Distribution of Arsenic from Poultry Litter in Broiler Chickens, Soil, and Crops

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The effect of the presence of organoarsenicals from feed additives in poultry house litter was investigated with respect to the distribution of arsenic in chickens raised on this litter, to the distribution of arsenic in soil fertilized with this litter, and to the distribution of arsenic in crops raised on soil fertilized with this type litter. Although measurable amounts of arsenic (15–30 p.p.m.) were found in litter, the arsenic content of soil and crops was unaffected by the use of poultry litter as fertilizer. Similarly, the arsenic content of birds was unaffected when raised on this type litter.

Excessive use of arsenical pesticide, herbicide, and defoliant sprays have resulted in the buildup of toxic levels of arsenic in soil and plants (Bishop and Chisholm, 1962; Schweizer, 1967; and Williams and Whetstone, 1940). However, there are few data available pertaining to the effects of poultry organoarsenical feed additives in poultry litter on the buildup of arsenic in soil and plants. Similarly there are few data available regarding the effects on the depletion of arsenic in edible tissues and feathers of poultry raised on litter compared to poultry raised in batteries. The effect on the depletion of arsenic by raising chickens on litter is of utmost importance to the commercial poultry grower since the Code of Federal Regulations Section 121. 1138 limits the residues of arsenic in chicken tissue used for human consumption to 0.5 part per million (p.p.m.) in muscle meat and 1 p.p.m. in edible byproducts such as liver. Poultry feathers are commonly incorporated into poultry feed as hydrolyzed feather meal and, therefore, the arsenic contributed by the feathers during the required withdrawal period prior to slaughter may play an important role in the depletion rate of arsenic from chicken tissues. In view of the paucity of this information, an examination was undertaken to determine the effect of fertilizing soil with poultry litter containing organoarsenical feed additives on the arsenic content of soil, crops grown on this soil, and drainage water through this soil; and the effect of raising broiler chickens on litter containing arsenical feed additives on the arsenic content of chicken tissues and feathers.

EXPERIMENTAL

Five commercial broiler companies in Arkansas representing a total weekly production of approximately 5 million birds (up to 1,500,000 birds per company) participated in part of this study. Three farms at three companies, two farms at two companies, and one processing plant at one company were visited in an attempt to obtain representative samples of poultry house litter and chicken feathers from birds of varying roxarsone (4-hydroxy-3-nitrophenylarsonic acid) medication status for arsenic analysis. Feathers, including breast feathers and long wing feathers, were pooled from five birds from each farm and a sample of feathers from the defeathering operation in the processing plant was taken. Composite litter samples (in use, 6–12 months) from several areas of each poultry house were also taken including those areas near the feeders and areas in the corners where birds tend to congregate.

To determine if raising broiler birds in pens on litter (fresh, unused corn cobs, arsenic content <0.1 p.p.m.) affected the arsenic content of poultry tissue, individual samples of liver, kidney, muscle, and skin were taken from birds withdrawn for five days after eight weeks of medication with 50 p.p.m. roxarsone in a complete broiler ration. Since withdrawal of medication for five days before slaughter is a requirement for the use of organoarsenical feed additives to enable residues of the drug to deplete below the established tolerance of 0.5 p.p.m. im meat and 1 p.p.m. in edible byproducts such as liver (Code of Federal Regulations, Section 121.1138), this practice was also used in this study. Birds similarly medicated but raised in batteries were used for reference purposes.

Forage type crop samples (alfalfa and clover) were sampled from fields which had been treated with arsenical-containing poultry litter for zero years (none used), two years, and 20 years. Samples of soil were obtained from the control field (no litter used), and from a field treated for 20 years with poultry house litter. A water sample was obtained from the latter field by drilling a hole five feet deep and collecting the water draining into this hole to represent drainge water from a treated field.

Total arsenic assays (Morrison and George, 1969) were performed on 10-gram samples of tissues, feathers, soil, and water, and on 5-gram samples of litter. Since the litter samples were taken from houses in which roxarsone was used, assays for this drug in the litter were made by the colorimetric method of Cavett (1956).

RESULTS AND DISCUSSION

Litter. Measurable levels of arsenic (15–30 p.p.m.) were found in the litter of every house in which roxarsone had been used (Table I). Arsenic levels in houses in which roxarsone had not been used were 2.6 and less than 0.1 p.p.m. in house V and U, respectively. Roxarsone assays of the litter indicated that 36 to 88% of the arsenic in the litter was attributed to the presence of the unchanged drug excreted via the droppings.

