Early Postmolt Performance of Laying Hens Fed a Low-Protein Corn Molt Diet Supplemented with Corn Gluten Meal, Feather Meal, Methionine, and Lysine

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ABSTRACT Commercial White Leghorn hens (65, 63, or 70 wk of age in Experiments 1, 2, and 3, respectively) were induced molted by feed withdrawal until approximately 28% body weight was lost. All hens were then weighed, and seven replicate groups of 12 hens each were fed molt diets. In Experiment 1, three diets consisted of a corn basal diet (7.9% CP) or this diet supplemented with corn gluten meal (CGM) and Lys or feather meal (FM), Met, and Lys. In Experiments 2 and 3, varying levels of FM and FM with Met and Lys were evaluated. A 16% CP corn-soybean meal diet was used as a positive control in all experiments. The molt diets were fed for 17, 15, and 17 d in Experiments 1, 2, and 3, respectively, and production performance was measured for 8 wk from the beginning of feeding the layer diet.

In all experiments, hens fed the 16% CP corn-soybean meal molt diet returned to egg production and regained body weight at a faster rate than did hens fed any of the other diets. In Experiment 1, early egg production of hens fed the corn basal diet supplemented with CGM and Lys or supplementation with FM, Met, and Lys was greater ($P < 0.05$) than that of hens fed the basal diet alone. In Experiment 2, very early egg production (Week 1) and body weight gain were lower ($P < 0.05$) for hens fed the corn basal diet than for hens fed the basal supplemented with FM, Met, and Lys. The addition of 5.75 or 8.5% FM or 5.75% FM plus Met and Lys generally increased ($P < 0.05$) early egg production and postmolt body weight gain compared to the corn basal diet in Experiment 3. The present study thus indicated that improved early postmolt performance may be achieved by supplementation of a low-protein corn molt diet with various combinations of CGM, FM, Met, and Lys.

(*Key words*: layer, molting, amino acids, corn gluten meal, feather meal)

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INTRODUCTION

Induced molting is a popular management technique used in the commercial egg industry. Numerous research studies have reported on recommended methods for conducting an appropriate molting program and North and Bell (1990) have provided an extensive review. Most molting programs recommend feed withdrawal to induce a molt, but the recommended type of nutritional recovery diets fed vary greatly among programs. The type of diet fed during the postmolt recovery period has been shown to affect subsequent postmolt performance. Swanson and Bell (1974) showed that hens return to egg production at a slow rate when fed a low-protein corn molt diet (7.5 to 8.5% CP). In comparison, Brake *et al.* (1979), Harms (1983), Andrews *et al.* (1987), and, more recently, Koelkebeck *et al.* (1991) have shown that hens fed higher protein molt diets (13 to 16%) return to egg production at a faster rate.

Even though previous work has shown that the return to postmolt egg production is slow when the hens are fed a low-protein molt diet, performance may be enhanced by supplementing this diet with one or more amino acids. Koelkebeck *et al.* (1993) reported that supplementation of a low-protein (7.6% CP) molt diet with Met, Lys, or Met, Lys, and Trp produced early postmolt performance that was nearly equal to that produced by feeding a 16% CP molt diet. In addition, it was estimated that the most economical molt diet to use would be a low-protein corn molt diet supplemented with 0.15% Met and 0.25% Lys.

There has been little or no research on the effects of supplementing a low-protein molt ration with ingredients other than Met and Lys. Thus, it was the objective

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Abbreviation Key: CGM = corn gluten meal; FM = feather meal.

TABLE 1. Composition and calculated analysis of the experimental molt diets and layer diet

