Feeding Behavior and Growth of Broiler Chicks Fed Larvae of the Darkling Beetle, *Alphitobius diaperinus*

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ABSTRACT Experiments were conducted to determine the effects of feeding larvae of the darkling beetle (lesser mealworm), *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae) to broiler chicks on chick growth. Chicks readily fed on the larvae and exhibited reduced growth in the absence of other feed. Chicks 3 to 8 d old restricted to a diet of only larvae consumed 1,552 ± 172 (mean ± SD) larvae per chick per day and their body weights were significantly less (mean = 84 g) at the end of the 6 d than for chicks on starter feed during the same time. After return to starter feed for 8 d after feeding on larvae for 6 d, the chicks did not compensate for the reduced weight and their body weights were significantly less (mean = 170 g) than for chicks on starter feed for the 14 d.

Chicks from age 2 through 9 d were given a choice between broiler starter feed and darkling beetle larvae. The numbers (mean ± SD) of larvae consumed per chick per day were: 389 ± 18, 631 ± 14, 496 ± 20, and 287 ± 33, for Days 2 to 3, 4 to 5, 6 to 7, and 8 to 9, respectively. The body weight of chicks feeding on starter feed and larvae was significantly greater than the weight of chicks consuming feed only. In the presence of larvae, the mean feed consumption per chick was less than for chicks provided with only starter feed. The beetle larvae were 68% crude protein and 21% fat (DM basis) and had higher amounts of 18 amino acids than the starter feed.

(*Key words*: darkling beetle, lesser mealworm, *Alphitobius diaperinus*, broiler chick feeding behavior, chick growth)

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INTRODUCTION

The litter in brooder and growout houses for broiler and turkey production is often infested with large numbers of the darkling beetle, *Alphitobius diaperinus* (Panzer) (Coleoptera: Tenebrionidae), also known as the lesser mealworm. The beetles are known reservoirs for many pathogens and the larvae cause major damage to insulation in poultry houses (Axtell and Arends, 1990). The consumption of beetle larvae by turkey poults has been shown to be detrimental to poult growth and a means of transmitting enteric pathogens (Despins and Axtell, 1994; Despins *et al.*, 1994).

Broiler chicks are often observed feeding on darkling beetle larvae in the litter and feed pans. However, the effects of that feeding have not been adequately investigated. In very limited experiments, Gould and Moses (1951) force-fed darkling beetle adults and larvae (whole and macerated) one time to chicks and found no adverse effects. Skewes and Monroe (1991) attempted to compare performance of broiler chickens in commercial growout houses with different population densities of darkling beetle adults and larvae; no relationships between darkling beetle population density and chick mortality, feed conversion, condemnation rate, and production cost were detected.

Controlled studies have not been conducted to examine the effects of allowing broiler chicks to ingest darkling beetle larvae. The objectives of the present re-

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search were: 1) to determine how many darkling beetle larvae broiler chicks will consume in the absence of an alternative feed and how this effects chick growth; and 2) to determine the number of beetle larvae broiler chicks will consume when given a choice between larvae and a starter feed, and the effects of this larval consumption on chick growth.

MATERIALS AND METHODS

Experimental Design

The broiler chicks were in pens consisting of a hard plastic wading pool (1 m diameter, .2 m height) with wood shavings litter (about 5 cm deep). A water dispenser and feeder pan were suspended above the litter at about breast height of the birds in each pen. Recommended floor area, feeder and watering requirements, and guidelines for care of chickens detailed in *Guidelines for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (Consortium, 1988) were followed.

Male hatchling Arbor Acres "Fast Feather" broiler chicks were obtained from the hatchery of the Department of Poultry Science, North Carolina State University. Unmedicated starter feed used in the experiments met or exceeded the National Research Council (1984) nutrient requirements for broiler chicks. Composition (percentage of total diet) of the feed, formulated at the North Carolina State University, Department of Poultry Science feed mill, was: corn, 58.9; soybean meal, 26.9; dicalcium phosphate, .8; limestone, .8; poultry fat, 3.6; poultry meal, 8.0; DL-methionine, .18; lysine, .07; salt, .4; choline chloride, .2; minerals [TM-90], .2; and vitamins [NCSU-90], .05.

