Trakia Journal of Sciences, Vol. 5, No. 2, pp 61-66, 2007

Available online at:
http://www.uni-sz.bg

ISSN 1312-1723

Original Contribution

STUDY ON THE LEVEL OF HEAVY METAL CONTAMINATION IN FEED MATERIALS AND COMPOUND FEED FOR PIGS AND POULTRY IN BULGARIA

D. Alexieva[1*], S. Chobanova[2], A. Ilchev[2]

[1]Department of Poultry Breeding, Faculty of Agriculture;
[2]Department of Animal Nutrition, Faculty of Agriculture,
Trakia University, 6000 Stara Zagora, Bulgaria

ABSTRACT

A total of 152 samples of feed ingredients and compound feed for pigs and poultry was analysed for concentrations of lead, cadmium, nickel, chromium, arsenic and mercury using Atomic Absorption Spectrophotometry. The data showed lead and cadmium levels in compound feeds for pigs and poultry in Bulgaria were higher compared to current European official regulations: 33.9% for lead and 20.34% for cadmium in studied samples. One third of analysed plant feed ingredients used in the production of compound feed had a cadmium content of 1 and over 1 mg/kg, *vs*. maximum allowed concentration of 1 mg/kg. As a whole, the average content of nickel, arsenic and mercury in compound feed for pigs and poultry, used in Bulgaria, is not disturbing. The monitoring of these elements' content is necessary as well, although not at the same level as, for instance, for lead and cadmium.

INTRODUCTION

The feed ingredients and the compound feed are strictly controlled with regard to two groups of substances – undesirable substances (heavy metals, dioxin and PCBs, pesticide and mycotoxin residues and micro-organisms) and forbidden substances (recycled fats, non-filtered ruminant fats, unauthorised feed ingredients, processed animal protein, hormones and others, including some supplements, GMO and medications)

In Bulgaria, the European official regulations for maximum allowed undesirable substances and products used in compound feed and feed ingredients, are introduced under *Act No 21/2006 (Official Gazette, No. 56/2006)*.

Heavy metals, being in the group of undesirable substances are a definite human health hazard because of their biocummulativity (Stwertka, 1996). The extensive contamination of various foods and beverages with heavy metals as well as their constant and continuous use represent a serious risk to human health, the most dangerous being lead, cadmium and mercury (Merian, Anke, Ihnat & Stoeppler, 2004, Fergusson 1990, Friberg, 1984, Nordberg , 2006 , Stone,1992).

According to Dachev & Murhova (2002), the areas in Bulgaria contaminated with heavy metals are over 8 321.2 ha, 2 380.8 ha out of them being polluted with twice the maximum allowed concentration (MAC). Other sources (Dimitrova, 2002) assert that the extent is much wider – 44 900 ha contaminated with heavy metals and metalloids, 8 160 of them being polluted with five times the respective MACs. In many regions with considerable pollution, forage crops are grown regardless of frequently indicated risks. Due to the free transfer of ingredients, forage crops from such regions could be found out in every part of the country.

Heavy metals are widely used in all fields of life (batteries, dyes, alloys, chemical compounds, pharmaceutical and cosmetic products) (WHO, 2001, Reese 2003, Zarogianniss, 2005) thus suggesting that the risk of pollution is very high and therefore, the strengthened control along the entire food chain.

As far as the feed ingredients and the compound feed for swine and poultry are an

*** Correspondence to**: *Dimitrina Alexieva, Department of Poultry Breeding, Faculty of Agriculture, Trakia University, 6000 Stara Zagora, Bulgaria; E-mail: d_alex@af.uni-sz.bg*

integral part of the consumer's food chain, they need to be assessed as potential sources of heavy metal contamination.

MATERIALS AND METHODS

The study aimed to find whether compound feed for poultry and pigs (being the major proportion of compound feed produced in Bulgaria) and common feed materials (both of local origin and imported) meet European quality requirements with regard to heavy metals' content.

152 samples of feed ingredients and compound feed for poultry and pigs from various regions of the country were analysed for lead, cadmium, nickel, chromium, arsenic and mercury content. The study was performed in 2005. The territory of the country was, for this purpose, divided into 6 regions and the number of samples obtained was as follows: Southwest region (SW) – 29, South Central region (SC) – 43, Southeast region (SE) – 6, Northwest region (NW) – 31, North Central region (NC) – 20 and Northeast region (NE)– 23 (**Figure 1**). The samples were obtained from large forage plants. The number of sources for the various ingredients was the highest for grain feed (corn, wheat) and the lowest – for fish meal. The conditional division of the country was made in order to include the entire territory at determining of used ingredient's quality.

