The levels of zinc, copper, manganese, selenium, chromium, nickel, cobalt, and aluminium in the meat, liver and kidney of swedish pigs and cattle

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Gehalt an Zink, Kupfer, Mangan, Selen, Chrom, Nickel, Kobalt und Aluminium in Fleisch, Leber und Nieren von schwedischen Schweinen und Rindvieh

Zusammenfassung. Es wurde der Gehalt an Zink, Kupfer, Mangan, Selen, Chrom, Nickel, Kobalt und Aluminium in Fleisch, Leber und Nieren vom Schwein und Rind aus schwedischen Schlachthäusern bestimmt. Diese Ergebnisse wurden mit denen anderer Untersuchungen verglichen. Die Durchschnittswerte für Zink, Kupfer, Mangan und Selen in verschiedenen Geweben waren ungefähr die gleichen wie in früheren Untersuchungen; die für Chrom und Nickel lagen alle im Intervall $<0{,}010$ bis zu 0,015 mg/kg, unabhängig von der Art der Gewebe, und die für Kobalt zwischen 0,001 und 0,043 mg/kg, mit den höchsten Werten in der Leber. Für Aluminium ergaben sich Durchschnittswerte zwischen 0,024 und 0,068 mg/kg, wobei die Gewebe vom Rind ungefähr doppelt so viel Aluminium enthalten wie die Gewebe vom Schwein. Die analytische Qualitätskontrolle wurde mit Referenzmaterial durchgeführt. Viel Arbeit wurde zur Minimierung und Kontrolle der Kontamination aufgewendet. Das kann zu einem Teil erklären, daß die Werte von Chrom, Nickel und Aluminium unserer Untersuchung zu den niedrigsten bisher veröffentlichten Werten gehören.

Summary. The levels of zinc, copper, manganese, selenium, chromium, nickel, cobalt, and aluminium were determined in samples of meat, liver and kidney from pigs and cattle from Swedish slaughterhouses. The results have been compared with those reported from other investigations carried out in recent years. For zinc, copper, manganese and selenium, the mean levels found in the different tissues were very similar to those reported in previous studies. The mean levels of chromium and nickel were found to be in the range <0.010–0.015 mg/kg, regardless of the type of tissue. Cobalt levels ranged from 0.001 to 0.043 mg/kg, the highest levels being in the liver samples. The mean levels of aluminium were between 0.024 and 0.068 mg/kg. Tissues from cattle contained approximately twice as much aluminium as tissues from pigs. Analytical quality assurance was carried out by analysing standard reference materials. A great effort was made to minimize and check contamination. This may partly explain the fact that the levels of chromium, nickel, and aluminium found in the present study are among the lowest reported.

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Introduction

In 1983, the Swedish National Food Administration initiated a control programme to monitor the levels of the contaminants lead, cadmium, arsenic and mercury in tissues from pigs and cattle [1]. It was then decided to use the same samples to determine the levels of zinc, copper, manganese, selenium, chromium, nickel, cobalt and aluminium, since available data for most of these elements are rather scarce. During the period 1984–1987, these elements were analysed at different intervals in the control programme. The levels found have been compared with the results obtained from other recent studies.

Sampling and analysis

Sampling

Samples of meat, liver and kidney from pigs and cattle were taken at regular intervals (10–15 animals/month) from Swedish slaughterhouses approved for export to the United States. Pigs are usually slaughtered when they weigh 110–150 kg, i.e. when they are approximately 6 months old. Cattle are normally not slaughtered before their weight has reached 600 kg, and the age of cattle at slaughter is 2 years or more.