Ingredients and analysis	Basal diet[1]	Experiment 1 Diet 2	Experiment 1 Diet 3	Experiment 2 Diet 2[2]	Experiment 2 Diet 3	Experiment 3 Diet 2	Experiment 3 Diet 3	16% CP Molt diet[3]	16% CP Layer diet[4]
	(%)								
Ground yellow corn	93.35	86.05	87.50	87.49	87.41	87.60	84.85	73.55	68.90
Soybean meal (dehulled)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	20.10	18.40
Corn gluten meal	0.00	7.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Feather meal	0.00	0.00	5.75	5.75	5.75	5.75	8.50	0.00	0.00
Limestone	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	8.50
Meat and bone meal	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.50
Dicalcium phosphate	2.00	2.00	2.00	2.00	2.00	2.00	2.00	1.90	1.25
Iodized salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
DL-methionine	0.00	0.00	0.05	0.05	0.05	0.00	0.00	0.00	0.00
L-Lysine·HCl	0.00	0.10	0.05	0.0625	0.1875	0.00	0.00	0.00	0.00
Trace mineral mix[5]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.05	0.05
Vitamin premix[6]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.10	0.10
Calculated analysis									
CP	7.9	11.8	12.1	12.1	12.1	12.1	14.1	16.00	16.00
ME, kcal/kg	3,127	3,150	3,067	3,067	3,067	3,067	3,043	2,953	2,865
Calcium	2.00	2.1	2.00	2.00	2.00	2.00	2.00	2.00	3.80
Available phosphorus	0.45	0.46	0.47	0.47	0.47	0.47	0.48	0.45	0.45
Methionine + cystine	0.19	0.50	0.64	0.64	0.64	0.59	0.73	0.55	0.54
Lysine	0.22	0.32	0.40	0.41	0.51	0.36	0.42	0.82	0.82

[1]The basal corn diet was fed as Diet 1 in Experiments 1, 2, and 3, respectively.

[2]Diet 2 was repeated in Experiment 3 and fed as Diet 4.

[3]The 16% CP corn-soybean meal molt diet was fed as Diet 4 in Experiments 1 and 2, and Diet 5 in Experiment 3.

[4]The 16% CP corn-soybean meal layer diet was fed to all hens for 8 wk after average egg production reached 10%.

[5]Provided per kilogram of diet: manganese, 75 mg; iron, 75 mg; zinc, 75 mg; copper, 5 mg; iodine, 0.75 mg; selenium, 0.1 mg.

[6]Provided per kilogram of diet: vitamin A from vitamin A acetate, 4,400 IU; cholecalciferol, 1,000 IU; vitamin E from α-tocopheryl acetate, 11 IU; vitamin B_{12}, 0.011 mg; riboflavin, 4.4 mg; d-pantothenic acid, 10 mg; niacin, 22 mg; menadione sodium bisulfite complex, 2.33 mg.

of this study to further examine the effects of supplementing a low-protein molt ration with protein and amino acids by using high protein ingredients. The two ingredients selected for evaluation were feather meal (FM) and corn gluten meal (CGM), which are widely available. Most of the emphasis was on evaluation of FM because this ingredient is an inexpensive source of CP and it contains high levels of Cys, an amino acid that is proposed to be needed in large amounts because of feather replacement (Brake *et al.*, 1979).

MATERIALS AND METHODS

Three experiments were conducted with Single Comb White Leghorn hens of the DeKalb Delta strain housed in a cage facility of commercial design. A 17-h daily photoperiod was maintained throughout the experiments and feed and water were supplied for *ad libitum* consumption prior to the initiation of each experiment. The hens were induced to molt by withdrawing feed only (free access to water was maintained) for 14, 12, or 11 d in Experiments 1, 2, or 3, respectively. Feed withdrawal was initiated when hens were 65, 63, or 70 wk of age, and body weight loss at the end of the feed withdrawal period were 28, 30, or 30% in Experiments 1, 2, and 3, respectively. All hens were weighed at the end of the feed withdrawal period, and seven replicate groups of 12 hens each (four adjacent raised wire cages, 30 × 46 cm, containing 3 hens each) were assigned to each dietary treatment so that body weights were similar among treatments. The dietary treatments (molt diets) consisted of a low-protein corn diet supplemented with CGM, FM, Lys, or Met and a 16% CP corn-soybean meal diet. The compositions of the experimental diets are depicted in Table 1. On the first 2 d following the feed withdrawal period, the molt diets were fed at a rate of 83 g per hen per d, and then consumed *ad libitum* until average egg production reached approximately 10% for all treatments. The molt diets were fed for 17, 15, or 17 d in Experiments 1, 2, and 3, respectively. All hens then consumed a 16% CP layer diet *ad libitum* (Table 1). Production performance was monitored in all experiments for 8 wk following the initiation of feeding the layer diet.

