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Proximate and heavy metal composition in chicken meat and tissues

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Abstract

Three different aged groups (4-week, 8-week and 18-week) of chickens were obtained from Manisa (in Turkey) Poultry Diseases Research and Vaccine Production Institute. Eleven metals (Cd, Ca, Cu, Fe, Pb, Mg, Mn, Hg, K, Na and Zn) and one non-metal (P) (heart, gizzard, livers, kidneys and spleens and some mineral matter in chicken tissues and meats) were determined using atomic absorption spectrophotometry. A flame photometer was used for determinations of sodium and potassium. After oven-drying of samples, P was determined by a colorimetric method. Proximate and mineral composition of heart, gizzard and meat from different aged group chickens were determined. It is concluded that there is wide variation in metal contents of these tissues.

1. Introduction

Retentions of thiamine, riboflavin, vitamin B6, niacin, vitamin E and minerals (Na, K, Ca, Mg, P, Fe, Cu, Zn) during cooking of beef, pork and chicken meat were investigated by Maskova, Rysou, Fiedlerova, and Holusova (1994). Electrothermal atomic absorption spectrometry has been used for simultaneous determination of Ag, Cd, Cr or Pb in solid reference materials such as bovine liver, oyster tissue and dogfish liver (Berglund & Baxter, 1995). A study was performed of effects of heavy metals on hepatic metallothionein in salmonid muscle and liver tissues and rainbow trout muscle and liver tissues (Deniseger, Erickson, Austin, Roch, & Clark, 1990).

In an earlier study (Hecht & Kumpulainen, 1995), samples of beef, veal, pork, chicken, turkey and horsemeat were analysed for Ca, Cu, Fe, Mg, Mn, Ni, Zn, Cd and Pb. Differences in minerals in meat products were investigated by Alcaide-Castinera, Gomez, Carmona-Gonzalez, and Fernandez-Salgvero (1990). Mn, Cu, Zn, Fe, Cd, Hg and Pb concentrations were determined in muscle meat, liver and kidney of ducks, geese, chickens, hens, rabbits and sheep slaughtered in the northern part of Poland (Falandysz, 1991). Mineral and heavy metal contents of retail meat and meat products were determined (Tamate, 1987). Rapid, direct atomic spectrochemical analyses of meat samples by the technique of slurry atomisation have been reported and Pb, Cd, Cr and Ni were detected at very low concentrations in homogenised beef liver by graphite furnace AAS (Fietkau, 1987).

In the present study, Hg, Cd, Cu, Pb, Ca, Fe, Mg, Mn, P, K, Na and Zn levels of chicken liver, kidney and spleen were determined using AAS. A flame photometer was used for determinations of Na and K. After oven-drying of samples, P was determined by a colorimetric method.

2. Materials and methods

Three differently aged groups of SPF chickens were supplied from the Poultry Diseases Research and Vaccine Production Institute in Manisa-Turkey. These were 4-week, 8-week and 18-week. There were 10 chickens in each group. Determinations of Cd, Ca, Cu, Fe, Pb, Mg, Mn, Hg, K, Na and Zn metals and P in 10 samples of heart, gizzard, liver, kidney and spleen of animals belonging to each group were obtained.

For recovery of Na, K, Mg, Ca, Fe, Mn, Pb, Cd, Cu and Zn the organs were digested using a mixture of HNO_3:H_2SO_4:$HClO_4$(4:1:1), v:v, (20 ml for 2–4 g sample) and heating at 80°C for 3 h. After cooling, 20 ml demineralized water was added, the digest was again heated up to 150°C for 4 h and brought to a volume of 25 ml with demineralized water.

For analysis of mercury, the technique described was as follows: digestion of 0.5 g the homogenised sample

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was carried out using 10 ml of a HNO_3:H_2SO_4: H_2O_2 oxi-acid mixture at a ratio of 4:1:1, v:v, at 60°C in a thermostatic bath, being completed in about 1.5 h. A solution of potassium permanganate at 6%, w/v, was used for oxidation of the sample. The excess of permanganate was reduced with a solution of hydroxylamine sulphate (Tüzen, Özdemir, & Demirbaş, 1998).

