Utilizing Different Ratios of Alfalfa and Layer Ration for Molt Induction and Performance in Commercial Laying Hens

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ABSTRACT Molting is a common practice used by the commercial egg industry to rejuvenate flocks for a second or third laying cycle. During this time the hens rest from production, and the reproductive organs are rejuvenated to increase production and quality during the next laying cycle. Although feed withdrawal (FW) is the most popular and effective method of molt induction, it has come under scrutiny due to food safety issues and animal welfare issues. This study involved feeding alfalfa mixed with layer ration at different ratios to hens to determine their ability to induce molt. The treatment ratios were 100% alfalfa (A100), 90% alfalfa and 10% layer ration (A90), and 70% alfalfa and 30% layer ration (A70). In addition, a fully fed (FF) nonmolted control and a FW negative control were used. Alfalfa is an insoluble, high fiber feedstuff with low metabolizable energy. Egg production for A90 and FW treatments ceased completely by d 6, whereas birds fed A100 and A70 ceased egg production by d 8. Ovary and oviduct weight of hens fed all molting diets decreased ($P < 0.05$) by an average of 1.5 to 2.5% (BW basis) compared with FF control during the 9-d molt induction period. As the percentage of layer ration increased, feed intake also increased and percentage of BW loss decreased during the 9-d molt induction period. Hens molted by FW lost an average of 25.8% BW, whereas A70 hens lost 18.9% BW. Nonmolted hens (FF) and A70 treatment hens had significantly lower ($P < 0.05$) egg production when compared with all other treatments over the 39-wk postmolt period. FF treatment hens also had lower ($P < 0.05$) albumen heights when compared with all other treatments. From these results, alfalfa or alfalfa mixed with layer ration appears to be viable alternatives to conventional FW methods for the successful induction of molt and retention of postmolt performance.

(*Key words*: molting, egg quality, alfalfa, egg production, laying hen)

2005 Poultry Science 84:362–369

INTRODUCTION

The commercial egg industry commonly uses induced molt procedures to rejuvenate flocks for a second or third laying cycle and to increase profits. According to Bell (2003), approximately 75% of commercial laying facilities in the United States use an induced molt program to rejuvenate flocks for increased productivity. Implementing an induced molt program can result in a 30% higher profit margin for producers when compared with an all-pullet operation (Bell, 2003). In addition to increased profit margins, an induced molt rejuvenates hen's reproductive tract to produce higher quality eggs, which are more marketable (Keshavarz and Quimby, 2002). The main purpose of molting is to cease egg production in order for the hens to enter a nonreproductive state, which increases egg production and egg quality postmolt (Webster, 2003).

Although there are several molting methods, feed withdrawal (FW) has been the most popular due to ease of application, economic benefits, and agreeable postmolt performance (Keshavarz and Quimby, 2002; Bell, 2003). The FW molting methods are viewed as logical because wild birds exhibit similar behavior when they undergo a natural molt; they lose as much as 40% of their BW while refusing to eat until the later stages of the molt (Mrosovsky and Sherry, 1980). However, recent concerns have been raised about animal welfare during the FW period because it is thought to be harmful to hens (Webster, 2003). Efforts have been made to reduce or even eliminate the use of such programs that require complete removal of feed from hens. For this reason, alternative methods that do not require complete removal of feed are being considered. Historically researchers have examined

Received for publication July 12, 2004.
Accepted for publication November 17, 2004.
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Abbreviation Key: A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer ration; A70 = 70% alfalfa and 30% layer ration; FF = full feed; FW = feed withdrawal; ULACC = University Lab Animal Care Committee.

alternative diets to FW that provide similar benefits while not altering the health of the animals. General dietary modification strategies have involved constructing diets that are deficient in some nutrients such as sodium or contain an excess of a particular compound such as zinc. In the past, studies have been conducted using diets mixed with high zinc concentrations (Bell, 2003), thyroxine (Keshavarz and Quimby, 2002), and low sodium concentrations (Berry and Brake, 1985) to induce molt. However, such diets have yielded inconsistent results, are costly, and can cause negative behavior such as cannibalistic pecking (Webster, 2003; Biggs et al., 2004). Low calcium diets have also been used; however, ovary and oviducts did not regress to a nonproductive state, and production did not cease completely and has been shown to cause osteoporosis and temporary paralysis (Webster, 2003). A second general approach has incorporated the use of insoluble plant fibers such as grape pomace (Keshavarz and Quimby, 2002), cotton meal (Davis et al., 2002), jojoba meal (Arnouts et al., 1993; Vermaut et al., 1997),wheat middlings (Seo et al., 2001), and alfalfa (Kwon et al., 2001; Landers et al., 2005).

