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

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

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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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CONTENTS

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 then 5%. The mean thickness of sections from

different organs varied from 43 to 81 µm, probably due to different adjustments of the microtone 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 deivations 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

Thanks are due to the Danish Agricultural and Veterinary Research Council for the financial support of the project, and to the Niels Bohr Institute, Copenhagen, for placing the Van de Graaff accelerator at our disposal for the investigations.

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. Siller, and H.J. Klein, Beitr. Path. 55-62 146 (1972)

Table 1. The mean values of the concentration of elements in kidney (renal cortex) from 10 pigs, in p.p.m. of dry matter. UC denotes the mean values of the experimental uncertainties in %, including systematic experimental errors estimated at 10%. SV denotes the standard deviations of the elemental contents in sections from the same animal. Only values based on results from more than one half of the sections are listed.

Element	1 Concentration (p.p.m.)	UC (%)	SV (%)	2 Concentration (p.p.m.)	UC (%)	SV (%)	3 Concentration (p.p.m.)	UC (%)	SV (%)	4 Concentration (p.p.m.)	UC (%)	SV (%)	5 Concentration (p.p.m.)	UC (%)	SV (%)
P	11708	10	7	10417	10	6	10575	10	4	[illegible]	10	5	11197	10	4
S	8280	10	6	5290	10	7	5050	10	5	4865	10	6	[illegible]	10	6
Cl	4836	10	8	4836	10	7	5015	10	5	4554	10	7	5850	10	5
K	9526	9	9	9509	8	5	[illegible]	9	4	9137	9	5	[illegible]	9	8
Ca	332	10	18	298	12	7	258	12	5	302	12	5	295	12	10
Mn	4.8	21	18	4.4	19	14	4.3	20	10	4.2	20	22	4.2	21	29
Fe	247	9	21	280	9	6	170	9	7	142	9	4	190	9	7
Ni	9.4	16	56	2.4	24	35	4.0	21	35	2.6	28	69	1.8	29	58
Cu	27.9	12	17	20.3	12	12	22.1	12	10	20.4	12	10	30.9	12	4
Zn	101	9	11	96.8	9	3	95.4	9	5	85.9	9	5	102	10	4
As	6.1	18	50	3.1	21	50	2.3	25	62	1.6	30	58	1.3	30	50
Se	4.6	18	22	4.4	17	11	3.9	18	9	4.0	17	8	4.2	17	4
Br	89.9	10	10	138	9	3	138	9	4	53.2	10	2	84.2	10	1
Rb	25.5	20	11	20.8	27	4	17.8	30	7	21.3	17	5	23.9	18	4
[illegible]	4.1	23	21	3.1	24	20	2.9	25	20	3.2	33	18	3.4	20	19

Element	6 Concentration (p.p.m.)	UC (%)	SV (%)	7 Concentration (p.p.m.)	UC (%)	SV (%)	8 Concentration (p.p.m.)	UC (%)	SV (%)	9 Concentration (p.p.m.)	UC (%)	SV (%)	10 Concentration (p.p.m.)	UC (%)	SV (%)
P	11295	10	4	12128	10	7	10625	10	5	11615	12	3	[illegible]	10	3
S	8505	12	6	[illegible]	10	5	5350	10	7	5568	10	7	[illegible]	10	4
Cl	6352	10	6	6121	10	6	5955	10	4	6220	10	2	5095	10	4
K	11095	9	5	[illegible]	9	3	9845	9	6	10595	9	4	[illegible]	9	5
Ca	357	12	12	377	13	8	280	12	8	317	12	7	[illegible]	12	9
Mn	5.9	20	18	8.4	18	9	4.6	19	16	6.1	17	14	5.0	19	11
Fe	210	10	10	322	9	11	223	9	7	145	9	5	285	9	5
Ni	8.3	21	86	11.7	18	60	5.3	19	62	2.9	23	45	3.1	25	45
Cu	24.2	13	16	29.5	13	27	30.1	12	11	35.2	12	7	30.2	12	11
Zn	104	10	6	135	9	7	114	9	5	116	9	4	115	9	6
As	10.7	15	55	7.4	17	67	2.0	25	29	2.0	25	30	2.6	21	30
Se	4.5	17	9	6.2	16	11	4.7	16	14	5.4	16	9	5.0	25	13
Br	89.7	10	5	101	10	5	75.4	10	4	25.8	12	4	75.5	10	6
Rb	21.8	22	6	24.1	22	8	19.6	20	7	23.5	14	5	21.6	19	7
[illegible]	4.4	22	17	5.6	21	21	4.1	21	13	4.4	21	11	4.4	20	7

Table 2. The mean values of the concentration of elements in liver from 10 pigs, in p.p.m. of dry matter. UC denotes the mean values of the experimental uncertainties in %, including systematic experimental errors estimated at 10%. SV denotes the standard deviations of the elemental contents in sections from the same animal. Only values based on results from more than one half of the sections are listed.