Sample pre-treatment

For the determination of zinc, copper, manganese, chromium, nickel, and cobalt, approximately 10-g samples of meat and liver

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were weighed into a platinum crucible. For kidneys, trimmed of fat, a cross-section slice of approximately 10 g was weighed into a platinum crucible. All samples were thereafter dry ashed at 450 °C according to a procedure described earlier [2]. The ash was finally dissolved in 20 ml 0.1 *M*-nitric acid. The determination of selenium was based on the methods described by Tam and Lacroix [3] and May [4]. In this method, 0.3 g of freeze-dried, finely ground sample was weighed into a quartz beaker. Five millilitres of methanol was added and thereafter mixed with 10 ml of an ashing aid solution consisting of 80 g magnesium nitrate and 8 g magnesium oxide in 200 ml deionized water. After thorough mixing, the sample was dried at 110 °C before dry ashing. The ashing temperature was increased from ambient to 450 °C at a maximum rate of 50 °C/h. After cooling, 10 ml of water and 15 ml conc. hydrochloric acid were added to the ash and the solution was heated on a water-bath for 1.5 h to reduce Se^{6+} to Se^{4+}. Finally, the sample solution was transferred to a 50-ml-volumetric flask and made up to the volume with deionized water. The standard solutions contained the same concentration of magnesium as the sample solutions.

Aluminium was determined by a method described by Frech et al. [5]. A sample of approximately 2 g was dissected with a scalpel and weighed into a quartz flask. The sample was first dried overnight at 70 °C, whereafter 3 ml nitric acid was added and the sample was heated gently until it dissolved and was finally heated to dryness. After cooling, 3 ml nitric acid was added and the solution was again heated to dryness. This procedure was repeated four times. The dry residue was dissolved in 0.5 ml conc. nitric acid and finally diluted to 5 ml with 0.1 *M*-nitric acid. – Sample blanks were prepared for all metals by allowing empty vessels to go through the ashing procedures and thereafter adding the appropriate amount of acid.

Analysis

Zinc, copper and manganese were analysed by flame atomic absorption spectrophotometry (AAS) at 213.9, 324.7, and 279.5 nm, respectively, in a Varian AA-6 instrument equipped with a H_2 lamp for background correction. An oxidizing air-acetylene flame was used for all three metals. Zinc and copper were determined from a calibration curve. Manganese was determined by the method of standard addition. – Selenium was determined by hydride generation/AAS at 196.0 nm, using a Varian VGA-76 hydride generator mounted on a Perkin-Elmer 305 B. The hydride was atomized in a T-shaped quartz cell heated by an air-acetylene flame and the selenium level determined from a calibration curve. Background correction was not used. – Chromium, nickel, cobalt, and aluminium were determined at 357.9, 232.0, 240.7, and 309.3 nm, respectively, by graphite furnace AAS in a Perkin-Elmer 3030/HGA-500 equipped with an AS 40 sample exchanger and a deuterium lamp for background correction. The method of standard addition was used for all graphite furnace determinations. The temperature programmes and type of graphite tubes used are shown in Table 1.

Analytical quality assurance

A standard reference material (SRM) was analysed in duplicate at regular intervals, together with the samples. Bovine liver from the U.S. National Bureau of Standards (NBS) was considered to be the most appropriate SRM for most metals. For some metals, however, additional quality assurance was carried out with some other SRM. The recoveries of metals were studied by adding standard solutions to a number of samples prior to the dry ashing. The results of the analysis of SRM's and the recovery studies are shown in Table 2.

In order to verify the levels of aluminium found in the various tissues, one sample each of meat, liver and kidney from a pig were sent to Dr. W. Frech, University of Umeå [5] for comparative analysis. The results from the above laboratory and our laboratory were as follows: for meat 0.009 and 0.027 mg/kg, for liver 0.031 and 0.027 mg/kg and for kidney 0.016 and 0.019 mg/kg, respectively. The comparative analysis confirmed that the results are of the same order of magnitude. Although the results for the meat sample differ somewhat, it should be kept in mind that these results are lower by a factor 10, than any of those previously reported. The mean levels of metals in the blank solutions, in mg/kg, were: for Zn 0.010, Cu 0.067, Mn 0.0003, Se 0.00001, Cr 0.002, Ni 0.002, Co 0.0002, and Al 0.001 mg/kg. These mean blank values were deducted from the analytical results before the concentrations were calculated. The limit of determination was calculated using the formula:

$$X_{bl}+(3\cdot SD_{bl}),$$

where X_{bl} = mean of the blanks and SD_{bl} = the standard deviation of the blanks. The limit of determination for the metals in the samples were: Zn 0.060, Cu 0.35, Mn 0.001, Se 0.003, Cr 0.010, Ni 0.010, Co 0.001, and Al 0.009 mg/kg.

Table 1. Instrumental parameters used for graphite furnace determinations in Perkin Elmer 3030/HGA-500

Element	Wavelength nm	Temperature programmes Parameter	Step 1	Step 2	Step 3	Step 4	Sample volume	Type of graphite tube
Cr	357.9	Temp °C	130	1200	2300	2700	20 µl	Pyrolytic
		Ramp S	1	10	0	2		
		Hold S	19	10	2	3		
Ni	232.0	Temp °C	130	1350	2500	2700	20 µl	Pyrolytic
		Ramp S	1	5	0	2		
		Hold S	19	20	2	2		
Co	240.7	Temp °C	130	1400	2300	2600	20 µl	Pyrolytic
		Ramp S	1	5	0	2		
		Hold S	19	25	2	2		
Al	309.3	Temp °C	140	1500	2400[a]	2600	30 µl	Normal
		Ramp S	30	15	0	1		
		Hold S	5	5	3	1		

[a] Gas-stop

Table 2. Results of the analysis of standard reference materials from the U.S. National Bureau of Standards, unless otherwise indicated

Metal	Standard reference material	Our results mean ± SD	Certified levels	Recoveries % mean ± SD
Zn	Bovine liver 1577	136 ±4 (20)	130 ±13	93 ± 8 (32)
Cu	Bovine liver 1577	186 ±7 (19)	193 ±10	85 ± 9 (32)
Mn	Bovine liver 1577A	11.0 ±0.6 (7)	9.9 ± 0.8	113 ± 6 (8)
	Oyster tissue	16.8 (2)	17.5 ± 1,2	
Se	Bovine liver 1577	1.2 ±0.05 (10)	1.1 ± 0.1	92 (2)
	Bovine liver 1577A	0.71 ±0.02 (18)	0.71 ± 0.07	
Cr	Bovine liver 1577	0.072 ± 0.005 (8)	0.088 ± 0.012	87 ± 20 (16)
Ni	Citrus leaves	0.78 (2)	0.6 ± 0.3	103 ± 12 (6)
	Oyster tissue	0.93 (2)	1.03 ± 0.19	
	Mussel (NIES)[a]	0.81 (2)	0.93 ± 0.06	
Co	Bovine liver 1577A	0.24 ±0.02 (6)	0.21 ± 0.05	106 ± 16 (16)
Al	Bovine liver 1577A	1.1 ±0.1 (5)	(2)[c]	99 ± 1 (3)
	Human serum[b]	0.050 (1)	0.020 ± 0.005	

[a] National Institute of Environmental Studies, Japan
[b] J. Versieck, Department of Internal Medicine, Division of Gastroenterology, University Hospital, Ghent, Belgium
[c] Non-certified level

Levels in mg/kg dry weight and the results of the recovery studies of standard added to samples of meat, liver and kidney from pigs before ashing. Results are represented as percentage recovery. Number of analyses in *brackets*

Table 3. The levels, in mg/kg fresh weight, of zinc, copper, manganese and selenium in meat, liver and kidney from pigs and cattle