Alfalfa is a readily available, high protein, high fiber feedstuff with one of the slowest rates of passage through the avian system (Matsushima, 1972; Sibbald, 1979; Garcia et al., 2000). Alfalfa is well balanced in amino acids and rich in vitamins, carotenoids, and xanthophylls that give poultry carcasses their desirable yellow color (Sen et al., 1998; Ponte et al., 2004). Alfalfa also contains high levels (2 to 3% of DM) of saponins, which have been shown to have hypocholesterolemic, anticarcinogenic, antiinflammatory, and antioxidant properties (Klita et al., 1996; Ponte et al., 2004). Alfalfa is extremely advantageous due to the fermentation properties by cecal microflora that are capable of limiting in vitro growth of *Salmonella* Typhimurium when alfalfa is present (Donalson et al., 2004a,b). The objective of this study was to evaluate the effectiveness of different ratios of alfalfa combined with layer ration on the induction of a molt, postmolt production, and postmolt egg quality (up to and including wk 39).

TABLE 1. Composition of Texas A&M University (TAMU) layer ration and alfalfa-layer ration combination molt diets

Ingredient	TAMU layer ration[1] (FF)	A90[2]	A70[2]	A100[2]
	(g/kg)			
Corn, yellow	567.18	56.72	170.15	—[5]
Soybean meal	316.33	31.63	94.90	—[5]
Vegetable oil	76.82	7.68	23.05	—[5]
Mono calcium phosphate	16.86	1.69	5.06	—[5]
Calcium carbonate	15.62	1.56	4.69	—[5]
Methionine, 98%	1.69	0.17	0.51	—[5]
Vitamin premix[3]	2.50	0.25	0.75	—[5]
NaCl	2.50	0.25	0.75	—[5]
Trace mineral premix[4]	0.50	0.05	0.15	—[5]
Alfalfa	—[5]	900.00	700.00	1,000.00
Total	1,000.00	1,000.00	1,000.00	1,000.00

[1]For diet formulation, crude fat concentrations were fixed at 100 g/kg. FF = full feed.

[2]A90 = 90% alfalfa and 10% layer ration; A70 = 70% alfalfa and 30% layer ration; A100 = 100% alfalfa.

[3]Provided milligrams per kilogram of diet unless otherwise noted: vitamin A, 8,818 IU; vitamin D, 2,205 IU; vitamin E, 5.86 IU; vitamin K, 2.2 IU; thiamine, 1.1 IU; riboflavin, 4.4 IU; niacin, 22 IU; pantothenic acid; choline, 500 IU; vitamin B_{12}, 0.013 IU; biotin, 0.055 IU.

[4]Trace mineral premix (Nutrius Premix Division, Bioproducts Inc., Cleveland, OH) provided milligrams per kilogram of diet unless otherwise noted: Mn, 68.2; Zn, 55; Cu, 4.4; I, 1.1; Se, 0.1.

[5]None used.

MATERIALS AND METHODS

Molting Procedure

A total of 120 White Single Comb Leghorn laying hens from 70 to 80 wk of age were obtained from a commercial laying facility. Birds were housed one per cage at the Texas A&M University Poultry Science Research Center (College Station, TX) and allowed 3 wk for acclimation. During this time the birds were fed a complete layer ration (Tables 1 and 2) ad libitum and allowed full access to water. Egg production was monitored to ensure that all hens were healthy and actively producing. After acclimation, hens were moved to a nearby house and placed 2 birds per cage for the molting procedure. The hens were then divided into 5 treatment groups (Table 2) with 24 birds per treatment: nonmolted control, full feed (FF); negative control, FW; 100% alfalfa (A100); 90% alfalfa and 10% layer ration (A90); and 70% alfalfa and 30% layer ration (A70). All treatments were allowed ad libitum access to water and their respective diets. Hens were placed on an artificial lighting program of 8L:16D for 1 wk before molt to allow normal production to continue while being photosensitized to ensure a more complete and rapid molt (Andrews et al., 1987a). Treatments were randomly assigned to cages throughout the house to ensure there was no variability in egg production or reproductive tract regression due to light stimulation. Hens were then molted for 9 d (Kwon et al., 2001; Landers et al., 2005) as part of a rapid molt as described by North and Bell (1990) and Parkhurst and Mountney (1988).