Element	1 Concentration (p.p.m.)	UC (%)	SV (%)	2 Concentration (p.p.m.)	UC (%)	SV (%)	3 Concentration (p.p.m.)	UC (%)	SV (%)	4 Concentration (p.p.m.)	UC (%)	SV (%)	5 Concentration (p.p.m.)	UC (%)	SV (%)
P	[illegible]	10	7	7057	10	5	[illegible]	9	6	[illegible]	10	9	[illegible]	10	4
S	6905	10	6	[illegible]	10	7	[illegible]	10	5	[illegible]	10	7	[illegible]	10	6
Cl	[illegible]	11	5	[illegible]	11	6	[illegible]	10	9	[illegible]	10	5	[illegible]	11	4
K	[illegible]	9	6	[illegible]	8	4	[illegible]	9	5	[illegible]	9	4	[illegible]	9	5
Ca	[illegible]	10	6	[illegible]	13	11	[illegible]	13	5	[illegible]	13	7	139	14	9
Mn	11.0	14	10	9.7	13	5	11.6	13	9	10.5	14	12	8.2	14	7
Fe	[illegible]	9	11	[illegible]	9	4	[illegible]	9	11	[illegible]	9	5	[illegible]	9	6
Ni	8.3	15	40	4.3	20	66	1.0	35	20	1.8	29	40	2.0	25	31
Cu	25.9	12	24	21.7	12	15	27.6	12	7	20.2	12	8	17.4	13	6
Zn	[illegible]	9	6	127	9	3	[illegible]	9	6	[illegible]	9	1	[illegible]	9	3
As	3.5	18	40	2.7	27	45				2.3	22	40	2.1	25	45
Se													0.7	30	35
Br	92.8	9	6	68.5	10	5	[illegible]	9	8	80.2	10	2	60.7	10	2
Rb	25.3	20	9	24.7	17	3	27	21	5	23.7	17	5	28.6	15	3
[illegible]	3.9	22	14	4.4	19	9	4.1	20	15	3.9	20	13	3.7	21	21

Element	6 Concentration (p.p.m.)	UC (%)	SV (%)	7 Concentration (p.p.m.)	UC (%)	SV (%)	8 Concentration (p.p.m.)	UC (%)	SV (%)	9 Concentration (p.p.m.)	UC (%)	SV (%)	10 Concentration (p.p.m.)	UC (%)	SV (%)
P	[illegible]	10	3	[illegible]	10	7	[illegible]	10	7	[illegible]	9	5	[illegible]	9	7
S	[illegible]	10	3	[illegible]	10	7	[illegible]	10	9	[illegible]	10	5	[illegible]	10	5
Cl	[illegible]	10	5	[illegible]	10	7	[illegible]	10	8	[illegible]	10	5	[illegible]	10	7
K	[illegible]	9	4	[illegible]	9	5	[illegible]	8	5	[illegible]	8	3	[illegible]	8	5
Ca	[illegible]	15	9	[illegible]	15	11	[illegible]	13	9	[illegible]	13	7	[illegible]	13	7
Mn	8.7	17	12	11.9	15	9	9.0	14	6	11.4	14	6	9.1	13	5
Fe	[illegible]	9	7	[illegible]	9	9	[illegible]	9	4	[illegible]	9	3	[illegible]	9	3
Ni	7.2	19	14	18.1	25	100	1.1	34	35	0.8	40	25	1.0	37	32
Cu	25.9	13	16	22.2	15	8	13.8	13	5	24.8	12	6	21.3	12	8
Zn	[illegible]	9	4	[illegible]	9	6	[illegible]	9	2	[illegible]	9	8	[illegible]	9	2
As	2.7	20	50	1.6	30	47	1.1	31	28	0.8	40	30			
Se				0.9	45	13				0.8	30	19	0.6	45	[illegible]
Br	94.5	9	3	[illegible]	9	4	68.9	9	4	70.9	12	4	81.2	9	3
Rb	30.4	18	4	38.2	17	6	29.4	37	5	35.1	12	4	27.8	17	4
[illegible]	3.7	21	10	6.2	19	12	2.6	24	17	5.2	19	9	4.2	21	20

