Short Communications

Mineral composition of poultry manure in South Africa with reference to the Farm Feed Act

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The mineral composition of poultry manure and litter from poultry enterprises throughout South Africa was determined. The manure contained high concentrations of macro and micro minerals. Ash content levels in more than 40% of the Breeder and Pullet litter and 80% of the Layer samples were higher than levels stipulated as acceptable for the Farm Feed Act of South Africa (Act 36 of 1947). More than 54% of the Pullet and Layer samples and 80% of the Broiler and Breeder samples contained less P than stipulated by law. The Cu concentration of most of the samples was below the legal limit of < 50 mg/kg. Only 3.8% of the Broiler, 17.8% of the Pullet, 4.5% of the Layer and 1.5% of the Breeder samples contained an acceptable concentration of minerals to qualify for registration as an animal feed. It is suggested that the minimum legal levels for P should be reduced and the maximum limits for Na should be increased.

Die mineraalinhoud van hoendermismonsters vanaf pluimvee-ondernemings regdeur Suid-Afrika is bepaal. Die hoendermis het hoë konsentrasies makro- en mikrominerale bevat. Die asinhoud van meer as 40% van die Jonghen- en Teelhenmis en 80% van die Lêhenmis was te hoog om te kwalifiseer vir registrasie as 'n veevoer in Suid-Afrika (Wet 36 van 1947). Meer as 54% van die Jonghen- en Lêhenmis en 80% van die Braaikuiken- en Teelhenmis het minder P as die wetlike minimum bevat. Die Cu-vlakke van die meeste van die monsters was laer as die wetlike vereiste van < 50 mg/kg. Slegs 3.8% van die Braaikuiken-, 17.8% van die Jonghen-, 4.5% van die Lêhen- en 1.5% van die Teelhenmis het die korrekte konsentrasies van al die voorgeskrewe minerale bevat om as veevoer te registreer. Daar word voorgestel dat die minimum wetlike vlakke vir P verlaag kan word, terwyl die maksimum vlakke van Na verhoog kan word.

Keywords: Legal requirements, mineral composition, poultry excreta, ruminants.

Poultry excreta is used widely as a ruminant feed and classified as a bulky protein/mineral supplement (Ruffin & McCaskey, 1990). In most countries its sale as an animal feedstuff is controlled by legislation, prescribing specific hygienic and nutritional standards. In South Africa, Act 36 of 1947 (Government Gazette, 1980) stipulates for registration, among other conditions, minimum or maximum levels of ash and certain minerals in broiler litter and layhen manure. Although poultry manure is an excellent source of certain minerals (Ruffin & Mccaskey, 1990), minerals in manure often are ignored in feed formulations. On the other hand, cases of mineral toxicity in ruminants consuming poultry manure have been reported, e.g. Cu toxicity in sheep (Van Ryssen *et al.*, 1977) and in cattle (Banton *et al.*, 1987), and milk fever in cows due to high Ca concentrations (Ruffin & McCaskey, 1990).

In view of the high cost of protein sources and the danger of protein shortages in South Africa, the Protein Advisory Committee commissioned a survey to evaluate the mineral composition of poultry excreta in South Africa in terms of its potential as an animal feed.

Poultry enterprises throughout South Africa were requested to submit representative litter/manure samples from their poultry houses. A total of 259 samples suitable for analysis was received and 30 samples from a previous survey (Van Ryssen *et al.*, 1977) were included in this study. The fowls received diets from 12 different feed suppliers and from home-mixed rations. The litter material was mainly wood shavings. Samples were classified as:

Broiler – broiler excreta mixed with bedding material (n = 106);
Pullet – pullet excreta mixed with bedding material (n = 45);
Layer – pure excreta from layers housed in cages (n = 67);
Breeder – excreta from broiler and layer parent stock housed on bedding (n = 65);
Backyard – pure manure from free ranging fowls (n = 6).

The Backyard samples are included because of some distinct characteristics.