Metal	Species	Tissue	*n*	Mean ± SD	Median	90th percentile	Min	Max
Zinc	Pig	Meat	126	24 ± 11	22	41	8.2	53
		Liver	126	74 ± 27	68	112	28	160
		Kidney	75	22 ± 3.3	22	26	16	33
	Cattle	Meat	7	49 ± 18	50		28	80
		Liver	7	40 ± 8.5	40		27	49
		Kidney	6	16 ± 1.5	16		13	17
Copper	Pig	Meat	126	0.90 ± 0.61	0.82	1.1	0.44	7.2
		Liver	126	9.0 ± 4.0	7.8	15	0.9	29
		Kidney	75	6.1 ± 2.0	5.6	8.5	2.9	15
	Cattle	Meat	7	0.87 ± 0.12	0.84		0.74	1.1
		Liver	7	39 ± 27	41		8.8	87
		Kidney	6	3.7 ± 0.59	4.0		2.8	4.2
Manganese	Pig	Meat	45	0.12 ± 0.052	0.11	0.17	0.058	0.33
		Liver	46	3.0 ± 0.52	2.9	3.5	2.0	4.7
		Kidney	46	1.5 ± 0.24	1.5	1.7	1.0	2.3
	Cattle	Meat	5	0.093 ± 0.044	0.070		0.049	0.14
		Liver	5	3.2 ± 0.67	2.8		2.7	4.3
		Kidney	5	1.1 ± 0.24	1.0		0.88	1.5
Selenium	Pig	Meat	72	0.094 ± 0.017	0.092	0.15	0.043	0.15
		Liver	72	0.50 ± 0.062	0.50	0.58	0.24	0.66
		Kidney	72	1.9 ± 0.35	1.9	2.3	0.36	2.8
	Cattle	Meat	7	0.030 ± 0.020	0.031		< 0.006	0.060
		Liver	7	0.10 ± 0.035	0.10		0.050	0.16
		Kidney	7	0.86 ± 0.28	0.74		0.46	1.3

n number of samples; 90th percentile is not calculated where $n < 10$

Contamination

The risk of contamination during the analysis of chromium, nickel and aluminium is considerable. A major effort was therefore made in order to identify and reduce the sources of contamination. The dishwashing procedure was important for all three metals. Sample exchanger cups, for example, were sometimes severely contaminated and needed extra cleaning before use. Fittings and equipment of stainless steel were found to be possible sources of chromium and nickel contamination. For aluminium, the ambient air and nitric acid, sometimes even very pure, were found to contaminate the samples unless precautions were taken. The use of a background correction was very important. The chromium levels, for example, became two to three times too high without a background correction.

Results and discussion

Zinc

The zinc levels found in this investigation are shown in Table 3. In Table 4, the results of a number of investigations of zinc in tissues of pigs and cattle, published since 1980, are compared with our results. Zinc is an essential metal and a daily intake of 15 mg has been recommended for adults [6]. Meat and meat products in general, and pig's liver in particular, are good sources of zinc in the diet.

Copper

Copper is also an essential metal, with a recommended daily intake of 2–3 mg for adults [6]. From the results of this investigation (Table 3), it can be seen that liver and kidney are good sources of copper in the diet.