Experiment 1. Measurement of Absolute Consumption of Larvae

The chicks were randomly assigned to six pens with five chicks per pen. There were three pens (replicates) for each of two treatments: 1) larvae only, and 2) starter feed only. The birds were marked with colored inks so that individual birds could be identified subsequently when weighing. For 2 d after hatching, all of the chicks were provided with starter feed.

Beginning the 3rd d after hatch and continuing through Day 8, the birds in Treatment 1 were fed only beetle larvae; the birds in Treatment 2 continued to feed on starter feed. Larvae (7 to 13 mm, length) were placed directly on the litter so the chicks could freely forage for them. Known numbers of larvae were added to each pen once a day. At three 48-h intervals, the larvae were separated from the litter by use of sieves and counted. Based on the number of larvae added per pen and the number recovered, the number of larvae consumed per chick per day was calculated. The recovery of larvae by sieving demonstrated that excess larvae were given to the chicks each day. After the 6 d of feeding on larvae, the birds in Treatment 1 were returned to starter feed. The birds in both treatments continued to be fed starter feed through Day 14 of life. Feed consumption and individual body weights were measured daily.

Experiment 2. Chick Growth as Affected by Darkling Beetles in the Diet

The chicks were randomly assigned to eight pens with seven chicks per pen. There were four pens (replicates) for each of two treatments: 1) larvae and starter feed, and 2) starter feed only. All of the birds were fed the starter feed for the 1st d after hatch. Beginning the 2nd d after hatch, the birds in Treatment 1 were given a choice between broiler feed and larvae (that is, the chicks could forage for larvae in the litter or feed from the feeder pans). The birds in Treatment 2 were provided with starter feed only. Known numbers of larvae were added to each pen in Treatment 1 once a day and larval consumption determined at 48-h intervals, as described for Experiment 1, through Day 9 of chick life. After the 8 d of feeding on larvae, the birds in Treatment 1 were returned to starter feed. The birds in both treatments continued to be fed starter feed through Day 14 of life. Feed consumption and individual body weights were recorded daily.

Live weight per larva was calculated by weighing 40 samples of 20 larvae each and the samples of larvae were dried in an oven for 16 h at 94 C to obtain dry weight. It was then possible to transform the data on the

TABLE 1. Effect of feeding a diet of only darkling beetle larvae to broiler chicks for 6 d (age 3 to 8 d) on chick growth and feed consumption, Experiment 1

Chick age	Body weight per chick			Feed consumption per chick		
	Feed only	Larvae only Days 3 to 8	Difference	Feed only	Larvae only Days 3 to 8	Difference
(d)	(g)			(g)		
1	57.9 ± 5.1[1]	56.2 ± 5.0	−1.7 NS	14.0 ± 3.0	12.0 ± 2.5	−2.0 NS
2	71.9 ± 8.8	68.2 ± 7.2	−3.7 NS	17.0 ± .8	14.3 ± 2.6	−2.7 NS
3	87.5 ± 7.4	77.4 ± 8.6	−10.1 **	23.0 ± 4.0	N/A[2]	. . .
4	108.3 ± 8.3	87.0 ± 10.2	−21.3 ***	29.8 ± 4.2	N/A	. . .
5	131.0 ± 8.7	99.0 ± 6.7	−32.0 ***	38.0 ± 4.5	N/A	. . .
6	156.1 ± 9.8	110.7 ± 7.5	−45.4 ***	57.8 ± 14.4	N/A	. . .
7	181.1 ± 11.4	120.0 ± 8.9	−61.1 ***	55.3 ± 2.6	N/A	. . .
8	210.4 ± 13.5	126.6 ± 9.8	−83.8 ***	50.0 ± 5.3	N/A	. . .
9	245.9 ± 15.5	156.9 ± 11.2	−89.0 ***	67.5 ± 5.0	31.8 ± 5.6	−35.7 *
10	288.0 ± 18.0	178.4 ± 12.0	−109.6 ***	75.3 ± 13.8	41.8 ± 15.8	−33.5 NS
11	325.9 ± 20.4	195.6 ± 17.0	−130.3 ***	61.7 ± 14.9	28.1 ± 2.4	−33.6 *
12	370.0 ± 22.6	222.8 ± 16.7	−147.2 ***	61.4 ± 12.7	40.8 ± 4.9	−20.6 NS
13	420.0 ± 24.4	258.4 ± 21.4	−161.6 ***	88.6 ± 23.4	43.0 ± 2.3	−45.6 *
14	467.8 ± 26.4	295.1 ± 25.4	−172.7 ***	75.9 ± 2.1	44.5 ± 2.8	−31.4 ***