Metal ion concentrations were determined as three replicates by Pye Unicam SP-9 atomic absorption spectrophotometer (AAS). A flame photometer (Biotechnical Instruments, Model 8T 624D) was used for determinations of alkali metals. After oven-drying of samples, P was determined by a colorimetric method. To eliminate the errors derived from matrix effect, the standard addition method was used instead of plotting a calibration curve (Skoog & West, 1981). To apply the standard addition technique, 20 g of organ sample was taken and 1 ml of heavy metal working solution was added which contained a determined amount of the metal ion. The standard-added sample was analysed in the same way as the one without standard addition. The number of replicates was also three for standard-added samples. Before applying the standard addition technique, a calibration curve was obtained to see the linear relationship between absorbance and lead concentration in the concentration range being worked. A similar curve was plotted for the relationship between absorbance and cadmium concentration.

Moisture content was determined by drying a 3–5 g sample at 105°C to constant weight (Boccard et al., 1981). Ashing was carried out at 750°C for 2 h (Perez & Andujar, 1980); protein content was determined by the block digestion method and ether-extractable intramuscular fat content by solvent extraction (Cunniff, 1995).

The element contents of food, soil, and water samples and pH values and organic-matter contents of soil samples used were also determined.

3. Results and discussion

Proximate and mineral compositions of three aged groups of chicken's heart and gizzard are presented in Table 1.

Ash content did not differ ($P > 0.05$) between aged groups in the same tissue. This shows the relative consistency of ash between tissues. Intramuscular fat contents were higher ($P < 0.05$) in the heart samples than those of the gizzard.

The average mineral compositions (mg/100 g) of different tissues are given in Table 2. Similar to other meat species, potassium was quantitatively the most important mineral in chicken tissues, followed by phosphorus and sodium (Tables 1 and 2) (Lawrie, 1990). The concentration of both manganese and iron were higher in the heart and gizzard, while zinc was higher in the other tissues. The manganese content is very high in other animal hearts and turkey gizzards (Bechtel, 1986).

In the liver sample, the highest Cu content was 3.7 mg/kg wet weight for 4-week chickens. The lowest concentration of Cu was 1.99 mg/kg in the spleen obtained from 8-week chickens.

In the kidney sample the highest Pb content was 0.103 mg/kg for 18-week chickens. The lowest content of Pb

Table 1
Proximate analysis and mineral composition of heart and gizzard from differently aged group chickens (mean ± SD)

	Heart			Gizzard		
Nutrient	4-week	8-week	18-week	4-week	8-week	18-week
Proximate[a]						
Water	74.7 ± 0.53	74.3 ± 0.52	74.6 ± 0.53	76.8 ± 0.51	76.4 ± 0.52	76.2 ± 0.52
Intramuscular fat	9.18 ± 0.17	9.11 ± 0.15	9.32 ± 0.13	3.85 ± 0.09	4.05 ± 0.10	4.18 ± 0.12
Protein (Nx6.25)	15.5 ± 0.45	15.6 ± 0.57	15.8 ± 0.61	17.9 ± 0.51	18.2 ± 0.51	18.2 ± 0.48
Ash	0.83 ± 0.05	0.85 ± 0.04	0.85 ± 0.06	0.82 ± 0.07	0.85 ± 0.05	0.85 ± 0.05
Minerals[b]						
Cadmium	0.003	0.004	0.004	0.002	0.003	0.003
Calcium	11.3 ± 0.36	12.3 ± 0.41	12.0 ± 0.54	8.12 ± 0.25	7.96 ± 0.12	8.05 ± 0.30
Copper	0.34 ± 0.06	0.35 ± 0.09	0.35 ± 0.08	0.11 ± 0.02	0.10 ± 0.03	0.12 ± 0.03
Iron	4.49 ± 1.32	5.61 ± 0.67	5.18 ± 0.84	5.82 ± 1.12	6.93 ± 0.91	6.84 ± 0.54
Lead	0.032	0.029	0.037	0.050	0.046	0.048
Magnesium	14.5 ± 1.25	15.4 ± 0.78	15.2 ± 0.62	15.9 ± 1.34	16.8 ± 0.76	16.6 ± 0.68
Manganese	87.6 ± 2.65	86.4 ± 3.21	89.6 ± 1.96	65.0 ± 2.33	64.5 ± 1.77	65.1 ± 2.45
Mercury	0.019	0.022	0.027	0.039	0.048	0.051
Phosphorus	177 ± 4.18	174 ± 6.71	175 ± 3.82	142 ± 2.34	138 ± 4.56	135 ± 1.78
Potassium	179 ± 2.89	180 ± 4.41	180 ± 3.11	239 ± 1.96	236 ± 3.87	237 ± 4.12
Sodium	72.3 ± 2.34	73.2 ± 1.83	74.1 ± 2.45	74.8 ± 2.35	75.1 ± 1.55	76.1 ± 2.86
Zinc	6.13 ± 0.46	6.22 ± 0.54	6.48 ± 0.72	3.05 ± 0.33	3.14 ± 0.38	3.18 ± 0.41

