	0.027	1	0.041	2	0.11	0.10	0.12	4	0.016	0.011	0.020
2005	4	0.025	0.015	0.030	1	0.033	2	0.12	0.11	0.12	4	0.019	0.013	0.023
2006	4	0.028	0.020	0.041	1	0.030	2	0.11	0.10	0.12	4	0.015	0.013	0.017
2007	4	0.025	0.018	0.033	1	0.024	2	0.15	0.15	0.15	4	0.013	0.013	0.014
2008	4	0.025	0.023	0.028	1	0.032	2	0.11	0.10	0.11	4	0.017	0.016	0.017
2009	4	0.027	0.026	0.028	1	0.017	2	0.11	0.11	0.11	4	0.021	0.019	0.025
Mean		**0.026**	**0.013**	**0.074**		**0.029**		**0.12**	**0.049**	**0.25**		**0.016**	**0.003**	**0.044**
n	**144**				**23**		**54**				**144**			

[1]= results for 1983-86 deleted on technical grounds.

Cobalt
Most results for wheat/rye flour and wheat bran were close to or below the LOD's of 0.005 and 0.016 mg/kg respectively. Therefore time trends could not be calculated (Tables 8-11).

Chromium
Most results for wheat and rye flour and wheat bran were below their LODs of 0.016, 0.016 and 0.040 mg/kg respectively. Therefore time trends could not be calculated (Tables 8-11).

Copper
The mean level in wheat flour was 1.45 mg/kg, ranging between annual means of 1.22-1.76 mg/kg, and the regression analysis indicated a significantly increasing time trend. In the biodynamic wheat flour the mean level was slightly higher; 2.01 mg/kg. For wheat bran the mean was 12.6 mg/kg. For rye flour the mean was 3.37 mg/kg, ranging between annual means of 2.68-4.18 mg/kg, and there was a significant decrease in the Cu-level over time (Tables 6, 8-11).

Iron
Up to 1994 wheat flour was fortified with iron, in order to improve the iron status in the population (mean value 1983-1994 = 69 mg/kg), and these result were not included in the regression analysis. The mean level in wheat flour after 1994 was 9.7 mg/kg with a range of 7.5-11.8 mg/kg. The period 1995-2009 did not indicate any significant trend in wheat flour. In biodynamic wheat flour the mean level was 14.0 mg/kg, and there was a significantly decreasing trend for the period 1987-2009. In wheat bran the mean level was 129 mg/kg, and there was a significantly decreasing trend for the period 1983-2009. Rye flour had a mean level of 29.8 mg/kg, ranging between 19.5-36.9 mg/kg, and there was a significantly decreasing trend for the period 1983-2009 (Tables 6, 8-11).

Manganese
The mean level in wheat flour was 4.85 mg/kg and ranging between 3.75-6.82 mg/kg. In biodynamic wheat flour the mean level was somewhat higher, 9.66 mg/kg. The wheat bran had a mean level of 107 mg/kg. For rye flour the mean was 25.1 mg/kg, range 17.0-47.3 mg/kg.

The regression analysis for wheat flour indicated a significantly increasing time trend, whereas wheat bran, biodynamic wheat flour and rye flour all showed a significantly decreasing trend (Tables 6, 8-11).

Nickel
The mean levels were <0.040, 0.077, 0.56 and 0.075 mg/kg, respectively for wheat flour, biodynamic wheat flour, wheat bran and rye flour. The regression analysis indicated that in wheat flour there was an increasing trend, whereas in rye flour the trend was decreasing. (Tables 6, 8-11). It should, however, be noted that the Ni-results are extremely variable within, as well as between, years. It cannot be excluded that contamination has contributed to this variability.

Lead
In wheat flour (including biodynamic) and rye flour the levels were, with a few exceptions, below the LOD of 0.013 mg/kg. In wheat bran the mean level was 0.029 mg/kg (Tables 8-11). No time trends were estimated.

Zink
For wheat flour the mean was 6.43 mg/kg and the range 5.12-8.40 mg/kg, and in biodynamic wheat flour the mean was 11.2 mg/kg. Rye flour had a mean of 24.3 mg/kg and ranging from 17.8-31.3 mg/kg. Wheat bran had a mean of 84 mg/kg. The regression analysis for wheat flour indicated a significantly increasing time trend at $p < 0.05$. In rye flour the results indicated a significant decrease (Table 6, 8-11).

Table 8. Mean metal levels in household wheat flour (mg/kg fresh weight) on the Swedish market 1983-2009. n.a.= not analysed.