[1]Mean ± SD.

[2]N/A = not applicable.

*$P \leq .05$.

**$P \leq .01$.

***$P \leq .001$.

numbers of larvae consumed daily per poult to dry matter weights. Likewise, 10 samples (10 g each) of starter feed were oven-dried and the daily intake of feed per bird converted to dry matter weight. The intake of various nutrients that was due to intake of larvae or to intake of feed was estimated by multiplying the dry matter weights of larvae or feed consumed by the respective percentage concentrations as determined by chemical analyses.

Samples of beetle larvae and starter feed were analyzed for nutrient content by a commercial laboratory.[2] The larvae were deprived of food and water for 24 h, stored at −70 C, and lyophilized before chemical analysis. Analysis of larvae and feed included crude protein, crude fat, 11 essential amino acids (Parkhurst and Mountney, 1988), 7 other amino acids, and several minerals.

Statistical Analysis

Data obtained in the experiments were analyzed by analysis of variance with treatment groups included as the independent variable using PROC GLM or PROC ANOVA (SAS Institute, 1988) at an α of .05 level of significance.

RESULTS

Experiment 1

The broiler chicks were effective foragers of darkling beetle larvae and immediately began searching the litter for the insects. The number (mean ± SD) of larvae consumed per chick per day for the 6 d was 1,552 ± 172; for each of the three 2-d feeding periods it was 1,332 ± 149, 1,927 ± 199, and 1,398 ± 168. Live larvae used in this experiment weighed (mean ± SD, n = 40) 16.9 ± 1.1 mg. The live weight intake of larvae per chick per day was about 23, 33, and 24 g for chicks aged 3 to 4, 5 to 6, and 7 to 8 d, respectively. Chicks consumed so many larvae that their crops became greatly distended and live larvae could be seen through the skin of the chick. Chicks that fed only on larvae for 6 d weighed ($P \leq .001$) less (84 g) than chicks that fed on starter feed (Table 1). After return to starter feed on Day 9, the insect-fed chicks continued to

[2]Woodson-Tenent Laboratories, Goldston, NC 27252.

weigh significantly less than the chicks on the starter feed through the end of the experiment on Day 14. The difference in mean body weight between the two groups was 173 g per chick at the end of the experiment. When the insect-fed chicks were returned to starter feed, consumption of feed was less ($P \leq .05$) than that of the control chicks on 4 of the last 6 d of the experiment.

Besides slower weight gain, the chicks showed signs of stress during the larval feeding period. The chicks were very vocal compared with the chicks on starter feed. The insect-fed chicks produced watery feces, and whole, apparently undigested larval cuticle was present in the feces. On the 5th d of feeding on larvae, several chicks appeared to have problems expelling the intestinal contents and each dropping consisted of a large mass of darkling beetle larvae. In addition, some chicks were less ambulatory and could move about the pen only through a combination of flapping their wings and waddling. After the chicks were returned to starter feed on Day 9, the loud vocal cries disappeared, the condition of the feces returned to normal, and the chicks with impaired mobility recovered their normal walking habits by the end of the experiment (Day 14).