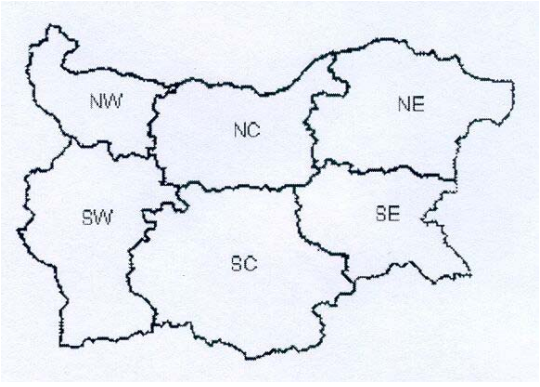

Figure 1: **Map of Bulgaria with the regions, where the samples have been collected from: SW – Southwest region, SC – South Central region, SE – Southeast region, NW – Northwest region, NC – North Central region and NE – Northeast region**

The analyses were carried out in the science laboratory of the Trakia University and the Regional Laboratory of the Executive Environment Agency – Stara Zagora, using atomic absorption spectrophotometry (AOAC, 1995). The mercury concentrations of some feeds were assayed on the accredited laboratory for food testing of the Institute for Cryobiology and Food Technology – Sofia.

RESULTS AND DISCUSSION

The allowed lead content in feed ingredients according to the current official regulations is 10 mg/kg. In the studied 93 samples of the common feed materials for pigs and poultry, the average lead concentration was 3.19 mg/kg, varying from 0 - 32 mg/kg (**Table 1**).

Only in two samples (one from wheat and one of imported fish meal), used in the SC region, were found lead content higher than 10 mg/kg. The data from the analysis of compound feed for pigs and poultry were however more alarming (**Table 2**).

The allowed lead content in compound feed is 5 mg/kg, the average value of all studied compound feed (59 samples) was 4.77 mg/kg, ranging between 1 to 9.5 mg/kg. The discrepancy with safety levels was higher in poultry compound feeds than in pig compound feeds (**Table 3**).

The percentages of non-conformities related to lead concentrations in compound feed for pigs and poultry were 13.33% and 55.17% respectively. For layer feed, the percentage was 100.

Taking into consideration that the components in compound feed for layers, broilers and pigs are almost identical, and that the greatest difference was the high proportion of limestone in feed for layers, it could be assumed that the higher lead content in layers feed might be due to this ingredient. This hypothesis deserves a more detailed investigation.

The allowed cadmium concentration in feed ingredients of plant origin according to the current regulations is 1 mg/kg, and in those of animal origin – 2 mg/kg. Out of the 93 samples from feed ingredients, 88 were of plant origin and 5 – of animal origin. In the former, the average cadmium content was 0.5 mg/kg (varying between 0 and 1.8 mg/kg), and in fish meal– 1.31 mg/kg (varying from 0 to 2.5 mg/kg).

The cadmium content in 8 samples of plant ingredients (1 Argentinean soybean meal used in NE Bulgaria, 1 sunflower meal – SC region, 1 wheat – NE regions, 1 corn NE region, 2 sunflower meals – NW region, 1 wheat – NW region and 1 sunflower meal – NC region) exceeded the maximum allowed levels. Furthermore, 22 samples of feed ingredients had the maximum allowed cadmium concentration of 1 mg/kg. They were from all regions of the country: 8 from

the NW, 7 – from the SC, 3 – from the NE, 2 – from the NC, 1 – from the SW and 1 – from the SE regions.

Compared to the allowed cadmium content in compound feed of 0.5 mg/kg, the average concentration in all studied compound feed samples (59 samples) was 0.27 mg/kg, ranging between 0 and 1.3 mg/kg. The non-conformity with allowed levels was higher in compound feed for poultry than in those for pigs (**Table 3**).