		Metal							
Year	**n**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
1983	6	n.a.	n.a.	1.62	*72.8**	4.10	n.a.	<0.013	5.87
1984	6	n.a.	<0.016	1.47	*76.2**	4.65	n.a.	<0.013	6.19
1985	6	n.a.	<0.016	1.33	*79.3**	4.33	n.a.	<0.013	6.00
1986	6	n.a.	<0.016	1.22	*73.7**	4.12	n.a.	<0.013	5.50
1987	6	<0.005	<0.016	1.25	*68.5**	4.13	<0.040	<0.013	5.22
1988	6	<0.005	<0.016	1.28	*62.7**	4.27	<0.040	<0.013	5.12
1989	6	<0.005	<0.016	1.30	*72.3**	3.75	<0.040	<0.013	5.51
1990	6	<0.005	<0.016	1.25	*63.2**	5.06	0.053	<0.013	5.56
1991	6	<0.005	<0.016	1.71	*49.2**	4.26	0.049	<0.013	6.26
1992	6	<0.005	<0.016	1.41	*74.1**	4.92	<0.040	<0.013	6.49
1993	6	<0.005	<0.016	1.47	*70.6**	4.98	<0.040	<0.013	7.02
1994	6	<0.005	<0.016	1.40	*59.5**	3.95	<0.040	<0.013	6.12
1995	6	<0.005	<0.016	1.63	9,94	4.65	<0.040	<0.013	7.17
1996	6	<0.005	<0.016	1.43	8,94	5.19	<0.040	<0.013	6.26
1997	6	<0.005	<0.016	1.56	11,6	5.85	<0.040	<0.013	7.08
1998	6	<0.005	<0.016	1.55	9,62	5.37	<0.040	<0.013	6.70
1999	6	<0.005	<0.016	1.36	7,48	5.54	<0.040	<0.013	6.63
2000	6	<0.005	<0.016	1.65	11,8	6.82	<0.040	<0.013	7.28
2001	4	<0.005	0.017	1.76	10,3	5.07	0.057	<0.013	7.62
2002	4	<0.005	<0.016	1.70	11,1	5.85	0.058	<0.013	8.40
2003	4	n.a.	n.a.	1.50	9,10	4.98	n.a.	<0.013	7.70
2004	4	n.a.	n.a.	1.44	8,44	5.55	n.a.	<0.013	7.36
2005	4	<0.005	<0.016	1.28	9,06	4.82	<0.040	<0.013	5.71
2006	4	<0.005	<0.016	1.42	9,07	4.60	<0.040	<0.013	7.04
2007	4	<0.005	<0.016	1.44	9,04	5.29	<0.040	<0.013	6.75
2008	4	<0.005	<0.016	1.52	9,40	4.34	0.047	<0.013	6.02
2009	4	<0.005	<0.016	1.50	9,34	5.15	<0.040	<0.013	6.80
Mean		**<0.005**	**<0.016**	**1.45**	**9.66**	**4.85**	**<0.040**	**<0.013**	**6.43**
n	**144**	**112**	**130**	**144**	**72**	**144**	**112**	**144**	**144**

* Iron fortified, not included in the mean, but described separately.

Table 9. Metal levels in biodynamic wheat flour (mg/kg fresh weight) on the Swedish market 1987-2009. n.a.= not analysed.

		Metal							
Year	**n**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni[1]**	**Pb**	**Zn**
1987	1	<0.005	<0.016	1.80	16.0	12.0	0.072	0.020	12.0
1988	1	<0.005	<0.016	2.16	23.4	13.8	0.080	0.016	14.0
1989	1	<0.005	<0.016	2.49	23.0	19.2	0.044	0.017	12.6
1990	1	<0.005	<0.016	1.69	17.0	9.59	0.170	0.016	8.71
1991	1	<0.005	<0.016	2.48	16.0	12.2	0.190	0.016	15.1
1992	1	0.005	<0.016	2.02	13.8	8.22	0.075	0.024	9.60
1993	1	0.006	<0.016	1.79	13.8	5.34	<0.040	<0.013	8.47
1994	1	<0.005	<0.016	1.35	9.11	5.41	0.064	<0.013	6.48
1995	1	<0.005	<0.016	3.43	11.4	7.25	0.067	<0.013	9.71
1996	1	<0.005	<0.016	2.57	18.3	13.2	0.119	<0.013	15.7
1997	1	<0.005	<0.016	1.79	13.5	9.37	0.065	<0.013	10.0
1998	1	<0.005	<0.016	2.22	14.4	11.1	0.074	<0.013	14.2
1999	1	<0.005	<0.016	1.88	11.3	12.3	0.055	<0.013	12.4
2000	1	0.005	<0.016	2.14	18.3	15.9	0.116	<0.013	13.6
2001	1	<0.005	<0.016	1.98	10.3	5.25	<0.040	<0.013	8.33
2002	1	<0.005	<0.016	1.93	12.6	7.13	0.052	<0.013	10.4
2003	1	n.a.	n.a.	1.86	12.3	6.57	n.a.	<0.013	12.3
2004	1	n.a.	n.a.	1.92	12.7	9.74	n.a.	<0.013	14.3
2005	1	<0.005	<0.016	1.69	9.29	6.74	0.056	<0.013	10.5
2006	1	<0.005	<0.016	1.55	9.28	6.92	0.048	<0.013	9.03
2007	1	<0.005	<0.016	1.90	11.9	8.33	0.058	<0.013	11.4
2008	1	<0.005	<0.016	1.83	9.56	6.58	0.056	<0.013	9.1
2009	1	<0.005	<0.016	1.88	13.8	10.1	0.095	<0.013	10.8
Mean		**<0.005**	**<0.016**	**2.01**	**14.0**	**9.66**	**0.077**	**<0.013**	**11.2**
n	**23**	**21**	**21**	**23**	**23**	**23**	**21**	**23**	**23**