The molt diet treatments in the three experiments were primarily designed to evaluate the effects of supplementing a low-protein corn molt diet with FM in combination with different levels of Met and Lys. Another high protein ingredient, CGM, was evaluated to a lesser extent in Experiment 1. The analyzed CP of the CGM and FM were 63 and 85%, respectively. The levels of CGM and FM were generally selected so as to provide a total dietary CP level of 12 to 13% because previous studies (Hoyle and Garlich, 1987; Koelkebeck *et al.*, 1991) have shown that these levels of CP yielded postmolt performance that was similar to a 16 or 17%

CP corn-soybean meal diet. The levels of amino acid supplementation were based on the amino acid levels and performance responses of our previous study (Koelkebeck *et al.*, 1993) and on the expected amino acid deficiencies of CGM and FM. All amino acids, CGM, and FM were added to the basal diet in place of corn, with Lys provided as L-Lys·HCl and Met as DL-Met.

The dietary treatments in Experiments 2 and 3 were based on the results of Experiments 1 and 2, respectively. In Experiment 2, Treatments 2 and 3 evaluated whether performance could be further improved by supplementing the 5.75% FM diet with higher levels of Lys (0.0625 and 0.1875%) because that diet was calculated to be very deficient in Lys. In Experiment 3, a higher level of 8.5% FM was evaluated in addition to the 5.75% level to determine whether performance could be further improved by a higher level of FM. In addition, the 5.75% FM diet plus 0.05% Met and 0.0625% Lys was evaluated to determine whether the Met-Lys acid supplementation was yielding any performance response over the FM alone.

For each experiment, body weights of all hens were measured each week for 3 wk following the start of feeding the molt diets. Egg production and mortality were recorded daily for 8 wk from the beginning of feeding the layer diet. Egg weight was measured each week on all eggs produced on 2 consecutive d. Egg yield (grams of egg per hen per day) was then calculated using hen-day egg production and egg weight. Feed consumption was measured weekly and feed efficiency was calculated using egg yield and feed consumption.

All data were analyzed by ANOVA procedures appropriate for a completely randomized design (Steel and Torrie, 1980). Significant differences among treatment means were assessed using Fisher's least significant difference test (Steel and Torrie, 1980).

RESULTS AND DISCUSSION

Mortality averaged 1.7, 3.9, and 0.7% from the beginning of feed withdrawal up to the end of 8 wk on the layer diet in Experiments 1, 2, and 3, respectively. Mortality rate did not differ significantly among treatments in any experiment.

In Experiment 1, very early postmolt egg production (Weeks 1 to 2 on layer diets) was improved ($P < 0.05$) for hens fed the basal supplemented with CGM and Lys or FM, Met, and Lys compared to hens fed the basal corn diet (Table 2). Egg production for Weeks 1 to 8 was not significantly different among hens fed the basal diet or basal supplemented with FM, Met, and Lys. However, egg production of hens fed the basal supplemented with CGM and Lys or those fed the 16% CP diet was greater ($P < 0.05$) than that of hens fed the basal diet (Weeks 1 to 8).

Body weight gain during the first 2 wk was greater ($P < 0.05$) for hens fed the 16% CP molt diet than any other treatment (Table 2). Body weight gain of hens fed the basal supplemented with CGM and Lys was greater than that of hens fed the basal corn diet from the period from 15 to 35 d. The 16% CP diet yielded the largest egg weights, with the CGM being intermediary between the corn basal diet, FM, Met, and Lys diet, and the 16% CP diet.

The effects of dietary molt treatments on egg weight and egg yield in Experiment 1, showed similar results as egg production, except that egg weight and yield were lower for hens fed the basal supplemented with FM, Met, and Lys compared to hens fed the high-protein molt diet during Weeks 1 to 8 (Table 2). Hens fed the basal supplemented with CGM and Lys had egg weight and egg yields not significantly different from those fed the 16% CP diet. Dietary treatment did not significantly effect feed efficiency during the 8-wk production period.

