Further Evaluation of Nonfeed Removal Methods for Molting Programs

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ABSTRACT The objective of this study was to evaluate several nonfeed removal methods compared with feed removal for induced molting of laying hens. An experiment was conducted using 576 Dekalb White hens (69 wk of age) randomly assigned to 1 of 8 dietary treatments. Two of these treatments consisted of feed removal for 10 d followed by ad libitum access to a 16% CP, corn-soybean meal diet or a 94% corn diet for 18 d. The other 6 treatments provided ad libitum access for 28 d to diets containing 94% corn, 94% wheat middlings (WM), 71% WM: 23% corn, 47% WM: 47% corn, 95% corn gluten feed, and 94% distillers dried grains with solubles (DDGS). At 28 d, all hens were fed a laying hen diet (16% CP), and production performance was measured for 40 wk.

The 2 feed removal treatments resulted in total cessation of egg production within 6 d. Egg production of hens fed the 94% WM, 71% WM: 23% corn, corn, corn gluten feed, and 47% WM:47% corn diets all decreased to 6% or less by d 12, 16, 19, 20, and 28, respectively. Egg production of hens fed DDGS never decreased below 18%. Body weight loss ranged from 10% (DDGS) to 26% (10-d feed removal), with the other treatments being similar at 17%. No consistent differences were observed among treatments throughout the 40-wk postmolt period for egg production, egg specific gravity, egg weight, egg yield, or feed efficiency. No differences were observed among feed removal treatments versus several nonfeed removal treatments for ovary and oviduct weights and blood heterophil:lymphocyte ratios during the molt period. In addition, interactive social behaviors were not different throughout the molt period between hens fed the 94% WM and those deprived of feed for 10 d. Our results indicate feeding WM, corn, corn gluten feed, and WM:corn diets are effective nonfeed removal methods for molting laying hens.

(*Key words*: wheat middlings, induced molting, egg production, laying hen, nonfeed removal)

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INTRODUCTION

Induced molting of hens is a practice used by most commercial egg producers to extend the productive life of their hens. Typically, molting has been achieved by fasting hens for 10 d or more. This method is criticized by animal rights groups who have pressured commercial egg producers and lawmakers to stop using induced molting programs that involve feed removal or result in anorexia. A number of studies have been conducted in an attempt to develop effective methods to molt hens without the use of feed removal. Low-sodium diets (Whitehead and Shannon, 1974; Nesbeth et al., 1976; Ross and Herrick, 1981; Scheideler et al., 2002) and high-Zn diets (Berry and Brake, 1987; McCormick and Cunningham, 1987) are 2 methods that have been researched extensively. However, neither of these alternative methods is widely practiced in the industry due to cost and inconsistent results.

Zimmerman et al. (1987) studied the use of 10 and 15% guar meal in molt diets and obtained results that were favorable as an alternative to fasting. More recently, Keshavarz and Quimby (2002) evaluated the use of a diet containing grape pomace with added thyroxine and a high-corn diet with or without thyroxine as alternatives to fasting. All of these treatments were found to be effective for induced molting.

Our laboratory recently conducted a study to evaluate the use of high-corn or high-wheat middlings (WM) molt diets as alternatives to fasting (Biggs et al., 2003). Both diets, particularly the WM diet, were found to be effective nonfeed removal methods for molting hens. The objective of the current study was to further evaluate the efficacy of WM and corn diets and also to examine the use of diets high in corn gluten feed (CGF) and distillers dried grains with solubles (DDGS), 2 readily available and inexpensive feed ingredients, as alternatives to fasting for induced molting of laying hens.

MATERIALS AND METHODS

All animal care procedures were approved by the university institutional animal care and use committee (IA-

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Abbreviation Key: CGF = corn gluten feed; DDGS = distillers dried grains with solubles; WM = wheat middlings.