During molt, bird weights were monitored at d 1, 5, 7, and 9. In accordance with the Texas A&M University Laboratory Animal Care Committee (ULACC) animal use protocols, any hen reaching 25% weight loss prior to the end of the trial (d 9) was removed from the respective diet and immediately placed on an FF layer ration feeding program. Feed intake was measured by weighing each diet prior to the start of the molt and after the 9-d molt period.

Collection of Organs, Egg Production, and Quality Parameters

At the end of the molt, 60 birds were euthanized with CO_2 gas according to approved Texas A&M ULACC protocols, and the ovaries, oviducts, kidneys, hearts, livers, and spleens were excised aseptically and weighed and expressed as relative weights (% of BW). The remaining 60 birds were returned to Texas A&M University layer

TABLE 2. Composition Analysis of Texas A&M University (TAMU) layer ration and alfalfa-layer ration combination molt diets

Nutrient	TAMU layer ration (FF)	A90[1]	A70[1]	A100[1]
Dry matter (%)	90.10	91.810	91.430	92.00
Crude protein (%)	15.00	17.250	16.750	17.50
Ether extract (%)	2.93	2.793	2.979	3.00
Crude fiber (%)	2.30	21.920	17.560	24.10
Ash (%)	10.15	9.115	9.345	9.00
Calcium (%)	3.25	1.621	1.983	1.44
Total phosphorus (%)	0.47	0.245	0.295	0.22
Available phosphorus (%)	0.25	0.223	0.229	0.22
Metabolizable energy (per kg)	2,872	962.2	1,386.6	750
Total metabolizable energy (per kg)	2,965	1,206	1,597.2	1,011
Xanthophyll (mg/kg)	12.32	91.232	73.696	100.00
Methionine (%)	0.31	0.247	0.261	0.24
Cystine (%)	0.27	0.198	0.214	0.19
Lysine (%)	0.72	0.729	0.727	0.73
Arginine (%)	0.93	0.714	0.762	0.69
Threonine (%)	0.56	0.677	0.651	0.69
Tryptophan (%)	0.17	0.224	0.212	0.23
Glycine (%)	0.61	0.799	0.757	0.82
Serine (%)	0.72	0.720	0.720	0.72
Histidine (%)	0.40	0.553	0.519	0.57
Isoleucine (%)	0.59	0.662	0.646	0.67
Leucine (%)	1.40	1.211	1.253	1.19
Valine (%)	0.69	0.825	0.795	0.84
Phenylalanine (%)	0.70	0.799	0.777	0.81
Tyrosine (%)	0.57	0.786	0.738	0.81
Choline (mg/kg)	1,314	1,392.3	1,374.9	1,401
Linoleic acid (%)	1.88	0.611	0.893	0.47
Sodium (%)	0.13	0.094	0.102	0.09

[1]FF = full feed (nonmolted); A90 = 90% alfalfa and 10% layer ration; A70 = 70% alfalfa and 30% layer ration; A100 = 100% alfalfa.

ration on an ad libitum basis (Parkhurst and Mountney, 1988; North and Bell, 1990). The lighting program was changed to 16L:8D to stimulate egg production. Egg production was measured daily (% of hen-day assuming 1 egg per day = 100%), whereas egg quality parameters were measured twice per week. Egg weight was measured with a balance[2] and recorded to the nearest 0.01 g. Egg length, albumen height, yolk height, and yolk diameter were measured with a caliper and recorded to the nearest 0.1 mm. Shell thickness was evaluated using NaCl solutions (Keshavarz and Quimby, 2002), the specific gravity of which ranged from 1.065 to 1.090 in increments of 0.005. Shell strength (kg) was measured with an Instron Universal Testing Machine[3] with a 50-kg load cell at a 10-kg load range and a crosshead speed of 50 mm/min (Park et al., 2004). Haugh units were calculated taking into account egg length and albumen height as an indicator of interior egg quality (Silversides et al., 1993). Egg production and quality were measured for 39 wk after molting.