[a] g/100 g edible portion.
[b] mg/100 g edible portion.

Table 2
Average mineral contents (mg/kg wet weight) in livers, kidneys and spleens obtained from 5-week and egg-period-aged chickens[b]

	Liver[c]			Kidney[c]			Spleen[c]		
Metal[a]	4-week	8-week	18-week	4-week	8-week	18-week	4-week	8-week	18-week
Cadmiunm	0.050	0.011	0.039	0.075	0.011	0.052	0.084	0.011	0.065
Calcium	11.1	10.9	11.0	9.15	9.18	9.41	9.51	9.44	9.58
Copper	3.70	3.24	2.95	2.97	2.31	2.68	2.17	1.99	2.42
Iron	0.814	0.896	0.905	0.847	0.838	0.866	0.901	0.895	0.923
Lead	0.065	0.092	0.088	0.064	0.074	0.092	0.065	0.082	0.103
Magnesium	23.5	25.1	24.9	20.8	21.6	21.7	24.6	25.5	28.4
Manganese	0.021	0.018	0.016	0.024	0.023	0.025	0.030	0.028	0.032
Mercury	0.050	0.039	0.084	0.075	0.037	0.052	0.009	0.011	0.014
Phosphorus	169	175	174	174	164	165	153	157	163
Potassium	213	216	219	220	219	226	215	216	217
Sodium	74.8	75.7	76.9	73.4	72.7	74.2	72.4	72.9	73.3
Zinc	26.9	26.6	28.1	24.3	23.0	23.2	21.9	22.8	24.0

[a] For five separate determination
[b] Relative standard deviation: 3.462.
[c] For all experiments: $t=2.456$ for $n=5$.

was 0.065 mg/kg in the liver obtained from 4-week chickens. Pb and Hg levels in chicken liver were determined as 0.102 and 0.053 mg/kg, respectively (Dağistan, 1996).

In the chicken meat, the highest content was Na, 84.3 mg/kg for 18-week chickens. The lowest level of Na was 62.0 mg/kg in the chicken sample obtained from 4-week chickens.

In general, Cu, Pb and Zn concentrations of the liver and the kidney from the chickens and Na, K, Ca, P and the chicken meat's Mg agreed with literature data (Table 2); however, Hg and Cd contents were lower than most published values (USDA, 1979; Bechhtel, 1986; Alcaide-Castinera et al., 1990; Falandysz, 1991; Maskova et al., 1994). There were wide variations in Cd and Pb contents of kidney from differently aged chickens, due to lack of standardisation of raw materials, processing methods and final products.

Proximate analysis and mineral composition of chicken meat, compared to that of ostrich and beef have been reported (USDA, 1979; Holland et al., 1991; Sales & Hayes, 1996). Protein and ash contents are constant between species. The exceptionally low intramuscular fat content of ostrich meat (0.65 g/100 g) in relation to that in beef (6.33 g/100 g) or chicken (3.08 or 3.66 g/100 g) is notable. Beef with a low moisture content has a high intramuscular fat content while the reverse is true for ostrich meat (Sales & Hayes, 1996).