TABLE 1. Composition of experimental molt diets containing corn, soybean meal (SBM), wheat middlings (WM), corn gluten feed (CGF), or distillers dried grains with solubles (DDGS) and the layer diet fed after the molt period

Ingredients and analysis	16% CP corn-SBM	Corn	WM	CGF	DDGS	71% WM: 23% corn	47% WM: 47% corn	Layer diet
				(%)				
Ground yellow corn	73.78	93.68	–	–	–	22.99	47.05	68.70
WM	–	–	94.34	–	–	71.25	47.00	–
CGF	–	–	–	95.00	–	–	–	–
DDGS	–	–	–	–	94.46	–	–	–
SBM (dehulled)	20.10	–	–	–	–	–	–	18.40
Meat and bone meal	–	–	–	–	–	–	–	2.50
Limestone	4.62	4.67	4.87	4.20	4.84	4.96	4.87	8.50
Dicalcium phosphate	0.80	–	0.38	0.10	–	0.10	0.38	1.25
Salt	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Mineral mix[1]	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Vitamin mix[2]	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Larvadex	0.05	0.05	0.05	0.05	0.05	0.05	0.05	–
Calculated analysis[3]								
Crude protein	16.0	8.0	14.2	20.0	25.9	12.6	11.1	16.0
Metabolizable energy, kcal/kg	2,962	3,138	1,887	1,663	2,343	2,195	2,516	2,865
Calcium	2.0	2.0	2.0	2.0	2.0	2.0	2.0	3.8
Nonphytate phosphorus	0.25	0.25	0.28	0.25	0.37	0.25	0.25	0.45

[1]Provided per kilogram of diet: manganese, 75 mg from manganese oxide; iron, 75 mg from iron sulfate; zinc, 75 mg from zinc oxide; copper, 5 mg from copper sulfate; iodine, 0.75 mg from ethylene diamine dihydroiodide; selenium, 0.1 mg from sodium selenite.

[2]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.

[3]Based on NRC (1994) feed composition tables.

CUC). An experiment was conducted using 576 Single Comb White Leghorn hens of the Dekalb White strain (69 wk of age). The hens were housed in a caged layer house of commercial design with water and feed provided ad libitum and were exposed to a 17-h daily photoperiod prior to the start of the experiment. Six replicate groups of 12 hens each (4 adjacent raised wire cages, 30 × 46 cm, containing 3 hens per cage) were allotted to each dietary treatment in a completely randomized design so that mean body weight was similar for each treatment. The 8 molt treatments consisted of two 10-d feed removal treatments that were followed by feeding a 16% CP corn-soybean meal diet or a high-corn diet (Table 1) for 18 d and 6 other treatments in which diets were provided ad libitum for 28 d. The latter dietary treatments were high corn, high WM, a diet containing 71% WM and 23% corn, a diet containing equal amounts of WM and corn, high CGF, and high DDGS (Table 1). The 8 molt diets were formulated to contain 2% Ca and at least 0.25% nonphytate P using NRC (1994) table values. At the start of the experiment (d 1), feed was withdrawn from the birds on the 10-d feed removal treatments. The birds on the other 6 treatments were fed their respective diets. On d 11, the birds deprived of feed for 10 d were fed the corn-soybean meal diet or the high-corn diet at a rate of 54 g/hen per d for the first 2 d following feed removal to minimize crop impaction. The corn-soybean meal diet is a well-balanced diet that results in hens rapidly regaining body weight and returning to egg production faster than hens being fed a high-corn diet. These 2 treatments, feed deprivation then fed either the corn-soybean meal diet or the high-corn diet, are programs used in many commercial operations. The hens on these 2 treatments were then provided access ad libitum to their respective diets for the next 16 d. On d 29, all birds were placed on a 16% CP layer diet (Table 1). The experiment consisted of a 4-wk molt period followed by a 40-wk postmolt production period (69 to 113 wk of age).

On d 1 (the initiation of feed removal or feeding molt diets), the photoperiod was reduced to 10 h. On d 24, the daily photoperiod was increased to 12 h and then to 13 h on d 31. Thereafter, the daily photoperiod was increased 15 min/wk for 16 wk until a 17-h photoperiod was established.

Egg Production and Performance

Egg production performance was measured for 44 wk following the initiation of feed removal or feeding the molt diets. Egg production and mortality were recorded daily throughout the 44-wk experimental period. Specific gravity, using the flotation method with NaCl solutions varying in specific gravity from 1.056 to 1.100 g/cm^3 in 0.004-increments, was measured weekly for all eggs produced on 2 consecutive d during wk 6 to 12, every 4 wk from wk 16 to 40, and then every week from wk 41 to 44. Egg weight and mass (calculated using hen-day egg production and mean egg weight) were measured on all eggs produced on 2 consecutive d every week during wk 6 to 12 and every 4 wk from wk 16 to 44. Feed consumption was measured every week from wk 1 to 12 and every 4 wk from wk 16 to 44. Feed efficiency (g of egg/g of feed consumed) was calculated on the week that egg weight was measured. Body weights of all hens were measured 5 d before onset of the experiment, on d 10 for the 2 feed removal treatments, and for all hens on d 28, at peak production (wk 14), and at 44 wk.