In Experiment 2, early egg production (Weeks 1 and 2) was significantly greater for hens fed the 16% CP molt diet than that for any other treatment (Table 3). Supplementation of the basal diet with FM, Met, and Lys significantly increased egg production ($P < 0.05$) during the 1st wk only and egg weight during the first 2 wk. Similar results were noted for early postmolt egg yield as for egg production in Experiment 2 except that the FM-Met-Lys treatments significantly increased egg weight and egg yield during the 8-wk production period (Table 3). Egg weight (Weeks 1 to 8) was increased ($P < 0.05$) for hens fed the 16% CP molt diet or those fed the FM-Met-Lys basal supplemented diets (Table 3).

Body weight gain was significantly lower ($P < 0.05$) for hens fed the basal corn diet than those fed the other diets in all the three weighing periods (Table 3). Hens fed the 16% CP molt diet regained body weight the fastest. By the end of the 3rd wk of feeding the molt diets, the hens fed the basal supplemented with FM, Met, and Lys had body weight gains not significantly different ($P > 0.05$) from those fed the 16% CP molt diet. Feed efficiency was lower ($P < 0.05$) for hens fed the basal corn diet than for those fed the 16% CP molt diet.

As observed in Experiments 1 and 2, hens returned to egg production at the fastest rate when fed the 16% CP molt diet in Experiment 3 (Table 4). Egg production (Weeks 1 to 8) was improved ($P < 0.05$) for hens fed the basal diet supplemented with 8.5% FM or 5.75% FM, Met, and Lys compared to hens fed the basal diet only. The results for egg weight and egg yield were similar to egg production for Experiment 3 (Table 4). Egg weight was significantly greater for hens fed the 16% protein diet than for those fed the basal or basal supplemented with 5.75% FM (Weeks 1 to 8).

As in Experiments 1 and 2, body weight gain during the postmolt period was lowest for hens fed the basal corn diet only, and was greatest for hens fed the 16% CP molt diet in Experiment 3 (Table 4). At the end of Week 3, cumulative body weight gain for hens fed the basal supplemented with 8.5% FM or the basal plus 5.75% FM,

TABLE 2. Effect of dietary molt treatments on hen-day egg production, body weight gain, egg weight, egg yield, and feed efficiency, Experiment 1[1]

	Hen-day egg production			Body weight gain			Egg weight			Egg yield			Feed efficiency
Dietary molt treatments	1 wk	2 wk	1 to 8 wk	15 to 21 d	15 to 28 d	15 to 35 d	1 wk	2 wk	1 to 8 wk	1 wk	2 wk	1 to 8 wk	1 to 8 wk
	(%)			(g per hen)			(g per egg)			(g egg/hen/d)			(g egg:g feed)
1. Basal corn diet (B)	7.5[c]	33.8[c]	55.0[c]	270[c]	390[bc]	422[c]	58.5[bc]	57.2[d]	61.2[bc]	4.4[c]	19.5[c]	34.2[c]	0.322[a]
2. B + 7.2% corn gluten meal + 0.1% L-Lys·HCl	20.5[b]	54.3[ab]	63.8[ab]	328[b]	459[b]	496[ab]	60.6[ab]	61.2[ab]	62.6[ab]	12.4[b]	33.3[ab]	40.3[ab]	0.357[a]
3. B + 5.75% feather meal + 0.05% DL-Met + 0.05% L-Lys·HCl	16.8[b]	48.1[ab]	62.4[abc]	317[b]	403[bc]	469[bc]	58.3[c]	59.7[bc]	61.1[c]	9.8[b]	28.7[b]	38.4[bc]	0.358[a]
4. Corn-soybean meal (16% CP)	37.5[a]	60.4[a]	69.4[a]	400[a]	583[a]	546[a]	62.4[a]	62.2[a]	64.0[a]	23.4[a]	37.5[a]	44.5[a]	0.381[a]
Pooled SEM	1.8	4.8	2.6	15	14	19	0.8	0.6	0.5	1.1	2.9	1.7	0.021

[a–d]Means within columns with no common superscript differ significantly ($P < 0.05$).

[1]Data are means of seven groups of 12 hens each during the first 8 wk on the layer diet.