[1]Results <0.044 was set to 0.022 mg/kg for calculation of the mean.

Table 10. Metal levels in wheat bran and kruska wheat bran in mg/kg fresh weight on the Swedish market 1983-2009. n.a. = not analysed.

		Metal							
Year	**n**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**[1]	**Zn**
1983	2	n.a.	n.a.	11.5	141	127	n.a.	0.037	91
1984	2	n.a.	<0.040	10.6	106	120	n.a.	0.029	80
1985	2	n.a.	<0.040	9.89	127	102	n.a.	0.065	74
1986	2	n.a.	<0.040	14.5	175	117	n.a.	0.027	79
1987	2	<0.016	<0.040	14.0	151	98	0.40	0.038	85
1988	2	<0.016	<0.040	13.1	120	131	0.20	0.052	96
1989	2	<0.016	<0.040	13.2	147	132	0.36	0.035	75
1990	2	0.017	<0.040	10.2	123	117	1.17	0.030	70
1991	2	0.033	<0.040	14.3	139	131	1.34	0.024	104
1992	2	0.018	<0.040	12.8	145	130	0.49	<0.018	100
1993	2	<0.016	<0.040	13.7	161	110	1.16	0.117	99
1994	2	<0.016	<0.040	12.9	139	101	0.57	0.024	104
1995	2	<0.016	<0.040	16.1	139	108	0.55	<0.018	91
1996	2	<0.016	<0.040	14.3	135	109	0.50	<0.018	71
1997	2	<0.016	<0.040	13.4	176	108	0.32	<0.018	75
1998	2	<0.016	<0.040	13.8	121	96	0.49	0.078	70
1999	2	<0.016	<0.040	13.2	111	115	0.61	<0.018	72
2000	2	0.021	<0.040	13.0	136	95	0.72	<0.018	84
2001	2	0.019	<0.040	15.6	117	97	0.42	<0.018	80
2002	2	0.025	<0.040	11.3	129	87	0.34	<0.018	86
2003	2	n.a.	n.a.	11.6	120	108	n.a.	<0.018	94
2004	2	n.a.	n.a.	11.4	110	111	n.a.	<0.018	91
2005	2	0.018	0.085	12.4	109	94	0.62	0.026	83
2006	2	<0.016	<0.040	11.9	127	97	0.55	0.043	83
2007	2	<0.016	<0.040	11.4	87	91	0.14	0.045	86
2008	2	<0.016	<0.040	10.3	108	89	0.46	<0.018	71
2009	2	<0.016	<0.040	10.3	89	80	0.41	<0.018	64
Mean		**<0.016**	**<0.040**	**12.6**	**129**	**107**	**0.56**	**0.029**	**84**
n	**54**	**42**	**48**	**54**	**54**	**54**	**42**	**54**	**54**

[1]Results <0.018 was set to 0.009 mg/kg for calculation of the mean.

Table 11. Metal levels in rye flour (mg/kg fresh weight) on the Swedish market 1983-2009. n.a. = not analysed.