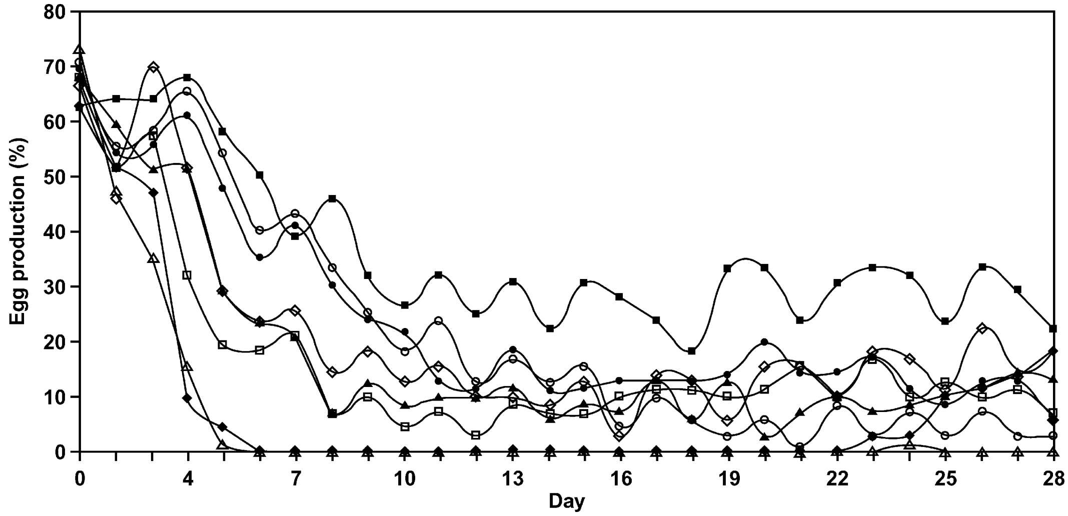

FIGURE 1. Daily hen-day egg production during the molt period of hens deprived of feed for 10 d and then fed corn-soybean meal diet (◆), hens deprived of feed for 10 d and then fed corn diet (△), hens fed the corn diet (○), hens fed the wheat middlings diet (□), hens fed the 71% wheat middlings:23% corn diet (◇), hens fed the 47% wheat middlings:47% corn diet (●), hens fed the corn gluten feed diet (▲), and hens fed the distillers dried grains with solubles diet (■).

Ovarian Regression

It was of interest to determine if there was a difference in the degree of regression in ovary and oviduct weight in birds having feed removed compared to hens continuously fed during the molt period. Ovarian regression is essential to obtain long-term egg production and egg shell quality during the second production cycle. An additional 12 hens (4 adjacent cages containing 3 hens/cage) were placed on the corn, 94% WM, CGF, DDGS, and the 10-d feed removal/corn-soybean meal treatments in order to determine ovary and oviduct weights at d 1, 10, 21, and 28. Three hens from each group of 12 were euthanized with CO2 gas on these days, and separate wet weights were measured for the ovary and oviduct from each hen. Data collected were analyzed as a percentage of body weight.

Physiological Stress

General physiological stress of hens was determined for selected treatments by counting leukocytes in blood obtained from a wing vein and calculating the heterophil:lymphocyte ratio (an elevated ratio indicating increased stress) using methods described by McKee and Harrison (1995). Blood samples were taken from the wing vein from 1 hen per replicate group from the 10-d feed removal/corn-soybean meal diet, corn, 94% WM, CGF, and DDGS treatments for a total of 6 hens per treatment on d 1, 10, and 28. Each hen sampled on d 1 was leg-banded after blood was drawn, and the same hen from each replicate group was sampled on d 10 and 28.