Table 4. Data from recent literature on the levels of zinc in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	22 (20)	90 (4)	26 (4)	1980	Finland [8]
	19 (23)	116 (15)	25 (15)	1984	Sweden [2]
	22.6 (100)			1985	USA [9]
	24 (126)	74 (126)	22 (75)	Present study	
Cattle		37.5 (190)	18.6 (190)	1979	Australia [18]
	41 (64)	46 (8)	21 (4)	1980	Finland [8]
	61.9 (181)	50.9 (180)	25.1 (178)	1983	Australia [10]
	44 (25)	42 (48)	17 (35)	1984	Sweden [2]
	47.2 (7)	40.3 (7)	18.1 (7)	1984	FRG [11]
		34 (28)	28 (28)	1985	USA [12]
	53.5	47.6	22.2	1987	Australia [13]
	49 (7)	40 (7)	16 (6)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 5. Data from recent literature on the levels of copper in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.73 (42)	11.7 (42)	6.0 (42)	1980	Sweden [14]
	0.87 (20)	16 (4)	6.0 (4)	1980	Finland [8]
		7.6 (15)	7.3 (15)	1984	Sweden [2]
	1.8 (100)			1985	USA [9]
	0.90 (126)	9.0 (126)	6.1 (75)	Present study	
Cattle		18.0 (190)	3.90 (190)	1979	Australia [18]
	1.2 (42)	54.2 (42)	3.7 (42)	1980	Sweden [14]
	0.81 (64)	67 (8)	4.3 (4)	1980	Finland [8]
	1.9 (181)	33.8 (180)	4.9 (178)	1983	Australia [10]
	1.4 (7)	113 (7)	4.2 (7)	1984	FRG [11]
		57 (48)	3.7 (35)	1984	Sweden [2]
		25 (28)	6.1 (28)	1985	USA [12]
	1.33	23.5	4.36	1987	Australia [13]
	0.87 (7)	39 (7)	3.7 (6)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 5 summarizes the results of investigations carried out since 1980 on copper in tissues of cattle and pigs. There was, with a few exceptions, a good agreement between the results of these investigations and those found in the present study.

Manganese

The levels of manganese found in this investigation are shown in Table 3. Table 6 summarizes the manganese levels reported in the studies carried out since 1980. The low manganese levels reported in a previous study by this laboratory [2] may be artificially low. Since that investigation, it has become evident that the method of standard addition has to be used to obtain satisfactory results. Manganese is regarded as an essential element in man's diet and the recommended intake for adults is in the range 2.5–5 mg/day [6].

Selenium

Selenium is an essential element for man's diet with a recommended daily intake in the range 50–200 μg for adults [6]. It has been suggested that selenium also protects against the toxic effects of some metals. The selenium levels found in this study are shown in Table 3. The tissue with the highest content was pig's kidney, with a maximum level of nearly 3 mg/kg. The Scandinavian region has a naturally low level of selenium in the soil. Animal feed in Scandinavia is therefore supplemented with selenium in order to avoid selenium deficiency in the livestock. In Table 7, the present results are compared with those found in some earlier studies.

Table 6. Data from recent literature on the levels of manganese in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.13 (20)	3.9 (4)	1.5 (4)	1980	Finland [8]
	0.16 (42)	2.8 (42)	1.7 (42)	1980	Sweden [14]
	0.078 (20)	2.1 (15)	0.81 (15)	1984	Sweden [2]
	0.30 (100)			1985	USA [9]
	0.12 (45)	3.0 (46)	1.5 (46)	Present study	
Cattle		2.72 (190)	1.07 (190)	1979	Australia [18]
	0.11 (64)	3.5 (8)	1.2 (4)	1980	Finland [8]
	0.14 (42)	3.1 (42)	1.1 (42)	1980	Sweden [14]
	0.066 (20)	1.9 (48)	0.70 (35)	1984	Sweden [2]
	0.093 (5)	3.2 (5)	1.1 (5)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 7. Data from recent literature on the levels of selenium in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.070 (20)	0.470 (4)	1.710 (4)	1980	Finland [8]
	0.14 (48)	0.51 (48)	2.34 (48)	1983	Sweden [15]
	0.08 (48)	0.56 (48)	2.41 (48)	1984	Finland [16]
	0.16 (50)			1985	Norway [17]
	0.094 (72)	0.50 (72)	1.9 (72)	Present study	
Cattle		0.17 (190)	1.10 (190)	1979	Australia [18]
	0.010 (64)	0.080 (8)	0.700 (4)	1980	Finland [8]
	0.04 (60)	0.16 (60)	1.12 (60)	1984	Finland [16]
	0.12 (180)	0.23 (178)	1.52 (178)	1984	Australia [10]
	0.072 (84)			1985	Norway [17]
	0.030 (7)	0.10 (7)	0.86 (7)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Chromium

The chromium levels found in this investigation (Table 8) are very close to or below the limit of determination. The distribution of results does not follow the normal distribution pattern. There was no correlation observed between chromium levels in the different tissues. The highest result may have been caused by contamination, but, due to the lack of samples, the analysis could not be repeated. As can be seen in Table 9, the results from this investigation are among the lowest reported in recent years. Chromium is an essential metal and the tentative recommended daily intake for man is 50–200 μg for adults [6]. In view of these results, meat, liver and kidney must be regarded as poor sources of chromium.