Experiment 2

Chicks actively searched for beetle larvae when the insects were placed on the litter, and they fed on the larvae in substantial numbers even in the presence of the starter feed. When given a choice between starter feed and darkling beetle larvae, the number of larvae consumed per chick per day was 389 ± 18, 631 ± 14, 496 ± 20, and 287 ± 33 for chicks 2 to 3, 4 to 5, 6 to 7, and 8 to 9 d old. The mean consumption over the entire 8 d was 451 ± 21 larvae per chick per day. There was no negative effect on the chick body weight due to feeding on both larvae and starter feed (Table 2). During the 14-d experiment, there were 7 d when chicks feeding on both larvae and starter feed were significantly heavier ($P \leq .05$) than the chicks on only starter feed but the weight differences were small. At the end of the experiment, chicks fed larvae and starter feed were 22 g heavier than the chicks that were fed only starter feed. Chicks feeding on larvae consumed slightly less starter feed each day than the chicks fed only starter feed. The difference in feed consumption per chick per day was 4.6, 11.4, 10.0, and 5.7 g for chicks 2 to 3, 4 to 5, 6 to 7, and 8 to 9 d old, respectively.

The darkling beetle larvae were about 68% crude protein and 21% crude fat (Table

TABLE 2. Effect of a diet of darkling beetle larvae and broiler starter feed for 8 d (age 2 to 9 d) on growth of broiler chicks, Experiment 2

Chick age	Body weight per chick		
	Feed only	Larvae and feed	Difference
(d)	(g)		
1	52.4 ± 4.1[1]	54.0 ± 4.7	1.6 NS
2	64.4 ± 5.7	65.6 ± 5.1	1.2 NS
3	79.5 ± 7.4	79.1 ± 6.3	−.4 NS
4	98.2 ± 8.6	100.0 ± 8.7	1.8 NS
5	115.1 ± 10.2	119.1 ± 10.4	4.0 NS
6	138.6 ± 12.4	146.1 ± 12.0	7.5 *
7	165.2 ± 14.8	173.4 ± 14.4	8.2 *
8	194.7 ± 17.1	204.1 ± 16.8	9.4 *
9	224.9 ± 19.7	236.0 ± 20.3	11.1 *
10	259.7 ± 23.7	272.3 ± 24.0	12.6 NS
11	300.5 ± 25.3	313.5 ± 29.6	13.0 NS
12	346.1 ± 28.4	363.5 ± 33.6	17.4 *
13	382.1 ± 29.8	400.8 ± 37.4	18.7 *
14	428.8 ± 33.3	450.5 ± 43.1	21.7 *

[1]Mean ± SD.

*$P \leq .05$.

3). The percentage of total protein intake attributable to the ingestion of beetle larvae was 35, 32, 20, and 10% for the chicks 2 to 3, 4 to 5, 6 to 7, and 8 to 9 d old, respectively. Calculated crude protein intake was greater ($P \leq .05$) for the chicks feeding on larvae at age 2 to 3 d and significantly less for those aged 4 to 5 d; protein intake was not different on Days 6 to 7 and 8 to 9. Crude fat intake was significantly greater only for chicks aged 2 to 3 d.