Table 1. *Concentration of heavy metals in feed materials, mg/kg**

Samples	Lead	Cadmium	Nickel	Chromium	Arsenic	Mercury
			Feed materials			
Number of samples	93	93	93	93	93	46
mean	3.19	0.54	3.07	1.53	0.108	0.0002
lowest	0	0	0	0	0	0
highest	32	2.5	16	6	1.480	0.009
			Wheat			
Number of samples	16	16	16	16	16	8
mean	4.05	0.46	2.18	0.97	0.050	0
lowest	0	0	0	0	0	0
highest	32	1.5	14	4	0.360	0
			Corn			
Number of samples	17	17	17	17	17	9
mean	1.44	0.42	0.96	0.65	0.008	0
lowest	0	0	0	0	0	0
highest	3.25	1.3	1.5	1	0.130	0
			Barley			
Number of samples	10	10	10	10	10	9
mean	1.53	0.10	0.48	1.05	0.019	0
lowest	0.5	0	0	0	0	0
highest	2.75	1	1	2.5	0.080	0
			Wheat bran			
Number of samples	8	8	8	8	8	2
mean	2.54	0.73	1.79	1.38	0.199	0
lowest	2	0	1	1	0	0
highest	3	1	2.8	2.5	1.480	0
			Sunflower meal			
Number of samples	12	12	12	12	12	5
mean	3.13	0.96	7.83	2.23	0.103	0.002
lowest	2	0.09	5	1	0	0
highest	6	1.8	9.5	4	0.350	0.009
			Soybean meal			
Number of samples	17	17	17	17	17	9
mean	2.77	0.40	3.87	1.76	0.193	0.001
lowest	1	0	2	1	0	0
highest	5.75	1.5	6.75	3	0.340	0.007
			Fish meal			
Number of samples	5	5	5	5	5	2
mean	12.02	1.31	2.16	1.79	0.116	0
lowest	6.5	0	1.5	2	0	0
highest	32	2.5	3.0	6	0.310	0
			Other ingredients			
Number of samples	8	8	8	8	8	2
mean	3.30	0.61	5.66	2.94	0.139	0.005
lowest	1	0	0	1	0	0
highest	6	1	16	6	0.340	0.009

** The data are presented for forages at a natural humidity.*

The percentage of non-conformities in compound feed for pigs was 3.33%, whereas in those for poultry (as a whole) was 41.38%, the value being higher in layers feed.

In the analysed 93 samples of the common feed ingredients for pigs and poultry, the average nickel content was 3.07 mg/kg, with variations from 0 to 16 mg/kg. Samples of wheat, corn, barley and wheat bran lower nickel concentrations than the average values

for all feed components, with only one exception (one wheat sample from SW Bulgaria). The soybean meal and the fish meal had a nickel content similar to the average value of all studied ingredients. In sunflower products, nickel concentrations were 2 and 3 times higher: average nickel concentration of 7.83 mg/kg in sunflower meal and 9.25 mg/kg in sunflower expeller.

Table 2. *Concentration of heavy metals in compound feed (CF), mg/kg**

Samples	***Lead***	***Cadmium***	***Nickel***	***Chromium***	***Arsenic***	***Mercury***
			CF for pigs and poultry			
Number of samples	59	59	59	59	59	25
mean	4.77	0.27	3.72	2.73	0.170	0.001
lowest	1	0	1.3	1	0	0
highest	9.5	1.3	7.0	11.5	0.790	0.009
			CF for pigs			
Number of samples	30	30	30	30	30	15
mean	3.65	0.12	3.17	2.33	0.165	0.002
lowest	1	0	1.3	1	0	0
highest	8	0.8	6.75	4.25	0.790	0.009
			CF for poultry			
Number of samples	29	29	29	29	29	10
mean	6.03	0.41	4.28	3.16	0.172	0
lowest	1.5	0	3.0	2.0	0	0
highest	9.5	1.3	7.0	11.5	0.68	0
			CF for layers			
Number of samples	12	12	12	12	12	5
mean	7.77	0.55	5.27	4.42	0.303	0
lowest	6	0	3.75	3	0	0
highest	9.5	1.3	7.0	11.5	0.68	0
			CF for broilers and pullets			
Number of samples	17	17	17	17	17	5
mean	4.80	0.34	3.57	2.26	0.079	0
lowest	1.5	0	3	2.0	0	0
highest	9.5	1	4.5	4.0	0.280	0

** The data are presented for forages at a natural humidity.*

Table 3. *Concentration of lead and cadmium in compound feed (CF) and feed ingredients (FI) – percentage of non-conformities compared to allowed levels*