Table 3. The mean values of the concentration of elements in liver from eight human beings, in p.p.m. of dry matter. MC denotes the mean value of the experimental uncertainties in %, including systematic experimental uncertainties in F and systematic experimental errors estimated at 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 Concentration (p.p.m.)	MC (%)	SV (%)	2 Concentration (p.p.m.)	MC (%)	SV (%)	3 Concentration (p.p.m.)	MC (%)	SV (%)	4 Concentration (p.p.m.)	MC (%)	SV (%)
F	72.8	10	9	9851	10	4	10090	10	3	9591	10	11
S	7886	10	9	8185	10	3	7791	10	2	7797	10	8
Cl	8747	10	6	7585	10	4	5463	10	4	6812	10	9
K	9035	9	5	9694	9	3	10423	9	4	11836	9	8
Ca	435	10	10	293	14	9	327	13	9	262	16	17
Mn	4.7	23	21	5.7	23	12	5.6	22	21	6.5	24	16
Fe	1627	9	7	1873	9	4	2058	9	8	984	9	8
Rb	6.2	21	73	5.8	26	57	4.7	25	36	3.1	34	41
Cu	21.6	13	13	22.8	14	18	26.9	13	38	22.6	13	13
Sr	179	9	4	330	9	4	194	9	5	252	10	7
As	2.9	21	40	5.8	20	56	3.4	28	42	1.9	29	43
Ag	1.1	31	21	1.4	30	14				1.1	35	9
Br	13.6	12	12	17.3	12	4	23.4	12	5	14.3	13	12
Rb	13.3	15	8	28.[illegible]	13	3	32.0	13	5	24.7	14	9
Ba	3.0	25	14	4.3	21	15	3.6	23	13	3.0	21	22
Cd				7.8	31	27	9.1	26	9	10.4	28	25
Pb	3.1	31	25				6.8	21	16			

Element	5 Concentration (p.p.m.)	MC (%)	SV (%)	6 Concentration (p.p.m.)	MC (%)	SV (%)	7 Concentration (p.p.m.)	MC (%)	SV (%)	8 Concentration (p.p.m.)	MC (%)	SV (%)
F	8427	10	5	7339	10	5	9126	10	6	9813	10	6
S	4771	10	5	4675	10	9	4793	10	5	4733	10	4
Cl	6854	10	4	4484	10	5	4896	10	3	6597	10	4
K	9158	9	4	7625	9	4	7903	9	5	9282	9	4
Ca	277	13	6	192	13	18	225	13	9	257	13	7
Mn	4.5	20	12	4.1	20	17	5.8	15	17	6.3	17	13
Fe	880	9	5	563	9	8	1560	9	4	1254	9	4
Rb	1.2	36	27	6.7	24	97	4.8	22	59	1.9	29	25
Cu	19.9	13	20	14.3	14	15	27.2	12	20	18.0	13	11
Sr	287	9	6	331	9	3	387	9	3	330	9	4
As							1.7	32	46	1.1	39	89
Ag	0.9	37	17				1.2	32	21	0.8	40	19
Br	19.1	12	6	10.1	13	6	10.8	13	8	11.5	12	20
Rb	17.7	14	6	18.1	15	5	18.3	13	3	12.9	15	8
Ba	3.0	24	18	3.5	22	21	3.9	22	12	3.1	20	21
Cd	6.8	29	19	19.0	19	15	9.9	26	23			
Pb				2.1	37	22	3.3	32	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 liv.rs, 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: Concentration (p.p.m.)	Rat liver: Standard Deviation (%)	Pig liver: Concentration (p.p.m.)	Pig liver: Standard Deviation (%)	Pig kidney: Concentration (p.p.m.)	Pig kidney: Standard Deviation (%)	Human liver: Concentration (p.p.m.)	Human liver: Standard Deviation (%)
F	12400	8	14500	13	10800	7	8800	12
S	9500	10	4500	24	6300	27	6600	28
Cl	3500	17	4500	21	3500	15	6400	22
K	11500	5	9700	12	10000	11	8870	23
Ca	220	11	190	10	320	10	280	26
Mn	7.4	13	10.1	13	5.2	25	5.8	25
Fe	660	29	420	57	260	27	1240	38
Cu	22	9	22	20	28	20	22	19
Zn	153	8	140	18	107	13	280	26
Ag	3.7	26	0.8	17	4.7	19	1.1	19
Br	25	7	77	39	85	41	19.0	31
Rb	72	5	28	18	22	9	20	34
Ba	4.8	17	4.2	22	4.0	20	3.9	21
Cd			<6		<6		10.9	41
Pb			<2		<2		3.5	54

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 (%)
F	1.09	12
S	1.29	16
Cl	1.99	17
K	1.04	8
Ca	1.72	10
Mn	0.52	21
Fe	0.60	45
Cu	1.40	41
Zn	0.77	12
Ag	0.88	15
Br	1.17	23
Rb	0.78	25
Ba	1.40	27