The presence of large amounts of unchanged drug in the litter is in agreement with the findings of Moody and Williams (1964a) who reported that roxarsone administered to hens was mostly excreted unchanged. The only transformation product excreted was 3-amino-4-hydroxyphenylarsonic acid which amounted to only 18% of the dose. There was no indication of the formation of arsenoxides or acetamido compounds. Excretion studies an other organoarsenical feed additives indicate that 4-nitrophenylarsonic acid is similarly excreted mostly unchanged (Moody and Williams, 1964b) and that arsanilic acid is excreted entirely unchanged (Moody and Williams, 1964c; Overby and Straube, 1965; Overby and Fredrickson, 1963, 1965; and Overby *et al.*,

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Table I. Arsenic and Roxarsone Content of Poultry House Litter of Commercial Farms in Arkansas

Source	Roxarsone Used	Arsenic Found, P.P.M.	Roxarsone Found, P.P.M.
House J	Yes	21.6	50
House K	Yes	15.5	50
House L	Yes	11.8	34
House M	Yes	27.0	47
House N	Yes	24.8	61
House O	Yes	29.6	54
House P	Yes	23.6	49
House Q	Yes	22.3	28
House R	Yes	18.0	...[a]
House S	Yes	12.6	43
House T	Yes	17.0	34
House U	No	<0.10	0
House V	No	2.60	...[a]

[a] Not assayed.

Table II. Arsenic Content in Feathers of Commercially Raised Broiler Chickens

Source	Roxarsone Fed to Chickens	Arsenic Found, P.P.M.
House K	Yes	0.60
House L	Yes	0.41
House M	Yes	0.70
House N	Yes	0.67
House O	Yes	1.32
House P	Yes	1.42
House Q	Yes	0.76
House R	Yes	0.80
House S	Yes	1.09
House T	Yes	0.75
House J	No	0.50
House U	No	<0.10
House V	No	<0.10
Processing plant[a]	No	<0.10

[a] Birds raised on a farm that used no arsenicals in the feed.

Table III. Ranking of Withdrawal Time and Arsenic in Litter with Respect to Arsenic Content in Chicken Feathers[a]

Feather Arsenic, P.P.M.	Withdrawal Time		Litter Arsenic	
	Days	Rank	P.P.M.	Rank
0.40	0	1	11.8	9
0.60	14	9	15.5	8
0.67	7	7	24.8	2
0.70	11	8	27.0	1
0.75	4	4	17.0	7
0.76	0	1	22.3	4
0.80	5	5	18.0	6
1.09	5	5	21.6	5
1.42	2	3	23.6	3

[a] The shortest withdrawal time and highest litter arsenic were assigned a rank of 1.

Table IV. Comparison of Arsenic Content after a 5-Day Withdrawal Period of Roxarsone Medication in Tissues of Broiler Chickens Raised on Litter *vs.* Broiler Chickens Raised in Wire Batteries

	P.P.M. As ± s	Range, P.P.M. As
Liver		
Litter	0.39 ± 0.13 (105)[a]	0.15–0.79
Wire	0.38 ± 0.12 (76)	0.18–0.73
Muscle		
Litter	<0.10 (105)	All <0.10
Wire	<0.10 (76)	All <0.10
Skin		
Litter	<0.10 (68)	All <0.10
Wire	<0.10 (76)	All <0.10
Kidney		
Litter	0.13 (45)	<0.10–0.23
Wire	0.12 (72)	<0.10–0.24

[a] Numbers in parenthesis indicate number of assays performed.

1965). Another source of drug in the litter would be from spilled feed, but this contribution would be small compared to the roxarsone contributed by the droppings.

Feathers. Since hydrolyzed feather meal is frequently incorporated into poultry feed at the 1–3% level as a protein supplement, the arsenic contributed by feather meal may play an important role in the arsenic depletion rate in poultry. The arsenic content in feathers of birds medicated with roxarsone was found to be between 0.4 and 1.4 p.p.m. with an over-all average of 0.85 p.p.m. (Table II) and, therefore, would not be expected to make any significant contribution to the total arsenic content of poultry feed. Only one group of birds not receiving an arsenical had a feather arsenic content in excess of 0.1 p.p.m. (House J).

There was no indication that the feather arsenic level was influenced by the presence of organoarsenicals in the litter since there was no correlation between feather arsenic levels and either litter arsenic levels or withdrawal time (Table III). This was determined by ranking the two variables in question against feather arsenic content. The shortest withdrawal time and the highest litter arsenic were assigned a rank of 1. The ranking data indicate that this type of relationship does not exist since, *e.g.*, the feathers with the highest arsenic had a withdrawal time rank of 3 and a litter rank of 3, ranking values which should produce a low feather arsenic level, not a high one as was observed. Since the rank of the arsenic in litter and the rank of withdrawal time are not related to the rank of the feather arsenic content, these variables apparently do not affect the arsenic content in feathers. The Spearman rank correlation coefficient (Siegel, 1956) was used to confirm this conclusion and was calculated to be −0.32. The large deviation from 1 indicates that there was no correlation between litter arsenic and withdrawal time on feather arsenic since to be significant at the 95% confidence level the value must be 0.60 or greater.