Analysed samples	***Lead***	***Cadmium***
CF and FI, total	*152*	*152*
including non-conformities, number	22	21
% non-conformities	14.47	13.82
Feed ingredients	*93*	*93*
including non-conformities, number	2	9
% non-conformities	2.15	9.61
CF for pigs and poultry	*59*	*59*
including non-conformities, number	20	12
% non-conformities	33.90	20.34
CF for pigs	*30*	*30*
including non-conformities, number	4	1
% non-conformities	13.33	3.33
CF for poultry, total	*29*	*29*
including non-conformities, number	16	12
% non-conformities	55.17	41.38
CF for layers	*12*	*12*
including non-conformities, number	12	5
% non-conformities	100	41.67
CF for broilers and pullets	*17*	*17*
including non-conformities, number	4	6
% non-conformities	23.53	35.29

It should be noticed that the average nickel content in compound feed was slightly higher but similar to that of feed ingredients (mean 3.17 in compound feed for pigs and 4.28 mg/kg in compound feed for poultry. In the current regulations (*Act No 21/2006*) there are no maximum allowed concentrations of nickel for feed ingredients and compound feed. The limits for the allowed nickel content in different human foods range between 0.1–8 mg/kg (0.1 mg/kg in milk, 0.5 mg/kg in meat and meat products, 3 mg/kg in legumes, 5 mg/kg in chocolate, 8 mg/kg in powdered cacao, 8 mg/kg in tea – *Act 31/2004*). Our data for nickel concentrations in feed materials and compound feeds are, in our view, not alarming, if compared to allowed nickel content in human foods.

The average chromium content in feed ingredients was 1.53 mg/kg, varying between 0 and 6 mg/kg. As a whole, the chromium content was lower in grain feed and higher – in protein feed – oil meals, expeller, fish meal. The highest chromium concentrations were observed in sunflower products: 2.23 and 4.38 mg/kg in sunflower meal and sunflower expeller, respectively.

The average content of chromium in compound feeds for pigs and poultry (as a whole) was 2.73 mg/kg. The concentrations of this element were higher in compound feed for poultry. Moreover, there were considerable differences between chromium content in feed for broilers and layers. In the latter, the average chromium amount was twice higher than in feed for growing poultry. The highest levels of chromium were detected in compound feed for hens. In the current regulations, there are no limits as to the maximum allowed content of chromium in feed materials and compound feed. Therefore, our data could be hardly interpreted. Taking into account the maximum allowed limits for chromium concentrations in human foods that range between 0.1 and 0.5 mg/kg, the values in compound feed could be accepted as high.

The allowed arsenic level in feed ingredients is 2 mg/kg. As seen from the results on **Table 1**, the average arsenic content in 93 analysed samples of feed ingredients was 0.108 mg/kg that was far below the maximum allowed content. Even the sample of wheat bran with the highest arsenic level (1.48 mg/kg) did not exceed the maximum allowed concentration.

In view of the low arsenic content in studied feed components, the respective concentrations in compound feed were logically also low, as confirmed by the performed analyses (**Table 2**).

The allowed arsenic content in compound feed is 2 mg/kg. In studied compound feed for pigs and poultry (as a whole) it was 0.170 mg/kg, i.e. significantly lower than allowed levels. The average arsenic concentrations in compound feed for pigs and poultry were very similar –0.165 and 0.172 mg/kg, respectively. Even the samples with highest arsenic content (0.79 mg/kg – compound feed for pigs; 0.68 mg/kg – compound feed for poultry), were about 2.5 times below the maximum allowed limits. In compound feed for layers, arsenic concentrations were twice higher than in pigs feed and about 4 times higher *vs*. compound feed for broilers. Taking into consideration that compound feed for layers, broilers and pigs contained the same ingredients, and that the only difference was the higher proportion of limestone in layer feed, it could be assumed that the higher arsenic content in layer feed was due to this material. This assumption however, needs further and more detailed analysis.

In the 46 analysed samples of feed materials, the average mercury content was 0.0002 mg/kg that was very low compared to maximum allowed concentrations of this element. The sample of sunflower meal with highest mercury concentration (0.009 mg/kg) was also below the allowed limit for feed ingredients of 0.1 mg/kg.

The allowed mercury level in compound feed is 0.1 mg/kg. In pig and poultry feed, considered as a whole, it was 0.001 mg/kg, or 100 times lower than the allowed level. Mercury was found only in compound feed for pigs – in pre-starter and starter feed. In compound feed for poultry – both for young birds and layers, no mercury was detected. It could be supposed that the higher mercury content in pre-starter and starter feed for pigs was related to the higher concentration of this element in zinc oxide. The latter, being source of zinc, participates in these types of pig feed with a higher share. However, this hypothesis needs to be supported by more detailed analyses. The fact that mercury content was much lower than the allowed limit, permitted us to assume the level of 0.1 mg/kg, equal to the maximum allowed level, as a limit of detection of this element. The screening of 81 samples of various feed ingredients and compound feed at the Accredited Laboratory for Food Analysis of the Institute of Cryobiology and Food Technologies – Sofia, did not detect samples with mercury content higher than 0.1 mg/kg.