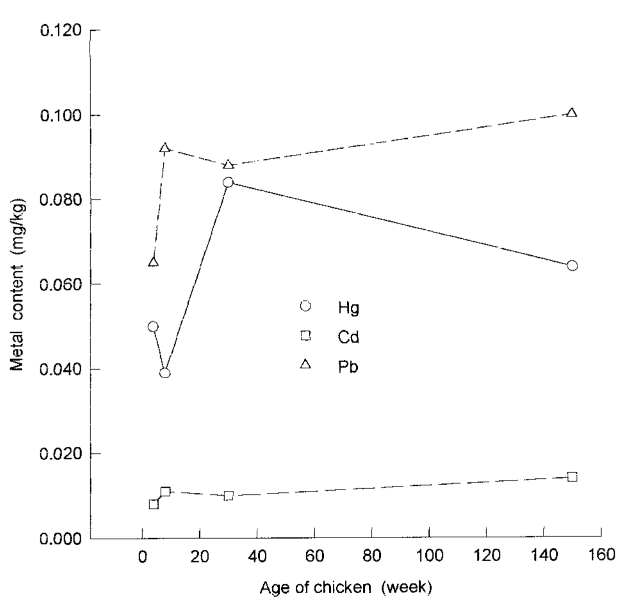

Fig. 1. Plots of some heavy metal contents in chicken liver.

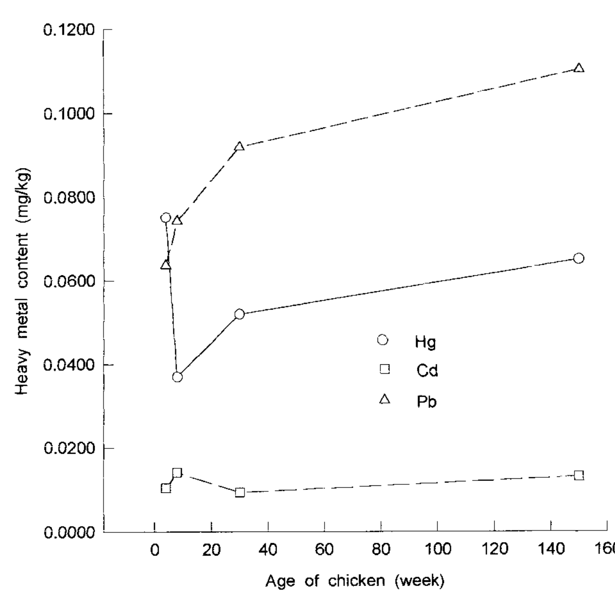

Fig. 2. Plots of some heavy metal contents in chicken kidney.

P, Mn and Fe contents were higher and Na lower in ostrich meat than either beef or chicken, while K, Ca, Mg, Cu and Zn classify as intermediate between beef and chicken. The Na content of ostrich meat has an advantage for people who have to consume a low Na diet. Fe is considered to be the most important minor mineral in meat, especially for adult women (Sales & Hayes, 1996). The amount of Fe potentially available from foods, however, not only depends upon the percent of Fe present, but also on the nature of that Fe (Monson, 1978).

Mineral contents per 100 g edible portion of raw chicken were found (Bechtel, 1986; USDA, 1986) to be: calcium, 12 and 12 mg, copper, 0.346 and 0.05 mg, iron, 5.96 and 0.9 mg, magnesium, 15 and 25 mg, manganese, 89 and 20 μg, phosphorus, 177 and 173 mg, potassium, 176 and 229 mg, sodium, 74 and 77 mg, and zinc, 6.59 and 1.5 mg respectively.