TABLE 3. Effect of dietary molt treatments on hen-day egg production, body weight gain, egg weight, egg yield, and feed efficiency, Experiment 2[1]

	Hen-day egg production			Body weight gain			Egg weight			Egg yield			Feed efficiency
Dietary molt treatments	1 wk	2 wk	1 to 8 wk	13 to 19 d	13 to 26 d	13 to 33 d	1 wk	2 wk	1 to 8 wk	1 wk	2 wk	1 to 8 wk	1 to 8 wk
	(%)			(g per hen)			(g per egg)			(g egg/hen/d)			(g egg:g feed)
1. Basal corn diet (B)	15.2[d]	54.1[b]	58.2[b]	228[c]	357[c]	431[b]	53.1[b]	57.8[c]	57.4[b]	8.0[d]	31.2[b]	33.6[c]	0.328[b]
2. B + 5.75% feather meal + 0.05% DL-Met + 0.0625% L-Lys·HCl	21.9[c]	59.7[b]	64.9[b]	267[b]	451[b]	512[a]	58.0[a]	60.5[b]	59.8[a]	12.7[c]	36.1[b]	38.9[b]	0.351[ab]
3. B + 5.75% feather meal + 0.05% DL-Met + 0.1875% L-Lys·HCl	28.9[b]	59.4[b]	63.6[b]	274[b]	484[ab]	522[a]	56.7[a]	60.4[b]	59.6[a]	16.4[b]	35.9[b]	38.0[b]	0.355[ab]
4. Corn-soybean meal (16% CP)	42.8[a]	73.7[a]	73.8[a]	362[a]	538[a]	552[a]	59.6[a]	63.0[a]	60.8[a]	25.4[a]	46.4[a]	44.9[a]	0.398[a]
Pooled SEM	2.0	4.0	2.4	11	18	25	1.1	0.7	0.5	1.1	2.4	1.4	0.020

[a–d]Means within columns with no common superscript differ significantly ($P < 0.05$).

[1]Data are means of seven groups of 12 hens each during the first 8 wk on the layer diet.

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TABLE 4. Effect of dietary molt treatments on hen-day egg production, body weight gain, egg weight, egg yield, and feed efficiency, Experiment 3[1]

Dietary molt treatments	Hen-day egg production			Body weight gain			Egg weight			Egg yield			Feed efficiency
	1 wk	2 wk	1 to 8 wk	12 to 18 d	12 to 25 d	12 to 32 d	1 wk	2 wk	1 to 8 wk	1 wk	2 wk	1 to 8 wk	1 to 8 wk
	(%)			(g per hen)			(g per egg)			(g egg/hen/d)			(g egg:g feed)
1. Basal corn diet (B)	8.7^{c}	32.8^{c}	49.5^{c}	256^{c}	306^{d}	364^{c}	58.0^{bc}	60.0^{b}	61.0^{b}	5.0^{c}	19.7^{c}	30.5^{c}	0.288^{c}
2. B + 5.75% feather meal	15.1^{b}	44.6^{b}	54.5^{bc}	266^{bc}	365^{c}	419^{bc}	57.3^{c}	61.8^{ab}	61.3^{b}	8.7^{bc}	27.4^{b}	33.7^{bc}	0.306^{bc}
3. B + 8.5% feather meal	13.5^{bc}	46.4^{b}	58.1^{b}	286^{b}	400^{bc}	461^{ab}	57.4^{bc}	62.2^{a}	62.1^{ab}	7.8^{bc}	28.9^{b}	36.4^{b}	0.326^{b}
4. As Treatment 2 + 0.05% DL-Met + 0.0625% L-Lys·HCl	17.3^{b}	44.0^{b}	57.7^{b}	279^{b}	406^{b}	452^{ab}	59.3^{b}	61.7^{ab}	62.1^{ab}	10.2^{b}	27.2^{b}	36.1^{b}	0.322^{b}
5. Corn-soybean meal (16% CP)	29.4^{a}	60.7^{a}	64.7^{a}	350^{a}	494^{a}	502^{a}	62.5^{a}	63.2^{a}	62.9^{a}	18.3^{a}	38.2^{a}	40.7^{a}	0.354^{a}
Pooled SEM	2.1	3.3	1.9	8	14	19	0.7	0.8	0.5	1.3	2.1	1.2	0.008

[a–d]Means within columns with no common superscript differ significantly ($P < 0.05$).

[1]Data are means of seven groups of 12 hens each during the first 8 wk on the layer diet.