		Metal							
Year	**n**	**Co**	**Cr**	**Cu**	**Fe**	**Mn**	**Ni**	**Pb**	**Zn**
1983	6	n.a.	n.a.	4.18	35.5	47.3	n.a.	0.021	31.3
1984	6	n.a.	<0.016	4.00	32.5	28.8	n.a.	<0.013	27.3
1985	6	n.a.	<0.016	3.23	35.8	30.3	n.a.	<0.013	26.2
1986	6	n.a.	<0.016	3.55	35.0	28.7	n.a.	<0.013	28.0
1987	6	<0.005	<0.016	3.30	32.2	22.5	0.049	0.013	25.0
1988	6	<0.005	<0.016	3.54	30.1	28.1	0.065	0.021	26.5
1989	6	<0.005	<0.016	3.42	36.9	31.7	0.064	0.014	23.5
1990	6	0.015	<0.016	3.22	32.4	28.4	0.206	0.014	22.2
1991	6	0.030	0.018	4.07	31.9	26.6	0.244	0.075	26.8
1992	6	<0.005	<0.016	3.84	34.0	24.7	0.056	<0.013	30.0
1993	6	<0.005	<0.016	3.19	34.8	20.6	0.064	<0.013	22.0
1994	6	<0.005	<0.016	2.95	30.8	17.3	0.059	<0.013	22.5
1995	6	<0.005	<0.016	3.57	33.8	23.4	0.041	<0.013	26.9
1996	6	<0.005	<0.016	3.27	29.0	23.1	0.048	<0.013	22.8
1997	6	0.010	<0.016	3.49	29.7	26.9	0.048	<0.013	25.2
1998	6	<0.005	<0.016	3.39	27.8	28.3	0.057	<0.013	25.8
1999	6	<0.005	<0.016	3.20	23.8	21.3	0.046	<0.013	23.4
2000	6	<0.005	<0.016	3.36	29.3	23.3	0.051	<0.013	21.6
2001	4	0.006	<0.016	3.40	24.8	23.6	0.057	<0.013	23.9
2002	4	0,007	<0.016	3.45	26.2	25.7	0.068	<0.013	25.7
2003	4	n.a.	n.a.	2.68	21.9	18.0	n.a.	<0.013	19.5
2004	4	n.a.	n.a.	2.82	21.8	18.0	n.a.	<0.013	19.4
2005	4	<0.005	<0.016	3.04	21.8	21.8	0.062	<0.013	23.9
2006	4	<0.005	<0.016	3.05	24.4	21.8	0.058	<0.013	22.5
2007	4	<0.005	<0.016	2.78	19.5	16.2	0.056	<0.013	17.8
2008	4	<0.005	<0.016	2.77	23.4	17.0	0.056	<0.013	18.2
2009	4	<0.005	<0.016	3.07	25.3	20.9	0.095	<0.013	19.3
Mean		**0.005**	**<0.016**	**3.37**	**29.8**	**25.1**	**0.075**	**<0.013**	**24.3**
n	**144**	**112**	**130**	**144**	**144**	**144**	**112**	**144**	**144**

Discussion

Cadmium

In a recent report on trends in heavy metals and environmental pollutants in basic foodstuffs [Ålander et al. 2012] it was noted that the Cd-level in both wheat and rye flour had decreased in a statistically significant way during the period 1976-2010, although the half life is rather long, 84 years or more. That report [Ålander et al. 2012] is based on the results from this study and complemented with data from other sources, and is thus not fully compatible with this report, which covers the period 1983-2009. Although no significant trend was observed for Cd in this survey, there were signs of decrease in all products except wheat flour.

Kirchmann et al. [2009] found a decrease of Cd in wheat grain from approximately 0.08 to 0.04 mg/kg in the period 1967-2003. The decrease was visible both in NPK-fertilized grain and non-fertilized grain, but the steeper decline in wheat fertilized with low Cd NPK fertilizer indicated that this was the main reason for the decrease.

In 1987 the NFA published a report on quality properties in 48 samples of household wheat flour from 24 different Swedish mills, carried out in 1985 [Andersson et al. 1987]. Cadmium was one of the parameters that were analysed. These Cd-results had a mean of 0.032 mg/kg and ranged between 0.013-0.058 mg/kg, which is well within the range found in this study. Although that survey stems from 1985, it is within the time frame of this study and covers a large geographic area, indicating a rather even geographical distribution of Cd in wheat flour. These results thus support the estimation of the average Cd-content in household wheat flour found in this survey.

Lead

The report by Ålander et al. [2012] found a significant decrease of the Pb-levels in both wheat flour and wheat bran for the period 1976-2010 with a half life of 16 years. Also the level in rye flour decreased during the same time period and with a half life of 8 years. Since the results for wheat and rye flours in this survey generally were below the LOD no time trend could be estimated. In wheat bran, however, a declining time trend was observed, but the results below the LOD unable the calculation of statistical significance.