Behavior

In order to determine the effect, if any, of the molt treatments on hen behavior, selected behavioral activities were video recorded. Video recordings were taken of hens fed the 94% WM and those that had feed withdrawn for 10 d and then fed the corn-soybean meal diet. Four adjacent cages were videotaped with each cage representing one experimental unit. One remote video camera was mounted above each treatment to be videotaped. The first recording occurred on d -2 (2 d prior to initiation of molt treatments) in which the cameras recorded hen activities in the left 2 side-by-side cages within each treatment group. On d -1, the cameras were swiveled to record the activities of hens in the right 2 side-by-side cages. This pattern of recording was repeated on d 3, 4, 9, 10, 20, 21, 27, and 28. All video recordings were done during the photoperiod on those days. To determine hen behavior, the video tapes were replayed, and behaviors were recorded for 2 h after the lights came on, during the middle of the d (1130 to 1330 h), and 2 h before the lights went out. The actual times of day were from 0400 to 0600 h, 1130 to 1330 h, and 1830 to 2030 h on d –2 and –1. The times for d 3, 4, 9, 10, 20, and 21 were from 0600 to 0800 h, 1130 to 1330 h, and 1200 to 1400 h. The morning and midday times were the same for d 27 and 28, but the last viewing period was from 1600 to 1800 h due to the extended photoperiod. During the previously mentioned times of the day, no human activity occurred in the egg production facility. These times of day were chosen to represent periods when aggressive behavior would be most likely to occur (morning and evening) and when leisure time would be prevalent (midday). When the videotapes were reviewed, each 2-h video recording was divided into 1-min intervals. A scanning technique similar to that employed by Koelkebeck et al. (1987) was used to record the occurrence of a behavioral act by any hen in a cage within each 1-min interval of each 2-h period.

The behavioral activities that were measured and recorded were interactive social behaviors (those behaviors that required at least 2 birds). These behaviors included

TABLE 2. Effect of nonfeed vs. feed removal molting treatments on hen-day egg production during the 4-wk molt period and 40 wk postmolt[1]

Treatment	Week 1	2	3	4	1 to 4	5 to 44
	(%)					
10-d feed removal, 16% CP	25[d]	0[d]	0[d]	9[bc]	8[e]	71[a]
10-d feed removal, corn	25[d]	0[d]	0[d]	0[d]	6[e]	68[a]
Corn	55[a]	20[b]	7[c]	5[cd]	22[bc]	64[a]
WM[2]	37[c]	7[cd]	11[bc]	11[bc]	16[d]	67[a]
71% WM:23% corn	44[b]	13[bc]	11[bc]	16[b]	21[bcd]	70[a]
47% WM:47% corn	52[a]	19[b]	14[b]	12[bc]	24[b]	62[a]
Corn gluten feed	44[b]	9[c]	8[c]	11[bc]	18[cd]	67[a]
DDGS[3]	58[a]	31[a]	27[a]	29[a]	36[a]	64[a]
Pooled SEM	2.2	2.9	1.8	2.6	1.8	2.4

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

[1]Data are means of 6 groups of 12 hens each.

[2]WM = wheat middlings.

[3]DDGS = distillers dried grains with solubles.

aggression, submission, standing on another bird, being stood upon, pecking a neighbor (hen in an adjacent cage), being pecked by a neighbor, feather pecking (pecking a cage mate), and avoidance or escape. The techniques to record these behavioral activities were developed by Anderson et al. (1989) and were followed to record these behaviors of the hens. For data summary, the percentage of total acts per behavior was used for analysis.

Statistical Analysis

All data were analyzed by analysis of variance procedures appropriate for a one-way completely randomized design (Steel and Torrie, 1980). The Fisher's protected least significant difference test was used to determine significant differences among treatment means.

Behavioral data were tested for normality (Shapiro-Wilk's test) and homogeneity of variances (Levene's test). It was determined that in order to satisfy normality and homogeneous variances, the data would need to be pooled by time of day (morning, midday, and evening) and by period (d –2 and –1, d 3 and 4, etc.). It was of interest to determine if there was a difference in social behaviors between the hens on the nonfeed withdrawal molting program and the conventional 10-d feed withdrawal program at specific time points during the molt period but not how these behaviors changed throughout the molt period. Thus, the behavioral data were pooled in this manner and analyzed using the GLM procedures of SAS software (SAS Institute, 1985).