The samples were dried for 24 h at 80 °C and milled. The samples were dry ashed at 500°C, except for Se and Hg assays. The concentrations of the following elements were determined, using a Plasma-100, sequential, argon plasma, atomic emission spectrometer: Ca, Mg, P, Na, K, Al, Cu, Fe, Mn, Zn, As, Cd, Cr and Pb. Analysis lines for the first 10 of these were the same as reported previously (Verbeek, 1984). For the remaining elements, lines used were: Cr(II) 283.56 nm, Cd(II) 214.44 nm, As(I) 197.20 nm, Pb(II) 220.35 nm. The sensitivity for As and Pb was relatively low, the quantitative limits in the sample material being 5 mg/kg and 2 mg/kg respectively when using a 5-s integration time. Vanadium and Mo were determined on a graphite furnace atomic absorption spectrophotometer; Hg was determined using the cold vapour atomic absorption technique. Selenium was determined by a fluorometric method (Koh & Benson, 1983). The accuracy of analyses was tested with a National Bureau of Standards reference standard (Washington, DC). The statistical programme, Minitab Statistical Software (Minitab Inc. State College, PA 16801, USA), was used to compare within means between sources.

The mean ash and mineral concentrations of the five groups of excreta are presented in Table 1. Skewed distribution curves were observed with Fe and Al, due to a few samples with very high concentrations, and with As, Pb and Cd, because a relatively large proportion of the samples had

Table 1 Mean mineral composition of poultry excreta from different South African sources

	Broiler	Pullet	Layer	Breeder	Backyard	S^2**
n	106	45	66	65	6	
g/kg DM						
Ash	151 ± 45	176 ± 85	353 ± 105	279 ± 111	417 ± 94	74
Calcium	25 ± 6.7	28 ± 13.0	88 ± 28.0	63 ± 26	39 ± 18.8	3.87
Phosphorus	15 ± 3.3	17 ± 5.6	23 ± 7.2	19 ± 4.8	13 ± 3.8	0.27
Magnesium	5.8 ± 1.1	6.7 ± 2.2	9.0 ± 2.8	7.5 ± 1.9	5.4 ± 1.2	0.039
Potassium	13 ± 3.4	17 ± 6.4	21 ± 8.0	17 ± 4.1	13 ± 4.8	0.29
Sodium	5.6 ± 1.6	4.9 ± 2.0	4.7 ± 1.7	5.3 ± 1.6	2.8 ± 1.8	0.029
mg/kg DM						
Aluminium	834 ± 1196	499 ± 505	1683 ± 2804	1799 ± 2072	9885 ± 5574	3423910
Arsenic	4.9 ± 13.8	0.27 ± 1.25	2.5 ± 11.0	6.4 ± 17.9	41.6 ± 37.5	176
Cadmium	0.32 ± 0.34	0.20 ± 0.29	0.50 ± 0.39	0.32 ± 0.36	1.5 ± 0.56	0.124
Chromium	11.2 ± 18.0	3.7 ± 6.0	9.2 ± 10.1	13.2 ± 16.0	51.6 ± 17.2	212
Cobalt	1.08 ± 0.96	0.85 ± 0.46	1.39 ± 1.54	2.2 ± 2.55	7.1 ± 4.72	2.44
Copper	43.6* ± 17.7	32.3 ± 13.6	45.9 ± 16.6	44.1 ± 17.2	36.2 ± 1.05	2863
Iron	1335 ± 1878	843 ± 473	2271 ± 2470	2589 ± 2718	16762 ± 10368	4501175
Lead	0.55 ± 2.02	0.07 ± 0.27	1.17 ± 5.08	0.44 ± 1.65	46.4 ± 69.74	8.33
Manganese	317 ± 128	374 ± 198	546 ± 364	421 ± 191	746 ± 645	52261
Mercury	0.48 ± 0.67	0.62 ± 0.62	1.71 ± 0.86	1.38 ± 0.73	1.60 ± 0.35	0.54
Molybdenum	1.5 ± 1.06	3.1 ± 3.56	10.4 ± 4.04	4.4 ± 3.00	9.1 ± 4.13	8.48
Selenium	0.62 ± 0.24	0.42 ± 0.22	0.47 ± 0.25	0.46 ± 0.22	0.12 ± 0.09	0.057
Vanadium	12.1 ± 8.38	8.4 ± 5.52	17.9 ± 12.8	26.9 ± 12.8	50.8 ± 32.7	124
Zinc	254 ± 59	259 ± 106	372 ± 129	285 ± 84	351 ± 196	8665

* Excluding the 1977 survey samples.