Nickel

The levels of nickel found in this study (Table 8) are close to or below the limit of determination. As for chromium, the distribution of results is skewed and no correlation was observed between the levels in the different tissues. In Table 10, a comparison is made between the results of this study and studies published since 1979. Nickel is possibly an essential metal for experimental animals. One of the several effects of nickel deficiency is impaired growth, as noted in rats [7].

Cobalt

Cobalt is an essential metal that is mainly deposited in the liver, to a great extent as the vitamin B_{12} complex. The level of cobalt in liver is consequently much higher than that in the other tissues, as can be seen in Table 8. Liver from cattle contains approximately four times as much cobalt as pig's liver. The levels found in liver in this study agree well with those reported in other studies (Table 11). The levels found in meat and kidneys in this investigation are lower than those previously reported.

Aluminium

The aluminium levels in tissues from cattle were, on average, twice as high as those in tissues from pigs (Table 8). When the present results are compared with those found in a number of earlier studies (Table 12), a trend towards lower levels can be seen in the more recent studies. The results from the present study are the lowest so far reported.

Table 8. The levels, in mg/kg fresh weight, of chromium, nickel, cobalt and aluminium in meat, liver and kidney of pigs and cattle

Metal	Species	Tissue	*n*	Mean ± SD	Median	90th percentile	Min	Max
Chromium	Pig	Meat	71	0.014 ± 0.052	< 0.010	0.022	< 0.010	0.44
		Liver	71	< 0.010 ± 0.005	< 0.010	0.011	< 0.010	0.024
		Kidney	71	< 0.010 ± 0.010	< 0.010	0.013	< 0.010	0.078
	Cattle	Meat	7	< 0.010 ± 0.006	< 0.010		< 0.010	0.020
		Liver	7	0.012 ± 0.025	< 0.010		< 0.010	0.068
		Kidney	7	< 0.010 ± 0.018	< 0.010		< 0.010	0.049
Nickel	Pig	Meat	34	< 0.010 ± 0.007	< 0.010	0.021	< 0.010	0.028
		Liver	34	0.011 ± 0.028	< 0.010	0.037	< 0.010	0.16
		Kidney	34	0.011 ± 0.014	< 0.010	0.020	< 0.010	0.076
	Cattle	Meat	5	0.011 ± 0.014	< 0.010		< 0.010	0.035
		Liver	5	< 0.010 ± 0.010	< 0.010		< 0.010	0.023
		Kidney	5	0.015 ± 0.013	0.014		< 0.010	0.035
Cobalt	Pig	Meat	36	0.001 ± 0.002	0.001	0.002	< 0.001	0.012
		Liver	36	0.010 ± 0.004	0.010	0.014	0.002	0.023
		Kidney	36	0.004 ± 0.002	0.003	0.007	0.001	0.011
	Cattle	Meat	3	0.001 ± 0.000	0.001		0.001	0.001
		Liver	3	0.043 ± 0.028	0.035		0.019	0.074
		Kidney	3	0.008 ± 0.004	0.010		0.003	0.010
Aluminium	Pig	Meat	10	0.032 ± 0.011	0.030	0.055	0.020	0.055
		Liver	10	0.028 ± 0.011	0.030	0.043	0.011	0.043
		Kidney	10	0.024 ± 0.014	0.020	0.062	0.014	0.062
	Cattle	Meat	5	0.050 ± 0.006	0.048		0.043	0.056
		Liver	5	0.068 ± 0.047	0.048		0.044	0.163
		Kidney	5	0.063 ± 0.029	0.053		0.038	0.112