RESULTS

Hens that were deprived of feed for 10 d lost 26% of their original body weight at the end of their feed removal period. By the end of the 28-d molt period, those hens then fed the corn-soybean meal had regained a substantial amount of weight and had final body weight losses of 12%, whereas the birds that had feed removed and were then fed the corn diet regained only 4% of their original body weight for a final weight loss of 22% at 28 d. Hens that were fed the DDGS for 28 d lost only 10% body weight. In contrast, birds fed the high-corn, high-WM, and 71% WM:23% corn diets lost 18% body weight; hens fed the 47% WM:47% corn diet lost 17%, and hens fed the CGF diet lost 14%. There were no differences ($P > 0.05$) in mortality among treatments during the molt period. The mortality during the molt period was low, ranging from 0 to 2.8% among treatments.

The decrease in daily hen-day egg production during the 28-d molt period is shown in Figure 1, and the weekly averages are shown in Table 2. Hens that were deprived of feed for 10 d ceased egg production by d 6. None of the hens on the other treatments totally ceased egg production during the molt period. Hens fed the WM, CGF, and the 71% WM:23% corn diets exhibited more rapid decreases in egg production than hens fed the corn, DDGS, and 47% WM:47% corn diets. Hens fed the former diets reached egg production lows of 2.8% on d 12, 20, and 16, respectively. Hens fed the corn diet and the 47% WM:47% corn diets showed more gradual reductions in egg production, reaching a low of 0.6% on d 21 and 5.6% on d 28, respectively. In contrast, egg production of hens fed the DDGS diet never decreased below 18% (d 18), and these birds maintained a higher ($P < 0.05$) mean level of production for the entire 4-wk molt period compared with the other 7 treatments. Postmolt hen-day egg production (wk 5 to 44) was not significantly different for any of the 8 treatments (Table 2).

For the nonfeed removal treatments, feed consumption during the first week of the molt period (Table 3) was highest ($P < 0.05$) for hens fed the DDGS and corn diets. Feed consumptions for hens fed the WM, CGF, and 71% WM:23% corn diets were lowest, with hens fed the 47% WM:47% corn diet being intermediate. After the first week, the hens increased their feed intakes over the next 3 wk in all the nonfeed removal treatments except for the corn treatment. Hens fed the corn diet maintained a feed consumption of approximately 67 g/hen per d during the first three wk, but during the last week of the molt

TABLE 3. Effect of nonfeed vs. feed removal molting treatments on feed intake during the 4-wk molt period[1]

	Week				
Treatment	1	2	3	4	1 to 4
	(g/hen per d)				
10-d feed removal, 16% CP[2]	0	63[de]	99[a]	73[b]	81[ab]
10-d feed removal, corn[2]	0	55[e]	87[b]	49[c]	65[cd]
Corn	65[ab]	69[cd]	66[c]	41[c]	60[d]
WM[3]	40[c]	78[bc]	89[ab]	93[a]	75[b]
71% WM:23% corn	45[c]	78[bc]	90[ab]	75[b]	72[bc]
47% WM:47% corn	59[b]	81[b]	86[b]	74[b]	75[bc]
Corn gluten feed	45[c]	85[ab]	94[ab]	91[a]	79[ab]
DDGS[4]	70[a]	94[a]	95[ab]	84[ab]	86[a]
Pooled SEM	3.3	3.7	3.8	5.1	3.5

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

[1]Data are means of 6 groups of 12 hens each.

[2]Values for the 10-d feed removal treatments are means for only those days that the hens received feed.

[3]WM = wheat middlings.

[4]DDGS = distillers dried grains with solubles.

period, their feed intake decreased to 41 g/hen per d. When summarized for the 4-wk molt period, hens fed the corn molt diet had lower ($P < 0.05$) feed intakes than all other nonfeed removal treatments.

Postmolt egg weight, egg mass, feed consumption, and feed efficiency (wk 5 to 44) are depicted in Table 4. No significant differences were found among treatments for these 4 parameters. In addition, no differences in egg specific gravity were detected among treatments during the beginning (wk 6 to 12), throughout, or the end (wk 41 to 44) of the 40-wk postmolt period (Table 5).

No significant differences ($P > 0.05$) were found among treatments for ovary and oviduct weights at d 1, 10, 21, and 28 of the molt period (Table 6). However, ovary and oviduct weights at d 28 were numerically higher for hens fed the DDGS diet than for those fed the other treatments, particularly compared with the 10-d feed removal. Ovary and oviduct weights decreased over time for all treatments, and the changes were generally similar to the changes in feed consumption (shown earlier). The effects of molting methods on heterophil:lymphocyte ratios are also presented in Table 6. Of the 5 treatments that were sampled, no significant differences were found in heterophil:lymphocyte ratios among treatments during each period.

