



Multi-element analysis of human liver and pig liver and kidney

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Title and author(s)

Multi-element Analysis of Human Liver and Pig Liver and Kidney

by K. Kemp, F. Palmgren Jensen, J. Ischeming Møller and Gyrd Hansen*

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Abstract

Our earlier developed [1] preparation technique for multi-element analysis of rat liver tissue by proton-induced X-ray emission spectroscopy (PIXE) was used on pig liver and kidney and on human liver. The detection limits and the reproducibility of samples from the same organ were the same as earlier. Only As and Ni showed great variations within the same organ. The investigation did not elucidate whether these variations were due to a really different distribution of these elements or to experimental errors. Unlike earlier investigations [2] our measurements showed relatively small variations within the same organ (5-10 per cent) of the concentration of most elements in human liver.

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1. Introduction

Our earlier investigations [1] have shown that analysis by proton-induced X-ray emission (PIXE) is very suitable for determination of the elemental content of rat liver. Simultaneously, all elements heavier than silicon can be determined in concentrations down to 0.5 ppm in dry tissue. The reproducibility of the results from different parts of the same organ was good for all the elements determined, even if only approximately 1/2 mg was used for the analysis.

This report describes an extension of the investigations to comprise pig liver and kidney and human liver. The purpose of the investigations was to test the method of preparation on other types of tissue, and to examine the homogeneity of these types of tissue.

2. Samples

Liver and kidney samples were taken from 10 pigs, all weighing approx. 60 kg when slaughtered. Feeding had been normal. The liver sections were taken from the centre of the organs. The kidney sections were taken from the centre zone of the renal cortex.

The human liver samples originated from four females and four males deceased at ages of 70-90 years in Copenhagen. The sections were taken from the centre of the liver.

3. Experiments and results

From each organ nine, 60 μm thick, self-supporting, freeze-dried cryostat sections [1] were analysed. These analyses were performed in order to determine the mean value and the variations in the concentration of the elements within the same organ.

In addition, one 2 mm thick sample from each organ was used for determination of the mean thickness of the corresponding 60 μm sections by comparing the concentration of Fe, Cu, Zn, and Rb in the two types of sample. Measurements of the energy loss of scattered protons were also performed in order to check the thickness variations. From the deviations of the results (tables 1-3) it was estimated that the thickness variations within the same organ were less than 5%. The mean thickness of sections from

different organs varied from 43 to 81 μm , probably due to different adjustments of the microtome in the different sectionings. The procedure for determining the means and variations of the section thickness has earlier been described in detail [1].

The results of the analysis are shown in tables 1-3, which include mean concentrations of each element from each organ, the corresponding estimated experimental uncertainty and standard deviation (scatter of the results around mean element concentration from each organ). For nearly all elements the scatter of the results can be explained by the experimental uncertainty. Only the standard deviations of Ni and As concentrations were considerably greater than the uncertainties. The mean values of the standard deviations for these elements were 57% and 50% for all organs analysed. These values are approximately twice the corresponding uncertainties. In the rat liver analysis [1] Ni was not included, but the As content determined showed no standard deviation greater than the uncertainties, within the same organ. The difference between the results for rats and our new results might be caused by a fine structure in the organs. However, it is not possible to exclude the occurrence of contamination (e.g. from the sectioning knife) in these measurements.

4. Discussion

In order to compare the content of elements in different types of organs, we calculated the mean values and the standard deviations of the analysis results from each type of organ (table 4). Due to the above mentioned reasons the results for Ni and As are omitted in the comparison.

A remarkable resemblance was found between the contents of most elements in the different organs. The differences in the standard deviations (smallest in rat and greatest in human tissue) can be explained by the very uniform feeding of rats, the less uniform feeding of pigs, and the varied eating habits of humans. The variation of the Fe content is probably due to differences in the amount of blood retained in the tissue. Neither the previously observed correlation between Fe, As and Se [1], nor other correlation between elements, was observed in human and pig tissue.

