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Acute Toxicity of Dietary Polybrominated Biphenyls in Bobwhite Quail

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Polybrominated biphenyls (PBB) have been used in the plastics industry as a component of radio, typewriter, and television housings to reduce flammability. Because PBB were produced entirely for industrial uses, interest in their oral toxicity was low. However, the summer of 1973 saw the accidental mixing of the fire retardant Fire-Master™ FFI, a polybrominated biphenyl, into livestock and poultry feeds in Michigan. Producers in both industries reported widespread adverse effects as a result of this contamination (Carter 1976) Following the contamination of the livestock industries, concern was felt for associated wildlife populations.

A literature review indicated that a pausity of information existed regarding research with PBB on avian species. Cecil (1973) studied one PBB (BP-6) while testing polychlorinated biphenyl effects on reproduction in chickens, and reported that egg production was reduced while shell thickness, egg weight, fertility and hatchability were unaffected. Cecil et al. (1974) also reported a reduction of phenobarbital sleeping time in Japanese quail treated with PBB (BP-6). Fries et al. (1973) reported resistance of PBB to transfer across biological membranes.

Research with Japanese quail by Babish et al. (1975) indicated that 1000 ppm of PBB in the diet resulted in animals going off feed, while levels up to 100 ppm were well tolerated for 9 weeks. Although feed intake and growth were similar in quail fed 0 to 100 ppm PBB, egg production was reduced with none of the eggs hatching from quail fed 100 ppm of PBB.

This investigation was undertaken to study the acute oral toxicity of PBB to Bobwhite Quail (Colinus virginianus). The median lethal dietary concentration (LC_{50}) of PBB was determined over 8 days and clinical signs of intoxication are described.

MATERIALS AND METHODS

The protocol for median lethal concentration (LC_{50}) described by Heath and Stickel (1965) was followed with no modifications. Specifically, all birds (n=100) were incubator-hatched progeny of the Bobwhite breeding colony maintained at Michigan State University. Bobwhite were used as

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a representative upland species. The experiment was conducted in thermostatically controlled laboratory brooder units. A 14-hr light regimen was used. Ten birds, 13-14 days old, were randomly assigned to each of the 10 groups the day prior to test initiation. Birds were acclimated on quail starter diet. Preliminary dose-range finding studies indicated that the 8-day LC_{50} would be around 500 ppm PBB; doses were selected between 100-700 ppm to maximize the observations around the 500 ppm figure.

The test diets were prepared by mixing the preweighed dry chemical with quail starter diet in a mechanical rotary feed mixer.

Mortality was recorded daily throughout the 8 day test period (5 days of treated diet, 3 days with an untreated diet). Test pens were checked 2 to 4 times per day. Signs of intoxication were noted and feed consumption was monitored.

Time-to-death values were evaluated by analysis of variance; differences among treatments were determined using Scheffe's procedure for unequal treatment size. All formulae were as described in Snedecor and Cochran (1971). Probit analysis (Finney, 1971) was used for estimating PBB concentrations which would produce 1 to 99 percent mortality (Table 2). The fiducial limits for each estimate were computed using a t-value of 1.96 (95% confidence interval).

RESULTS AND DISCUSSION

Intoxication was seen to precede mortality in all cases. Recovery did not occur after the signs of intoxication were observed. Initially birds showed asthenia and decreased activity. Low carriage, an unkept appearance and wing droop followed and were associated with the general lethargy. Intoxicated individuals showed a limited ataxia preceding diarrhea, decreased activity, and death. Mortality usually occurred overnight and dead birds found at the beginning of the next day were severely dehydrated; this was probably due to the temperature in the brooder.

Food consumption appeared to decrease as PBB concentration in the diet increased (Table 1). As intoxication progressed (particularly between 400 and 700 ppm) anorexia became pronounced causing feed consumption to decline. However, quail have been shown to respond to gustatory cues (Wilcoxon et al., 1971) If such a cue were associated with PBB this could account for the trend in decreased food consumption seen. However, in nature the Bobwhite quail readily accept a wide variety of food plants. Therefore, it seems unlikely that reduced palatability would explain the decreased food intake at these doses (Rosene 1969).

Table 1. Food Consumption, Percent Mortality and Mean Time-to-Death for Bobwhite Quail Fed Rations Containing Different Levels of PBB

Concentration of PBB in feed (ppm)	Estimated Food Consumption[a] (g/bird/day)	(% of control)	Mortality[(b)] (No. dead/No. exposed)	Time-to-Death[(c)] (days)
Control	5.7	100	0/10	N.D.[(d)]
100	4.3	77	0/10	N.D.
200	3.6	64	1/10	8
300	3.5	63	1/10	6
400	3.5	61	1/10	8
450	3.4	61	4/10	6.8 ± 0.8[e]
500	2.9	52	9/10	5.4 ± 0.2[f]
550	2.7	47	7/10	6.4 ± 0.4[e]
600	2.7	47	10/10	5.3 ± 0.3[f]
700	2.1	37	10/10	5.5 ± 0.3[f]

(a) Estimated from weighing back food not consumed and dividing by number of bird-days; (b) over entire 8-day protocol; (c) each value is mean ± SEM of 1-10 observations; (d) no deaths observed; (e,f) values with common superscripts are not significantly different ($p>0.05$)

The earliest mortality was seen at 3 day (700 ppm). The greatest mortality was recorded at day 6, the day after ingestion of the maximum amount of the compound. Contrary to the response noted with many pesticides, mortality did not decrease after removal of the PBB from the diet, but continued to the final day of the test. This probably reflects the relatively long biological half-life of PBB. Fries et al. (1976) demonstrated a half-life of 226 days for the hexabromobiphenyl isomer in the body fat of white leghorn hens.

Table 2. Dietary Concentrations of PBB Estimated[a] to Produce Between 1 to 99 Percent Mortality within Eight Days

Percent of Animals Expected to Die Within 8 Days	Dietary Concentration (ppm)	95% Confidence Interval (ppm)
1	208	6-307
5	257	20-349
10	287	36-377
20	329	73-417
30	363	121-455
40	395	181-503
50	428	253-577
60	463	326-716
70	503	390-994
80	555	443-1577
90	637	501-3165
95	713	544-5734
99	881	624-17785

(a) Estimated from probit analysis of 8-day mortality data listed in TABLE 1.

Animals consuming 600 ppm or more of PBB in the diet died earliest in the study. Death resulted from the consumption of approximately 140 mg of PBB over all dietary concentrations greater than 200 ppm. The possibility of random deaths exists but it was felt this was unlikely since no deaths occurred in the control group or at the 100 ppm level and all birds exhibited typical clinical signs prior to death.

As seen in Table 2, the dietary LC_{50} found in this study was 428 ppm, with 95% confidence limits of 253-577 ppm. Table 2 also lists LC values and 95% confidence intervals for dietary PBB for 1 to 99 percent mortality.

It has been shown that rats can tolerate dietary levels of PBB as high as 1000 ppm over 4 weeks with no adverse effect on weight gain or food intake (Aftosmis et al., 1972). In comparison, Bobwhite quail appear to be rather sensitive to PBB, with an 8-day LC_{50} of 428 ppm and a reduction in feed consumption o 64 percent of controls at 200 ppm.

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