The incidence of social interactive behaviors of hens fed the 94% WM diet and 10-d feed removal then 16% CP treatments are depicted in Table 7. These data show that there were no significant differences ($P < 0.05$) between treatments for each behavior observed as measured by the percentage of total acts committed per day during each period.

DISCUSSION

Increased pressure from animal rights groups and recent restrictions by food companies on acceptance of eggs from molted hens (Egg Industry, 2000) have prompted research into evaluating alternatives to feed removal for induced molting of laying hens. Although previous research on this subject has generally shown that feed removal is the most effective and economical method, there

TABLE 4. Effect of nonfeed vs. feed removal molting treatments on postmolt egg production parameters from 5 to 44 wk[1]

Treatment	Egg weight[2] (g/egg)	Egg mass[2] (g egg/hen per d)	Feed intake (g/hen per d)	Feed efficiency (g of egg: g of feed)
10-d feed removal, 16% CP	66[a]	48[a]	115[a]	0.418[a]
10-d feed removal, corn	66[a]	46[a]	112[a]	0.411[a]
Corn	67[a]	44[a]	114[a]	0.387[a]
WM[3]	66[a]	45[a]	114[a]	0.395[a]
71% WM: 23% corn	67[a]	48[a]	117[a]	0.408[a]
47% WM: 47% corn	68[a]	42[a]	112[a]	0.380[a]
Corn gluten feed	68[a]	46[a]	114[a]	0.406[a]
DDGS[4]	67[a]	43[a]	113[a]	0.381[a]
Pooled SEM	0.6	1.8	2.4	0.012

[a]Means within a column with a common superscript do not differ significantly ($P < 0.05$).

[1]Data are means of 6 groups of 12 hens each.

[2]Egg weights were measured weekly during wk 6 to 12 and every 4 wk thereafter.

[3]WM = wheat middlings.

[4]DDGS = distillers dried grains with solubles.

TABLE 5. Effect of nonfeed vs. feed removal treatments on egg specific gravity during the postmolt period[1]

Treatment	6 to 12 wk	41 to 44 wk	6 to 44 wk
	(g/cm^3)		
10-d feed removal, 16% CP	1.0806[a]	1.0738[a]	1.0770[a]
10-d feed removal, corn	1.0806[a]	1.0731[a]	1.0770[a]
Corn	1.0791[a]	1.0722[a]	1.0756[a]
WM[2]	1.0799[a]	1.0723[a]	1.0762[a]
71% WM:23% corn	1.0795[a]	1.0729[a]	1.0761[a]
47% WM:47% corn	1.0793[a]	1.0723[a]	1.0759[a]
Corn gluten feed	1.0793[a]	1.0730[a]	1.0762[a]
DDGS[3]	1.0788[a]	1.0725[a]	1.0756[a]
Pooled SEM	0.0006	0.0008	0.0005

[a]Means within a column with a common superscript do not differ significantly ($P < 0.05$).

[1]Data are means of 6 groups of 12 hens each.

[2]WM = wheat middlings.

[3]DDGS = distillers dried grains with solubles.

may be alternatives to feed removal that are effective and economical. Our previous study (Biggs et al., 2003) showed that feeding diets high in WM or corn, particularly WM, were effective methods that yielded postmolt performance that was comparable to a 10-d feed removal method.

The objective of the present study was to further evaluate diets containing high levels of WM and corn and also to evaluate diets containing combinations of WM and corn and diets containing a high level of CGF or DDGS. Diets containing combinations of WM and corn are less bulky and more suitable for commercial feeding systems, and CGF and DDGS are economical ingredients that are readily available in the Midwest. All diets resulted in decreased egg production and body weight during the molt period. The 94% WM, 95% CGF, and 71% WM: 23% corn diets were the most effective for causing egg production to rapidly decrease in the first week of the molt period. The corn diet also resulted in an almost total cessation of egg production, but the response was much slower and more gradual than that observed for the former 3 diets. The 47% WM:47% corn and the DDGS diets, particularly the DDGS diet, were less effective. Although feeding the latter diets reduced egg production, it was never decreased below 5.6% (d 28) and 18% (d 18) for hens fed the 47% WM:47% corn and DDGS, respectively (Figure 1). Hens fed the DDGS diet also had the highest oviduct and ovary weights, suggesting limited ovarian regression for this treatment.