Since the longer withdrawal times did not appear to influence the depletion of feather arsenic, it can be concluded that the small amount of arsenic retained in chicken feathers as a result of medication is probably tightly bound and, therefore, slow to deplete.

Tissues. Raising birds on litter known to contain arsenical feed additives did not alter the tissue arsenic level when compared to birds raised in batteries ($p = 0.05$) after a five-day withdrawal of medication (Table IV). The observed tissue arsenic levels are in agreement with previously reported findings for tissue arsenic after withdrawal of medication (Hüni and Zanetti, 1963; Kerr *et al.*, 1963; Overby and Fredrickson, 1965; and Simon, 1966). The lack of an effect of poultry litter on tissue arsenic agrees with the findings of Brugman *et al.* (1968) who reported that feeding poultry

Table V. Arsenic Content of Soils, Crops, and Drainage Water

Sample	Length of Time Treated with Poultry Litter	Arsenic Found,[a] P.P.M.
Soil	20 years	1.83
Soil	None	2.65
Crop, alfalfa	20 years	0.12
	2 years	0.10
	None	0.10
Crop, clover	20 years	0.15
	2 years	<0.10
	None	0.17
Drainage water	20 years	0.29

[a] Average of three samples.

litter containing roxarsone to lambs did not cause residues of arsenic to accumulate in the tissue nor did it affect growth. These findings are similar to those of Overby and Frost (1962a,b) and Calesnick *et al.* (1966) who reported the non-availability of arsenic in the meat of animals medicated with arsanilic acid. Although the identification of the compounds retained in meat of animals has not been established, Overby and Fredrickson (1965) did show that the components present in the meat of chickens were identical to the components detected as an excretion product.

That the roxarsone in litter does not contribute to the tissue arsenic can be explained in several ways. First, the the amount of litter consumed is probably small compared to the amount of feed consumed and, therefore, the amount of roxarsone contributed by the litter would not add significantly to the total drug intake. Second, the roxarsone present in the litter would be primarily that which has been excreted in the droppings and, as has been reported by Brugman *et al.* (1968), is apparently unavailable. Therefore, consumption of litter containing arsenicals would be of minor significance in either the accumulation or depletion of arsenic in poultry tissue.

Soil, Crops, and Water. The arsenic content of soil and ground water was apparently unaffected by treatment of the soil with poultry house litter (Table V) and is in agreement with published data for natural arsenic levels in soil and water (Bishop and Chisholm, 1962; Schroeder and Balassa, 1966; Small and McCants, 1962; Vallee *et al.*, 1960; and Williams and Whetstone, 1940). The arsenic content of the forage crops studied contained less than 0.2 p.p.m. arsenic regardless of the extent of litter treatment of the soil. These levels are in agreement with published data for naturally occurring arsenic in plants (Frost, 1967; McBee *et al.*, 1967; Shtenberg, 1941; Vallee *et al.*, 1960; and Williams and Whetstone, 1940) but are not in agreement with plant arsenic data of plants grown on fields treated with arsenical pesticide, herbicide, or defoliant sprays (Bishop and Chisholm, 1962; Schweizer, 1967; and Williams and Whetstone, 1940). Use of these sprays can result in soil arsenic levels as high as 550 p.p.m. and plant arsenic levels as high as 83 p.p.m. (Williams and Whetstone, 1940).

That the use of poultry litter containing arsenical feed additives does not appear to affect the arsenic content of soil and crops is not surprising since the amount of arsenic contributed by litter used as fertilizer would only be between 50 and 100 grams of arsenic per acre per year or 1 to 2 p.p.m. of arsenic. This estimate is based upon a use rate of 4 to 6 tons of poultry litter per acre which is the recommended fertilization rate for poultry litter (Benson, 1968). To produce a soil arsenic level equivalent to that which has been reported from the use of arsenical sprays (*i.e.*, 550 p.p.m.), litter would have to be applied at the rate of 2200 tons per acre. Since arsenical sprays are inorganic arsenic compounds such as lead arsenate, calcium arsenate, and arsenic trioxide, or simple organic arsenicals such as copper acetoarsenite, mono- and disodium methanearsonate, cacodyl, and cacodylic acid, this may also add to the explanation of the difference between the soil and plant arsenic levels due to arsenical sprays *vs.* the soil and plant arsenic levels due to arylarsenical feed additives such as roxarsone.

CONCLUSIONS

The arsenic content in litter from poultry houses in which arsenicals had been used did not appear to affect the arsenic content of poultry tissues or feathers. The arsenic content of soils or crops grown on soils treated with litter is similarly not affected. It is, therefore, concluded that the use of poultry litter for the purposes described does not increase the arsenic content of poultry tissues, soils, or crops.

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