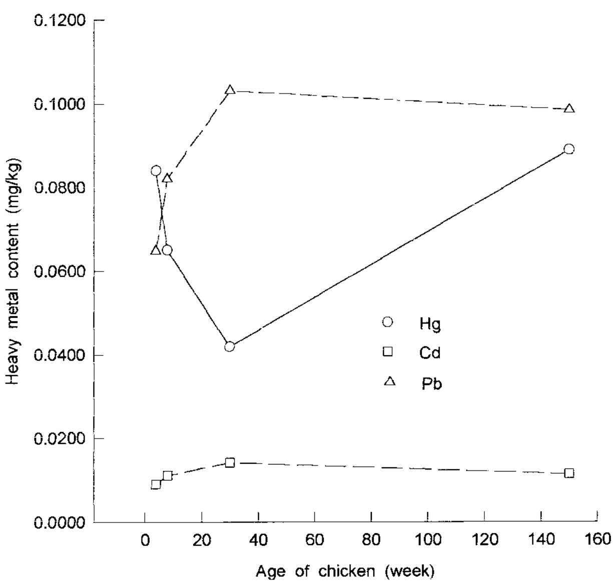

Fig. 3. Plots of some heavy metal contents in chicken spleen.

Mineral contents per 100 g edible portion of beef and ostrich were found (Holland et al., 1991; USDA, 1986) to be calcium, 7 and 8 mg, copper, 0.14 and 0.10 mg, iron, 2.1 and 2.3 mg, magnesium, 20 and 22 mg, manganese, 40 and 60 μg, phosphorus, 180 and 213 mg, potassium, 350 and 269 mg, sodium, 61 and 43 mg, and zinc, 4.3 and 2.0 mg, respectively.

Hg, Cd and Pb levels of differently aged chickens in their livers, kidneys and spleens are seen in Figs. 1–3.

From Figs. 1–3, the levels of Hg in the samples of tissue obtained from differently aged chickens as a whole ranged from 0.037 to 0.089 mg/kg. The sample showing the highest level was spleen which reached up to 0.089 mg of Hg per kg wet weight. The lowest proportion of Hg was in the kidney of 8-week chicken. Dağistan (1996) reported that the Hg content averaged 0.14 mg/kg in liver and other organs of chickens fed 0.95 mg Hg/kg feed. The highest Cd content (0.014 mg/kg) was found in the liver from 150-week chickens. The levels of Cd in the samples obtained from differently aged chickens, as a whole ranged from 0.006 to 0.015 mg/kg.

A study was made of trace metals, after partial hepatectonomy, in rat liver (Srivastava et al., 1988). The effects of Cd, Mn and Ni on the levels of Cu, Mn, Fe and Zn in liver were studied in sham-operated and partially-hepatectomized rats, 72 h after metal administration. Partial hepatectomy produced significant increase in the level of Zn and decrease in the levels of Cu, Fe and Mn. The metabolic dispositions of these essential micronutrients were significantly altered as a result of Cd administration in both the groups. Mn and Ni had little effect and only affected the level of Zn.

The fact that toxic metals are present in high concentrations in the feeds is of particular importance in relation to the FAO/WHO (1976) standards for Pb and Cd as toxic metals. The maximum permissible doses for an adult are 3 mg Pb and 0.5 mg Cd per week, but the recommended doses are only one-fifth of those quantities.

Chickens, like other animals, ultimately depend on plants to synthesise inorganic material into organic

Table 3.
Results of element analyses of food, soil and water samples (mg element/kg sample) and properties of soil samples

Sample	Hg	Cd	Cu	Pb	Zn	Mg	Mn	Fe	Ca	K	Na	P
Average concentration of elements in feed												
Using for 4-week	0.009	0.031	0.390	0.174	51.1	24.7	12.6	78.6	18.8	12.7	48.4	290
Using for 18-week	0.003	0.018	0.380	0.217	49.7	28.4	15.0	66.9	57.5	86.5	62.3	269
Maximum concentration of elements in soil	0.626	5.12	41.0	3.48	54.9	42.6	105	186	22.5	316	98.6	316
Maximum concentration of elements in water	< 0.001	0.006	0.018	0.036	2.13	1.42	1.10	10.764	4.84	26.4	18.5	32.8
Other properties of soil samples												
pH value	2.86 (min)	6.78 (max)										
Organic-matter content (mg/kg dry weight)	396 (min)	916 (max)										

compounds they can use as food. The element contents of food, soil and water samples (mg element/kg sample) and other properties of soil samples are presented in Table 3.

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