Larvae were higher than the broiler starter feed in concentration of the 18 amino acids. Tyrosine, in particular, was 8.6 times higher in concentration in the larvae than in the starter feed. Actual calculated amino acid intake by the chicks in the two treatments were different ($P \leq .05$) in some cases. Cases of significantly less amino acid intake by chicks feeding on larvae during one or more of the four age groupings were: arginine (4 to 5 d), glycine (4 to 5 and 8 to 9 d), isoleucine (4 to 5 d), leucine (4 to 5 and 8 to 9 d), phenylalanine (4 to 5 d), aspartic acid (4 to 5 and 8 to 9 d), cystine (4 to 5 and 8 to 9 d), glutamic acid (4 to 5 and 8 to 9 d), proline (4 to 5 d), serine (4 to 5 d), and tyrosine (6 to 7 d). Cases of significantly greater amino acid intake by chicks feeding on larvae during one or more of the four age groupings were: histidine (2 to 3 and 4 to 5 d), isoleucine (2 to 3 d), tryptophan (2 to 3 d), valine (2 to 3 d), and tyrosine (4 to 5 and 8 to 9 d).

TABLE 3. Chemical analyses of broiler chick starter feed and beetle larvae used in Experiment 2

Constituent	Broiler starter feed	Darkling beetle larvae
	(% of dry matter weight)	
Crude fat	7.35	20.68
Crude protein	26.01	67.85
Fiber	3.71	7.29
Ash	5.90	5.01
Phosphorus	.61	.90
Calcium	1.20	.03
Sodium	.17	.20
Magnesium	.15	.14
Potassium	.62	.79
Manganese	.0112	.0016
Copper	.0024	.0027
Iron	.0231	.0218
Zinc	.0157	.0268
Essential amino acids		
Arginine	1.60	3.35
Glycine	1.47	2.89
Histidine	.75	2.60
Isoleucine	1.02	2.56
Leucine	2.08	4.03
Lysine	1.43	3.90
Methionine	.65	1.87
Phenylalanine	1.17	2.79
Threonine	1.01	2.34
Tryptophan	.33	1.09
Valine	1.19	3.29
Other amino acids		
Alanine	1.42	3.93
Aspartic acid	2.60	4.83
Cystine	.34	.52
Glutamic acid	4.34	7.03
Proline	1.63	3.56
Serine	1.27	2.56
Tyrosine	.55	4.76

DISCUSSION

These experiments show that broiler chicks feed readily on darkling beetle larvae in the litter and consume large numbers, at least during the first 9 d of life. Experiment 1 demonstrated that young chicks that feed only on beetle larvae experience low weight gain and show signs of distress. After return to starter feed, those chicks gain weight but not as rapidly as chicks fed only starter feed, at least through 14 d of age, which was the duration of the experiment.

Consequently, if young chicks feed only on larvae, the adverse effects on weight gain may be long-lasting. Some chicks in commercial flocks have been observed feeding extensively on beetle larvae and having crops full of larvae and litter: this may result in some mortality and poor performance in flocks.

Gould and Moses (1951) force-fed larvae to chicks only one time and the conclusion of no adverse effects has little meaning. Skewes and Monroe (1991) could not demonstrate relationships between beetle populations in commercial broiler houses and flock performance but the estimates of beetle populations in the houses were inadequate; too few tube traps were used to sample the beetle population in view of the high variability of that method (Safrit and Axtell, 1984).

Experiment 2 demonstrated that chicks given a choice between beetle larvae and

starter feed readily consumed the larvae along with the feed. The result was slightly reduced feed consumption but no adverse effect on chick weight gain. From 10 to 35% of the protein intake by the chicks was due to consumption of larvae. There were some differences in amino acid intake between chicks consuming larvae and starter feed and chicks fed only starter feed, but those varied with the bird age.

This report provides data showing how readily and extensively young broiler chicks feed on darkling beetle larvae found in the litter. This behavior increases the risk of disease because the larvae are known to be reservoirs for many viral, bacterial, and fungal pathogens of poultry (Snedeker *et al.*, 1967; De las Cases *et al.*, 1968, 1972, 1973, 1976; Harein *et al.*, 1970; Despins *et al.*, 1994; McAllister *et al.*, 1994). Further, the present study suggests that broiler production may suffer even in the absence of disease. If some of the chicks feed excessively on the larvae there will be poor weight gains and perhaps mortality. However, broiler production should not suffer if the consumption of beetles is small in relation to feed consumption.

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