The ratios between the concentration of the single elements in the pig kidney and liver are shown in table 5. It is seen that the calculated standard deviations are in most cases smaller than expected from the

random variation estimated as the squared sum of the standard deviations of pig liver and kidney results (cf. table 4). This indicates a correlation in the content of the two organs from the same animal. The greatest difference in the concentrations of the same element is found for Se; also S, Cl, Ca, and Mn showed ratios differing from one.

The possibility of using small samples (< 1g wet weight) to represent a whole human organ has been investigated by Schicha et al. [2]. The standard deviations were determined by analysis of a great number of samples from each organ. The deviation for liver was found to be approximately 15% for Co, Fe, Se, and Zn. This is considerably greater than the values listed above (table 3).

Acknowledgements

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References

1. K. Kemp, F. Palmgren Jensen, J. Tscherning Møller, and G. Hansen, *Risø-M-1732* (1972) (Danish Atomic Energy Commission)
2. H. Schicha, K. Kasperek, L.E. Feinendegen, V. Sillar, and H.J. Klein, *Beitr. Path.* 55-62 146 (1972)

Table 1. The mean values of the concentration of elements in today (round current) from 10 pigs, in p.p.m. of dry matter. IC denotes the mean values of the experimental uncertainties in %, including systematic experimental errors estimated at 10%. IC denotes the standard deviations of the chemical contents in sections five, the same animal. Only values based on results from one site are half of the sections are listed.

Element	1		2		3		4		5	
	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD
P	1270	10 7	1037	10 6	1075	10 5	970	10 5	1177	10 6
S	870	10 6	739	10 7	700	10 5	695	10 6	700	10 6
Cl	604	10 8	426	10 7	503	10 5	574	10 7	500	10 5
K	956	9 9	990	8 5	970	9 4	977	9 5	1000	9 1
Na	552	10 10	478	12 7	478	12 5	407	12 5	477	12 10
Ca	6.8	21 10	6.6	19 10	6.3	20 10	6.2	20 10	6.2	20 10
Mg	27	9 23	20	9 6	170	9 7	14	9 6	104	9 7
Fe	5.4	10 10	2.4	26 35	6.0	21 25	2.6	20 20	1.8	20 10
Zn	27.9	12 17	20.3	12 12	20.1	12 12	20.4	12 10	20.0	12 6
Cu	10	9 11	95.8	9 3	94.4	9 5	84.9	9 5	102	10 6
Mn	6.1	10 10	3.1	21 30	2.3	25 42	1.6	30 35	1.3	30 30
Co	6.6	10 10	6.6	17 11	3.9	10 9	6.0	17 8	6.2	17 6
As	69.9	10 10	138	9 3	138	9 4	73.2	10 2	64.2	10 1
Se	25.5	10 11	26.8	10 6	17.8	10 7	21.5	10 5	20.0	10 6
Mo	6.1	21 21	3.1	26 20	2.9	25 20	3.2	23 10	3.4	26 10

Element	6		7		8		9		10	
	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD
P	1125	10 4	1238	10 7	1075	10 5	1185	10 3	1000	10 3
S	890	10 6	900	10 5	700	10 7	700	10 7	700	10 6
Cl	621	10 6	621	10 6	705	10 6	600	10 2	705	10 6
K	1005	9 5	1000	9 3	970	9 6	1000	9 4	974	9 3
Na	307	12 12	307	13 8	20	12 8	107	12 7	20	12 9
Ca	5.9	10 10	6.4	10 9	6.6	10 10	6.1	12 10	6.0	10 11
Mg	20	10 10	302	9 11	25	9 7	145	9 5	20	9 5
Fe	5.3	21 26	11.7	10 10	5.3	10 12	2.9	23 15	3.2	25 15
Zn	24.2	13 16	29.5	13 27	30.1	12 11	32.2	12 7	30.2	12 11
Cu	10	10 6	138	9 7	110	9 5	100	9 6	110	9 6
Mn	10.7	15 15	7.4	17 17	1.0	25 20	2.0	20 20	2.6	20 10
Co	6.5	17 9	6.2	16 11	6.7	16 10	5.4	16 7	5.0	16 13
As	66.7	10 5	100	10 5	75.4	10 6	20.0	12 6	75.0	10 6
Se	21.0	10 6	26.1	21 8	19.6	10 7	25.5	14 5	21.6	10 7
Mo	6.4	21 17	5.6	21 25	6.1	21 13	6.4	21 11	6.4	20 7

Table 2. The mean values of the concentration of elements in litter from 10 pigs, in p.p.m. of dry matter. IC denotes the mean values of the experimental uncertainties in %, including systematic experimental errors estimated at 10%. IC denotes the standard deviations of the chemical contents in sections four, the same animal. Only values based on results from one site are half of the sections are listed.