** Least significant difference:

$$\text{LSD } (P<0.05) = 2\sqrt{\frac{S^2\,(n_1 + n_2)}{n_1 n_2}}$$

where n_1 and n_2 are the two values within a mineral being compared.

(Backyard samples not included in statistical analyses.)

concentrations below detection limits and therefore were recorded as zero. In general, the concentrations of all minerals in the Layer and Breeder samples were substantially higher than those in the Broiler and Pullet samples. The Backyard samples contained substantially higher levels of trace minerals than the other groups, except for Cu, Se, Hg and Zn. The percentage of samples in each class of manure, not meeting the minimum or maximum limits as prescribed by Act 36 of 1947 (Government Gazette, 1980), and having Ca:P ratios wider than the calculated ratios according to that Act, are presented in Table 2.

The ash concentrations in 40% of the Breeder and Pullet and 80% of the Layer samples were above the levels stipulated by Act 36 of 1947 (Table 2). The very high ash content in the Backyard samples suggests that most of the ash originated from ingested soil.

Table 2 Percentage of samples with crude ash and mineral concentrations* not meeting the minimum or maximum limits as stipulated by the Farm Feed Act in South Africa (Act 36 of 1947)

	Broiler			Laying hen		
	Limits of	Outside limits		Limits of	Outside limits	
	Act 36 (g/kg)	Broilers (%)	Pullets (%)	Act 36 (g/kg)	Layers (%)	Breeders (%)
Ash	<150	17.9	40.0	<250	80.3	40.0
Ca	< 35	3.8	11.1	< 80	39.4	15.4
P	> 15	82.1	57.8	> 20	54.5	84.6
Na	< 5	42.5	26.7	< 5	28.8	40.0
Cu	<0.05	18.9 (14.9**)	4.4	<0.05	12.1	15.4

* Concentrations adjusted to a 12% moisture content as stipulated by Act 36 of 1947.

** Excluding the 1977 survey samples.

Although about 40% of the Layer manure contained more than the legal limit of 80 g Ca/kg feed (Table 2), the mean value of 88 g Ca/kg compared well with published values for similar samples, e.g. 78 g/kg (Blair & Knight, 1973), 88 g/kg (Bhattacharya & Taylor, 1975) and 85.2 g/kg (Essig, 1975). At least 54% of the samples in all four groups contained less P than the legal minimum level (Table 2). However, if the litter was to constitute only 10% of a diet, most survey samples would provide the P requirements of beef cattle and sheep, viz. 1.6 to 3.8 g/kg (NRC, 1984; 1985). The P levels in the survey samples corresponded well with those in the literature. The minimum limits for P in Act 36 possibly could be reduced, because ruminants can tolerate Ca:P ratios as high as 7:1 (Miller, 1983).

The Mg and K concentrations of most of the survey samples fell within the safe limits for ruminants, especially if litter constituted less than a third of the ration. Therefore, Mg and K in litter probably would not have a harmful effect on ruminants. More than 40% of Broiler and Breeder samples exceeded the maximum legal level for Na (Government Gazette, 1980). These Na levels compared well with levels in excreta reported by Blair & Knight (1973), Jimenez (1974), Bhattacharya & Taylor (1975) and Westing *et al.* (1985). The toxic level for sodium chloride in diets is above 100 g (39.3 g Na)/kg DM (NRC, 1984). This is much higher than the highest level of about 10 g Na/kg, measured in the survey, suggesting that the legal limit may be too low.