Kirchmann et al [2009] noted a sharp decline in Pb in wheat grain (from ~ 0.1 mg/kg to ~ 0.02 mg/kg) in the period from around 1980 to 2003. EFSA has re-evaluated its provisional tolerable weekly intake (PTWI) of 25 µg/kg body weight for Pb and concluded that there is no lower limit under which adverse effects could be guaranteed not to occur and therefore a new guidance limit could not be established. This indicates that methods with lower detection limits than those used in this report are needed in order to quantify Pb in foods, such as cereals.

Nutritional metals
Concern has been raised on the likelihood of substantial change (decrease) in the nutritional content of plant food available on the market. A report from the NFA in 2008 [Mattisson et al. 2008] discussed different factors that may affect nutriational factors. One reason for lowered metal values could be due to depletion of the soil. It may also be an effect of the differences in analytical techniques. In one cited study it was found that the levels of Cu and Fe in fruit and vegetables were significantly lower in 2004 than in the 1930-ies. The analytical techniques used in the 1930-ies were, however, very different from the techniques used today, and it is therefore difficult to compare metal results, in the milligram to microgram/kg range, that are so far separated in time. In the longitudinal study presented here all results are derived from the same analytical technique, and with a rigorous analytical quality control system that was evolved over the last two to three decades. The results presented here are therefore fully comparable over the study period.

In wheat flour the regression analysis indicated a significant increase for the metals Cu, Mn and Zn. In biodynamic wheat flour and wheat bran Fe and Mn decreased significantly. In rye flour Cu, Fe, Mn, Ni and Zn decreased significantly in concentration over time. The somewhat contradictory results is probably influenced by the fact that samples of wheat flour and wheat bran may come from different regions, which means that, e.g. soil conditions and fertilizing may be different.

The study on wheat grain by Kirchmann et al. [2009], covering the period 1967-2003 found no significant changes in Mn and Zn, whereas Cu and Fe declined significantly.

Cobalt
The mean results for wheat flour, wheat bran and rye flour were <0.005 mg/kg, <0.016 mg/kg and 0.005 mg/kg, respectively. Kirchmann et al. [2009] found very low Co-levels in wheat grain: 0.002-0.005 mg/kg, which is in the same order of magnitude as the findings in this study.

Chromium
The mean results for wheat and rye flour were <0.016 mg/kg, and in wheat bran <0.040 mg/kg. Kirchmann et al. [2009] found results in the range 0.01-0.03 mg/kg in wheat grain.

Nickel
This survey found a significant increase in wheat flour and a significant decrease in rye flour. The results by Kirchmann et al [2009] indicated an increase in wheat grain.

The role of mineral fertilizers

In 1970 the mean Cd-level in phosphate fertilizers used in Sweden was approximately 150 mg/kg P. In 1993 the European Commission imposed a Maximum Limit (ML) of 100 mg Cd/kg P in mineral fertilizers. Sweden got an exemption and could use taxation as a means to reduce the Cd-level: A progressive tax was added on phosphate fertilizers containing more than 5 mg Cd/kg P. A probable effect of this tax was that in 2009 the average Cd level in mineral fertilizers was 6 mg/kg P [KemI 2011]. Our results for wheat flour, wheat bran and rye flour show no significant change during this period which indicates that the Cd-burden on farm-land used for cereal production is not increasing. Furthermore, the decrease of Cd in wheat grain reported by Kirchmann et al [2009] indicates a lowered Cd-level in soil, at least in some agrarian regions. The Swedish exemption for Cd in mineral fertilizers was dropped in 2010. Thus, Sweden now has a ML of 100 mg Cd/kg P. The EFSA has revised the PTWI for Cd and lowered it from 7 to 2.5 mg/kg body weight. Furthermore, EFSA concluded that the intake level of Cd in many European countries, including Sweden, is already very close to the PTWI of 2.5 mg/kg body weight [EFSA 2012], and that the intake of Cd must not increase, in order to protect the European public health. In order to maintain the present Cd-balance in a sustainable way, the average level in fertilizers should be lower than 12 mg/kg P. To days ML of 100 mg/kg P in mineral fertilizers is far above that level [KemI 2011].

The accumulation of Cd may differ between wheat varieties due to genetic variations. This makes it possible to develop varieties less prone to accumulate Cd. But simultaneously it may complicate plant selection, since properties such as yield, resistance to diseases etc. are the primary properties of interest in plant breeding [Eriksson 2009]. It is therefore not likely that wheat varieties less prone to accumulate Cd will be introduced in the near future.

Considering the history and the current development it will remain important to follow the Cd-level, as well as certain other metals in household flour on the Swedish market.

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ISSN 1104-7089