Element	1		2		3		4		5	
	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD
P	1000	10 7	700	10 1	1000	9 6	970	10 7	1000	10 6
S	690	10 6	700	10 7	690	10 5	690	10 7	690	10 6
Cl	700	11 3	100	12 6	700	10 7	700	10 3	700	11 6
K	1000	9 6	700	8 6	1000	9 7	1000	9 6	1000	9 3
Na	20	10 6	120	12 11	100	12 3	120	12 7	100	10 9
Ca	11.0	16 10	9.7	17 3	11.6	12 9	10.5	10 11	10.2	10 7
Mg	10	9 11	10	9 6	10	9 11	10	9 3	10	9 6
Fe	6.2	15 10	6.5	10 10	1.0	10 10	1.5	10 10	1.0	10 10
Zn	20.9	12 10	20.7	12 10	20.4	12 7	20.4	12 8	19.4	13 6
Cu	10	9 6	107	9 3	104	9 6	10	9 1	10	9 3
Mn	5.5	10 10	2.7	20 10			2.3	20 10	2.1	20 10
Co										
As	10.0	9 6	10.5	10 5	10	9 9	10.2	10 2	10.7	10 1
Se	25.5	10 9	24.7	12 3	27	11 5	25.2	12 5	26.6	12 3
Mo	5.9	20 10	6.5	10 9	6.1	20 10	5.9	20 11	5.7	20 10

Element	6		7		8		9		10	
	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD	Concentration (p.p.m.)	IC SD
P	900	10 3	1000	10 7	690	10 7	1000	9 5	1000	9 7
S	600	10 3	600	10 7	600	10 9	600	10 5	600	10 5
Cl	700	10 3	700	10 7	700	10 8	700	10 7	700	10 7
K	1000	9 4	1000	9 5	690	6 5	1000	1 3	1000	8 5
Na	10	10 5	100	10 11	10	10 3	100	10 7	10	10 7
Ca	6.7	17 12	11.9	15 9	6.0	10 6	11.4	10 6	6.2	12 5
Mg	10	9 7	10	9 9	10	9 4	10	9 3	10	9 3
Fe	7.2	10 10	10.1	10 10	1.1	10 10	6.0	10 10	1.0	10 10
Zn	20.9	13 10	20.2	13 8	13.8	13 5	20.6	12 6	20.3	10 8
Cu	10	9 4	100	9 6	10	9 2	10	9 1	10	9 2
Mn	6.7	10 10	1.6	20 10	1.1	20 10	6.0	10 10		
Co										
As	10.0	9 3	100	9 4	10.0	9 4	10.0	10 4	10.2	9 3
Se	20.4	10 6	20.2	10 6	20.4	10 5	20.4	12 4	20.8	10 6
Mo	5.7	21 10	6.2	10 10	2.6	10 10	5.2	10 9	6.0	20 10

Table 3. The mean values of the concentration of elements in liver from eight human beings, in p.p.m. of dry matter. UC denotes the mean value of the experimental uncertainty in %, including systematic experimental uncertainty in F and systematic experimental errors estimated of 10% . SV denotes the standard deviations of the element contents in sections from the same organ. Only values based on results from more than one half of the sections are listed.