The energy level of the diet seems to be an important factor in causing a rapid reduction in egg production. Hens fed the low-energy WM and CGF diets had very low feed intakes during the first week, which was followed by a 2-fold increase in feed consumed during the subsequent 3 wk. The low feed consumption during the first week could be a result of reduced palatability or the change in energy density of the diet. The increased feed consumption during the subsequent week was probably due to adjusting or compensating for the lower energy level and any palatability effects. In addition to feeding low-energy diets, continuously feeding hens a low-protein corn diet was also effective in reducing egg production to a low level. However, the reduction in egg production was much slower than those observed for the low-energy WM and CGF diets. The more gradual response to the corn diet was at least partially due to the less severe decrease in feed consumption during the first week. Feed intake of hens fed the corn diet was relatively stable during the

TABLE 6. Effect of nonfeed vs. feed removal molting treatments on ovary and oviduct weight and heterophil:lymphocyte ratio during the 4-wk molt period

	Ovary[1]				Oviduct[1]				Heterophil: Lymphocyte ratio[2]		
Treatment	d 1	d 10	d 21	d 28	d 1	d 10	d 21	d 28	d 1	d 10	d 28
	(% of body weight)										
10-d feed removal, 16% CP	2.9[a]	0.7[a]	0.9[a]	0.2[a]	3.1[a]	1.7[a]	1.5[a]	0.5[a]	0.60[a]	0.64[a]	0.48[a]
Corn	2.3[a]	2.1[a]	0.6[a]	0.8[a]	3.1[a]	3.3[a]	1.4[a]	1.6[a]	0.30[a]	0.68[a]	0.72[a]
Wheat middlings	2.3[a]	0.3[a]	0.9[a]	1.6[a]	2.7[a]	1.2[a]	1.3[a]	2.2[a]	0.89[a]	0.56[a]	0.54[a]
Corn gluten feed	2.6[a]	1.1[a]	0.2[a]	0.7[a]	3.6[a]	2.2[a]	0.6[a]	1.1[a]	0.64[a]	0.64[a]	0.68[a]
DDGS[3]	2.6[a]	1.5[a]	1.1[a]	2.5[a]	3.0[a]	2.3[a]	1.4[a]	3.5[a]	0.50[a]	0.66[a]	0.49[a]
Pooled SEM	0.44	0.46	0.64	0.68	0.21	0.49	0.74	0.80	0.149	0.144	0.132

[a]Means within a column with a common superscript do not differ significantly ($P < 0.05$).

[1]Data are means of 3 hens.

[2]Data are means of 6 hens.

[3]DDGS = distillers dried grains with solubles.

TABLE 7. Effect of nonfeed (94% wheat middlings diet) vs. feed removal (10-d feed removal and then fed a corn-soybean meal diet) treatments on social behaviors of hens[1]