CONCLUSIONS

Lead and cadmium levels in compound feeds for pigs and poultry in Bulgaria were higher than those specified in the current official regulations in 33.90% (for lead) and 20.34% (for cadmium) of studied samples.

One third of analysed plant feed ingredients, used in the production of compound feed had a cadmium concentration of 1 and over 1 mg/kg, *vs.* maximum allowed limit of 1 mg/kg.

In 41.38% of analysed samples of compound feeds for poultry, cadmium concentrations were higher than maximum allowed limits.

In compound feed for layers, the increased lead and cadmium amounts emphasized upon a more strict control of mineral supplements, especially limestone.

The monitoring of the level of heavy metal contamination of the common feed materials is not an entirely consistent criterion ensuring that produced compound feed would be in compliance with the current regulations for allowed heavy metal concentrations. The control of feed components should comprise all ingredients, including microcomponents.

The average nickel content in the common feed ingredients and compound feed for pigs and poultry, used in Bulgaria, was not alarming. The monitoring of this element is also necessary although not at the same extent as, for instance, for lead and cadmium.

Despite the absence of limits for allowed chromium concentrations in feed, the results obtained by us were, in our view, worrying. The average chromium content in compound feed (particularly for layer hens) was several times higher than allowed chromium concentrations in human foods. More detailed investigations are needed for determination of six-valent chromium and for determination of the potential hazards for animals and humans.

As a whole, the average arsenic concentration in the main ingredients and compound feeds for pigs and poultry, used in Bulgaria, was considerably below the maximum allowed limit, permitting a less frequent control of this element.

The average mercury content in feed ingredients and Bulgarian compound feed for pigs and poultry were many times lower than the maximum allowed concentrations. This signifies that practically, no control for mercury amounts in compound feed is necessary.

ACKNOWLEDGMENTS

The authors thank Mr. Miroslav Vassilev from Lohmann Animal Health, Mrs. Nadya Krebs from Degussa, Bulgaria and Mrs. Ledinka Vassileva from the National Grain and Feed Service for their support in the realization of this project.

REFERENCES

1. Act No. 21 (2006) for maximum allowed concentrations of undesirable substances and products in feed, *Official Gazette*, 21.
2. AOAC (1995). Official Methods of Analysis. 15th ed. Association of Official Analytical Chemists, Washington, DC.
3. Dachev, D. & K. Marhova. (2002). On some institutional problems, related to the ecological effect of mines and industrial objects on the environment. *Annual of the University of Mining and Geology "St. Ivan Rilski", vol. 45* (1), Sofia: Geology, pp. 153-156.
4. Dimitrova, I. (2002). Environmental pollution and its negative impact on human health, *Ecopolis – the Third Sector, 21*.
5. Fergusson, J.E. (1990). The heavy elements: Chemistry environmental impact and health effects. Oxford, U.K:Pergamon Press.
6. Friberg, L. (1984) Cadmium and kidney, *Environmental Health Perspectives*, *54*, 1-11.
7. Merian, E., Anke, M., Ihnat, M. & Stoeppler, M. (2004). Elements and their compounds in the Environment.Vol. 3: Nonmetals, particular aspects. Arsenic (pp. 1321-1364). Weinheim, Germany: Wiley VHC Verlag Gmbh and CoKG.
8. Nordberg G. F. (2006), Subcellular Targets of Cadmium nephrotoxicity, *Environmental Health Perspectives*, *114,* 191-194.
9. Reese, R.G. (2003).Arsenic. Mineral Commodity Summaries. US Geological Survey
10. Stone, R. (1992). Mercurial Debate. *Science* (March 13), 1356-1357.
11. Stwertka, A. (1996). A Guide to the Elements. Oxford University Press.
12. WHO (World Health Organization) (2001). Environmental Health Criteria 224. Geneva: Second edition.
13. Zarogianniss P., October 2005, Environmental Risk Reduction Strategy and Analysis of Advantages and Drawbacks for Hexavalent Chromium (final report).