Met, and Lys was higher than those fed the basal diet and not different from that of hens fed the 16% CP diet. Feed efficiency was improved ($P < 0.05$) for those fed the basal plus 8.5% FM or basal plus 5.75% FM, Met, and Lys compared with that for hens fed the basal corn diet only (Table 4). However, feed efficiency was significantly higher ($P < 0.05$) for hens fed the 16% CP molt diet than for those on any other molt diet treatment.

In an economic analysis comparing the net income minus feed costs for the diets utilized in Experiment 3, the 16% CP molt diet yielded the highest income minus feed costs (data not shown). Based on a price of $0.63 per dozen eggs and computing the feed costs for all molt diets plus the 16% layer diet, the 16% corn-soybean meal diet produced an income of $73.02 for production of all hens for the 8-wk production period. The next most profitable treatment was the basal corn diet with 8.5% FM added, and the lowest income minus feed costs occurred for those hens fed the low protein corn diet ($43.49). These figures were based on a cost of $0.1134, $0.1179, $0.1307, and $0.1304 per kilogram of diet for the basal corn diet, basal with 8.5% FM, the 16% CP corn-soybean meal diet, and the 16% layer diet, respectively. Thus, this economic comparison still favored the high protein molt diet; however, supplementing the low protein corn molt diet with FM and FM plus Met and Lys improved the economic profitability over the low protein corn diet alone.

The results obtained herein agree with earlier reports that showed that hens fed a high protein molt diet (16 to 17% CP) returned to egg production and regained body weight at a faster rate than those fed a low-protein molt diet (Brake *et al.*, 1979; Harms, 1983; Andrews *et al.*, 1987; Koelkebeck *et al.*, 1991, 1993). The results presented here further indicate that early production performance may be enhanced by supplementation of a low-protein corn molt diet with CGM and Lys, FM alone, or FM, Met, and Lys. Thus, in situations in which FM and CGM are inexpensively priced, the use of these ingredients may be economical in molt diets. In general, the 16% corn-soybean meal molt diet yielded postmolt performance as measured by egg production, body weight gain, egg weight, egg yield, and feed efficiency that was the highest, intermediary in the diets containing FM or CGM with or without Lys and Met supplementation, and lowest in the corn basal diet. This difference may have been due primarily to insufficient dietary Trp, which is very deficient in CGM and FM. In addition, the lower digestibility of amino acids in FM compared to corn and soybean meal (NRC, 1994) may have been a contributing factor.

REFERENCES

Andrews, D. K., W. D. Berry, and J. Brake, 1987. Effect of lighting program and nutrition on reproductive performance of molted Single Comb White Leghorn hens. Poultry Sci. 66:1298–1305.

Brake, J., P. Thaxton, J. D. Garlich, and D. H. Sherwood, 1979. Comparison of fortified ground corn and pullet grower feeding regimes during a forced molt on subsequent layer performance. Poultry Sci. 58:785–790.

Harms, R. H., 1983. Influence of protein level in the resting diet upon performance of force rested hens. Poultry Sci. 62: 273–276.

Hoyle, C. M., and J. D. Garlich, 1987. Postfasting dietary protein requirements of induced molted hens. Poultry Sci. 66:1973–1979.

Koelkebeck, K. W., C. W. Parsons, R. W. Leeper, and J. Moshtaghian, 1991. Effect of protein and methionine levels in molt diets on postmolt performance of laying hens. Poultry Sci. 70:2063–2073.

Koelkebeck, K. W., C. M. Parsons, R. W. Leeper, and X. Wang, 1993. Effect of supplementation of a low-protein corn molt diet with amino acids on early postmolt laying hen performance. Poultry Sci. 72:1528–1536.

National Research Council, 1994. Nutrient Requirements of Poultry. 9th rev. ed. National Academy Press, Washington, DC.

North, M. O., and D. D. Bell, 1990. Flock recycling. Pages 433–452 *in*: Commercial Chicken Production Manual. 4th ed. Van Nostrand Reinhold, New York, NY.

Steel, R.G.D., and J. H. Torrie, 1980. Principles and Procedures of Statistics: A Biometrical Approach. 2nd ed. McGraw-Hill Book Co., New York, NY.

Swanson, M. H., and D. D. Bell, 1974. Force Molting of Chicks. II. Methods. University of California Leaflet 2650. University of California, Davis, CA.