In this survey, the Cu concentration in broiler litter was substantially lower than that in the 1977 survey (Van Ryssen *et al.*, 1977). This may suggest that $CuSO_4$ is not used today as a growth stimulant in broiler diets in South Africa (Van Ryssen *et al.*, 1977). Only a few samples in the survey contained more than the legal limit of 50 mg Cu/kg DM (Table 2).

The concentrations of Fe and Al in the survey samples agreed well with those found by Jimenez (1974), Essig (1975), Westing *et al.* (1985) and Ruffin & McCaskey (1990). Although no legal limits are set for Fe and Al concentrations in litter, the mean levels in the Layer and Breeder samples were in the range considered toxic to livestock (Neathery & Miller, 1977; NRC, 1980). The main toxic effects of Fe and Al are those of induced deficiencies of other minerals (Valdivia *et al.*, 1982; Phillippo *et al.*, 1987). The level of these minerals in the survey samples were well above the requirements of the ruminant. Therefore, it seems unlikely that deficiencies in these minerals due to Fe and Al would occur.

If litter forms only part of a diet, the survey samples should hold no risk of Mn, Co, Se or Zn toxicity to ruminants and, in fact, should be a good source of these minerals. With a maximum safe level of 50 mg/kg (NRC, 1980), V in the survey samples presented no risk of toxicity to ruminants. Products containing arsenic, used as growth promoters in poultry diets, can result in As residues in poultry manure (Calvert, 1973). A total of five samples in the survey had As levels above 50 mg/kg, the maximum tolerable level for As in the organic form (NRC, 1980). The 'Backyard' manure, however, tended to have high As levels. The Commission of European Communities (CEC, 1976) stipulated maximum permissible As levels in animal feeds to be 2—10 mg/kg. At high inclusion rates of litter in a diet, some survey samples may exceed this CEC limit.

At an inclusion rate of 33% in a diet, most of the survey samples of poultry litter would contribute less than 0.5 mg Cd/kg (NRC, 1980) to the diet and therefore should not be a risk. A concentration of 30 mg Pb/kg feed is the maximum tolerance level for most species (NRC, 1980). The CEC (1976) prescribed the maximum legal limit for Pb in animal feedstuffs to be 5—10 mg/kg. With the exception of two Layer samples with levels above 20 mg/kg, the Pb levels in all other samples in this survey were very low. An interesting exception is the 'Backyard' samples, which contained between 10 and 202 mg Pb/kg, presumably due to consumption of soil. Fish meal in poultry diets often contains relatively high levels of Hg (NRC, 1980), high enough that Hg may accumulate in the poultry products. A large proportion of ingested Hg would be excreted into the manure, and thus be available to ruminants. The NRC (1980) suggested a level of 2 mg Hg/kg as the maximum tolerable dietary level for domestic animals, while the CEC (1976) stipulated maximum levels of between 0.1 and 0.5 mg Hg/kg. A small proportion of the samples in this survey exceeded 2 mg Hg/kg, though many of the Layer samples would not meet the CEC standards. If litter forms only a part of the diet, Hg should pose no threat to livestock.

Based on all the legal limits stipulated by Act 36 of 1947, only 3.8% of the Broiler, 17.8% of the Pullet, 4.5% of the Layer and 1.5% of the Breeder samples in the survey qualified for registration as an animal feed.

According to this survey, relatively high, even toxic, levels of some minerals can be present in manure. In the case of many minerals, the first manifestation of 'toxicity' and, therefore, the criterion used to arrive at an upper safe limit, is an induced deficiency of other minerals (NRC, 1980). These deficiencies may not necessarily occur when poultry manure is fed as a minor component of a diet. However, imbalances may exist, mainly in Layer manure, because of its high Ca concentration.

If the results are evaluated in terms of stipulations required by the Farm Feed Act of South Africa, only a small number of samples met the standards. Most samples would be disqualified because P levels are too low and ash and Na concentrations are too high. This raises the question of whether the requirements of the Law are too strict or unrealistic. The legal limits for P should be lowered. Because of the diluting effect of ash on the nutritional value of the manure, it seems unwise to increase the maximum limits for ash. Since Na, at the levels present in the litter is not toxic to ruminants, the legal limit for Na should be increased.

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