Element	1			2			3			4		
	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)
P	72.28	10	9	108.1	10	4	147.9	10	3	95.1	10	11
S	7886	10	9	8125	10	3	7781	10	2	7797	10	8
Cl	8747	10	6	7385	10	4	5455	10	4	6812	10	9
K	3035	9	5	3644	9	3	10423	9	4	11826	9	8
Ca	455	10	10	295	14	9	527	13	9	262	16	17
Na	4.7	23	21	5.7	23	12	5.6	22	21	6.5	24	16
Pb	1627	9	7	1493	9	4	2028	9	8	904	9	8
Mg	6.2	21	73	3.8	26	57	4.7	23	26	3.1	34	41
Cu	21.6	13	13	21.8	14	10	26.0	13	20	22.0	13	13
Mn	179	9	4	330	9	4	194	9	5	252	10	7
As	2.9	21	40	5.8	20	26	3.4	28	42	1.9	29	43
Se	1.1	31	21	1.4	30	14				1.1	36	9
Br	13.6	12	12	17.5	12	4	23.4	12	5	14.3	13	12
Mo	13.3	15	8	28.1	13	3	32.0	13	5	24.7	14	9
Si	3.0	25	14	4.5	21	15	3.6	23	13	3.0	21	22
Co				7.8	31	27	9.1	26	9	10.4	28	25
Zn	3.1	31	23				6.8	31	16			

Element	5			6			7			8		
	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)	Concentration (p.p.m.)	UC (%)	SV (%)
P	947	10	5	7353	10	5	9126	10	6	9813	10	6
S	4771	10	5	4953	10	9	4753	10	5	4733	10	4
Cl	6804	10	4	4016	10	5	4894	10	3	6397	10	4
K	9138	9	4	7623	9	4	7900	9	5	9882	9	4
Ca	277	13	6	182	13	18	223	13	9	257	13	7
Na	4.5	20	12	4.1	20	17	4.8	15	17	6.3	17	13
Pb	880	9	5	963	9	8	1360	9	4	1294	9	4
Mg	1.2	36	27	6.7	24	57	4.8	22	39	1.9	39	25
Cu	19.9	13	20	14.5	14	15	27.2	12	20	18.0	13	11
Mn	287	9	6	334	9	3	397	9	3	930	9	4
As							1.7	30	46	1.1	39	39
Se	0.9	37	17				1.2	32	21	0.8	40	19
Br	19.1	12	6	10.1	13	6	10.2	13	8	11.5	12	20
Mo	17.7	14	6	18.1	15	3	18.3	13	3	18.9	15	8
Si	3.0	24	13	3.5	22	21	3.9	22	12	3.1	20	23
Co	6.8	29	19	19.0	19	15	9.9	26	23			
Zn				2.1	37	22	3.5	31	27	2.2	40	18

Table 4. The mean values and calculated standard deviations of the concentrations of elements in eight rat livers, 10 pig kidneys and livers, and eight human livers. All concentrations are in p.p.m. of dry matter. The values for the rat liver are calculated from the results in ref. 1.

Element	Rat liver		Pig kidney		Pig kidney		Human liver	
	Concentration (p.p.m.)	Standard Deviation (%)	Concentration (p.p.m.)	Standard Deviation (%)	Concentration (p.p.m.)	Standard Deviation (%)	Concentration (p.p.m.)	Standard Deviation (%)
P	12400	8	18200	13	10800	7	8800	12
S	5980	10	4900	24	6300	27	6000	28
Cl	3500	17	2900	21	3500	15	6000	22
K	11500	5	9900	12	10000	11	8800	23
Ca	200	11	190	10	300	10	260	26
Na	7.4	13	10.1	13	5.2	25	5.8	25
Pb	660	29	420	57	200	27	1240	30
Cu	22	9	22	20	26	20	22	19
Mg	133	8	140	12	107	13	260	26
Mn	3.7	26	0.8	17	4.7	14	1.1	19
As	23	7	77	39	85	41	15.0	31
Se	72	5	28	12	22	9	20	24
Si	6.8	17	4.2	22	6.0	20	3.9	21
Co			6		6		10.3	41
Zn			62		62		3.9	24

Table 5. The ratio between the elemental contents in 10 pig kidneys and livers, and the calculated standard deviation.

Element	Concentration ratio kidney/liver	Standard deviation (%)
P	1.29	12
S	1.29	10
Cl	1.09	17
K	1.04	8
Ca	1.72	10
Na	0.51	21
Pb	0.60	45
Cu	1.40	41
Mn	0.77	12
As	0.80	13
Se	1.17	23
Si	0.78	23
Co	1.00	27