n Number of samples; 90th percentile is not calculated where $n < 10$

Table 9. Data from recent literature on the levels of chromium in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.048 (42)	0.042 (42)	0.045 (42)	1980	Sweden [14]
	0.040 (20)	0.010 (4)	0.010 (4)	1980	Finland [8]
	0.014 (70)	< 0.010 (71)	< 0.010 (71)	Present study	
Cattle		0.05 (190)	0.03 (190)	1979	Australia [18]
	0.038 (42)	0.052 (42)	0.050 (42)	1980	Sweden [14]
	0.030 (64)	0.010 (8)	0.020 (4)	1980	Finland [8]
	< 0.010 (176)	0.010 (175)	< 0.010 (172)	1983	Australia [10]
		0.117 (28)	0.125 (28)	1985	USA [12]
	0.044 (3)	< 0.10 (3)	0.22 (3)	1985	FRG [19]
	0.0306 (57)	0.0223 (58)	0.0180 (59)	1986	Austria [21]
	0.088 (47)			1987	Italy [20]
	< 0.010 (7)	0.012 (7)	< 0.010 (7)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 10. Data from recent literature on the levels of nickel in meat, liver and kidney of pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.015 (42)	0.19 (42)	0.15 (42)	1980	Sweden [14]
	< 0.020 (20)	< 0.020 (4)	< 0.020 (4)	1980	Finland [8]
	< 0.010 (34)	0.011 (34)	0.011 (34)	Present study	
Cattle		0.33 (190)	0.46 (190)	1979	Australia [18]
	0.029 (42)	0.19 (42)	0.11 (42)	1980	Sweden [14]
	< 0.020 (64)	< 0.020 (8)	< 0.020 (4)	1980	Finland [8]
	0.0052 (7)	0.0078 (7)	0.0091 (7)	1984	FRG [11]
		0.049 (28)	0.090 (28)	1985	USA [12]
	0.011 (5)	< 0.010 (5)	0.015 (5)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 11. Data from recent literature on the levels of cobalt in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	0.005 (42)	0.033 (42)	0.036 (42)	1980	Sweden [14]
	< 0.010 (20)	0.010 (4)	0.070 (4)	1980	Finland [8]
	0.001 (36)	0.010 (36)	0.004 (36)	Present study	
Cattle		0.07 (190)	0.03 (190)	1979	Australia [18]
	0.003 (42)	0.033 (42)	0.027 (42)	1980	Sweden [14]
	< 0.010 (64)	0.065 (8)	0.040 (4)	1980	Finland [8]
	0.0077 (7)	0.0889 (7)	0.0499 (7)	1984	FRG [11]
	0.001 (3)	0.043 (3)	0.008 (3)	Present study	

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

Table 12. Data from recent literature on the levels of aluminium in meat, liver and kidney from pigs and cattle

Species	Meat	Liver	Kidney	Published	Country [Ref.]
Pig	< 2 (3)	< 2 (1)		1970	USA [22]
	4 (20)	9 (4)	9 (4)	1980	Finland [8]
	1.2[a]			1985	USA [23]
	0.5 (3)			1985	United Kingdom [24]
	0.85 (6)[b]			1987	USA [25]
	0.032 (10)	0.028 (10)	0.024 (10)	Present study	
Cattle	< 1 (5)	< 2 (1)		1970	USA [22]
	5 (64)	16 (8)	11 (4)	1980	Finland [8]
	0.2[a]			1985	USA [23]
	0.26 (24)			1987	USA [25]
	0.050 (5)	0.068 (5)	0.063 (5)	Present study	

[a] Cooked in non-aluminium utensils

[b] Smoked ham

Mean levels in mg/kg fresh weight. Number of samples in *brackets*

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