Behavior	Observation period[2]	Wheat middlings	10-d feed removal
		(% of total acts per d)	
Aggression	Prefeed removal	28.7 ± 1.2[a]	23.0 ± 9.7[a]
	Early feed removal	30.3 ± 3.4[a]	31.6 ± 4.4[a]
	Late feed removal	33.8 ± 3.0[a]	21.4 ± 11.4[a]
	Early postfeed removal	43.0 ± 4.4[a]	28.3 ± 12.7[a]
	Late postfeed removal[3]	41.1 ± 8.7[a]	33.1 ± 3.4[a]
Submission	Prefeed removal	15.1 ± 2.2[a]	7.4 ± 3.1[a]
	Early feed removal	11.1 ± 3.8[a]	15.0 ± 7.6[a]
	Late feed removal	9.1 ± 1.4[a]	10.9 ± 10.9[a]
	Early postfeed removal	21.5 ± 5.7[a]	9.7 ± 4.9[a]
	Late postfeed removal[3]	10.3 ± 3.6[a]	12.6 ± 3.5[a]
Stood on/stood upon[4]	Prefeed removal	16.9 ± 2.3[a]	21.4 ± 3.9[a]
	Early feed removal	20.4 ± 2.0[a]	9.6 ± 4.1[a]
	Late feed removal	6.5 ± 1.2[a]	10.0 ± 10.0[a]
	Early postfeed removal	1.1 ± 1.1[a]	2.9 ± 1.0[a]
	Late postfeed removal[3]	6.9 ± 4.7[a]	9.8 ± 3.6[a]
Pecked neighbor	Prefeed removal	7.3 ± 2.5[a]	2.5 ± 1.5[a]
	Early feed removal	6.7 ± 2.6[a]	19.4 ± 7.7[a]
	Late feed removal	13.0 ± 2.4[a]	33.6 ± 6.4[a]
	Early postfeed removal	27.5 ± 9.3[a]	7.8 ± 4.6[a]
	Late postfeed removal[3]	6.9 ± 4.7[a]	1.7 ± 1.0[a]
Pecked by neighbor	Prefeed removal	0.0 ± 0.0[a]	3.9 ± 3.9[a]
	Early feed removal	3.9 ± 3.0[a]	2.5 ± 1.5[a]
	Late feed removal	14.4 ± 6.7[a]	1.8 ± 1.8[a]
	Early postfeed removal	2.3 ± 2.3[a]	1.1 ± 1.1[a]
	Late postfeed removal[3]	2.6 ± 2.6[a]	4.9 ± 1.9[a]
Feather pecking	Prefeed removal	15.1 ± 2.2[a]	17.3 ± 11.8[a]
	Early feed removal	7.1 ± 2.7[a]	5.6 ± 2.3[a]
	Late feed removal	14.2 ± 8.9[a]	12.3 ± 2.3[a]
	Early postfeed removal	3.4 ± 3.4[a]	37.6 ± 21.4[a]
	Late postfeed removal[3]	3.9 ± 3.9[a]	14.3 ± 8.0[a]
Avoid/Escape	Prefeed removal	0.0 ± 0.0[a]	3.1 ± 1.8[a]
	Early feed removal	0.0 ± 0.0[a]	6.6 ± 3.6[a]
	Late feed removal	2.6 ± 2.6[a]	0.0 ± 0.0[a]
	Early postfeed removal	3.4 ± 3.4[a]	9.7 ± 5.7[a]
	Late postfeed removal[3]	21.2 ± 5.0[a]	13.7 ± 7.2[a]

[a]Means within a row with a common superscript do not differ significantly ($P > 0.05$).

[1]Data are means of 4 groups of 3 hens each expressed as a percentage of total acts recorded per day.

[2]Prefeed removal period (d −2 and −1), early feed removal (d 3 and 4), late feed removal (d 9 and 10), early postfeed removal (d 20 and 21), and late postfeed removal (d 27 and 28).

[3]Late postfeed removal means are means of 2 groups of 3 hens each due to technical malfunctions with recording equipment.

[4]Stood on/stood upon are separate behaviors but were combined because means were identical.

first 3 wk and then decreased during the fourth week. Thus, the effects of protein or amino acid deficiency took longer to manifest themselves on reproduction than the effects of energy deficiency. Due to the continued decreases in body weight and egg production during the 4-wk molt period, hens fed the corn diet were not able to replenish their lost body stores, and, consequently, they returned to egg production at a slower rate than hens on the other treatments. Many researchers have shown that the return to egg production following a period of feed removal requires a period to replenish body stores (Brake et al. 1979; Harms 1983; Andrews et al. 1987; Zimmerman and Andrews 1990; Koelkebeck et al. 1991, 1999).

Hens fed the DDGS and 47% WM:47% corn diets exhibited less severe body weight losses and decreases in egg production compared with hens on the other treatments. These responses probably occurred because neither of these diets was as singly deficient in energy or protein and amino acids as the other diets.

There were no significant differences found among treatments for any measured parameter (egg production, egg weight, egg mass, feed intake, feed efficiency, or egg specific gravity) during the postmolt (wk 5 to 44) period. It was somewhat surprising that the DDGS and 47% WM:47% corn treatments, particularly the DDGS, did not produce lower egg specific gravity, because these treatments did not cause as large a reduction in body weight and egg production during the molt period. The lack of difference in heterophil:lymphocyte ratio among treatments suggests that there was little effect of molt treatment on stress for the hens. The feeding of WM as an alternative molting method did not have any adverse effect on hen social behaviors when compared with a traditional molt program of feed withdrawal. Therefore, this suggests that a nonfeed withdrawal program will not compromise the behavior of hens. Overall, our results indicate that feeding diets high in corn, WM, CGF, or a 71% WM:23% corn combination are effective alternative molt programs.

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