Statistical Analysis

Data were analyzed using the GLM procedure of SAS software (2001). Differences in parameters (egg production, feed intake, g of BW loss, % of BW loss, organ weights, internal egg quality, and external egg quality) among treatment groups, when significant, were compared using Duncan's multiple range test. None of the data were transformed prior to analysis. The level of significance used in all results was $P < 0.05$.

[2]Navigator model N14120, Ohaus Corporation, Pinebrook, NJ.
[3]Model 1011, Instron Corp., Canton, MA.

RESULTS AND DISCUSSION

Body Mass

Hens fed diets A100, A90, and FW showed significantly greater ($P < 0.05$) percentages of body mass loss (25.1, 23.9, and 25.8% respectively) than those fed the A70 diet (18.9%). FF birds exhibited the least amount of body mass loss (5.2%) when compared with all other treatments of molted hens (Table 3). Body mass loss has been shown to be directly related to postmolt performance. To optimize postmolt performance, a body mass loss of 25 to 30% should be achieved (Baker et al., 1983). Approximately 25% of the body mass loss was attributed to decreases in liver and reproductive organ weights (Berry and Brake, 1985). The weight loss exhibited by nonmolted (FF) hens could be explained by the reduced photoperiod , because photoperiod and nutrient deprivation have similar modes of action on the hypothalamic hypophyseal axis causing an inhibition of circulating reproductive hormone concentrations with subsequent ovary regression and weight loss (Andrews et al., 1987a; Berry, 2003). The reduced photoperiod also leaves fewer daylight hours for feeding,

TABLE 3. Effects of alfalfa, alfalfa-layer ration, feed withdrawal molt diets, and a nonmolt diet on feed intake, body weight loss, and percentage of body weight loss during a 9-d molting period

Treatment[1]	Feed intake (g/bird)	Body weight loss (g/bird)	Body weight loss (%)
FF	736.4 ± 16.5[a]	82.2 ± 24.7[c]	5.2 ± 1.5[c]
FW	0	400.9 ± 11.4[a]	25.8 ± 0.6[a]
A100	82.0 ± 22.6[d]	392.4 ± 9.9[a]	25.1 ± 0.5[a]
A90	272.3 ± 39.0[c]	373.3 ± 10.8[a]	23.9 ± 0.6[a]
A70	409.4 ± 23.5[b]	289.2 ± 13.0[b]	18.9 ± 0.7[b]

[a–d]Means within a column with no common superscripts differ significantly ($P < 0.05$); n = 6, 24, and 24 for feed intake, body weight loss, and percentage of body weight loss, respectively.

[1]FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

which decreases feed consumption and causes weight loss as exhibited by all hens (Andrews et al., 1987b). Hens on A100 and A90 lost more body mass than hens on A70 due to a decreased feed intake, which could be attributed to several factors including a higher percentage of alfalfa in the diet.

Organ Weight

Ovarian weight loss occurs simultaneously with body mass loss due to the regression of the ovaries that is directly associated with the rejuvenation process (Brake, 1993). Unmolted control, FF hens had higher ($P < 0.05$) ovarian weights than hens on all other molted treatments (2.17% BW). No significant differences in ovarian weights were found among FW (0.55 % BW), A100 (0.71% BW), A90 (0.60% BW), and A70 (0.48% BW; Table 4) treatments. Similar results were published by Landers et al. (2005) in which ovarian weights from hens fed 100% alfalfa meal were not significantly different from FW hens. No differences ($P < 0.05$) were found among treatments when comparing heart and spleen weights. Control (FF) birds had significantly higher liver weights when compared with all other treatments (2.25% BW), whereas FW-treated birds had significantly lower liver weights (1.49% BW) than all treatments except the A100 group (1.60% BW). Liver weight loss indicates a loss of liver energy sources, such as glycogen and lipids, which are metabolized in the liver (Berry and Brake, 1985). Weight loss from the liver is also indicative of the loss of estrogen-dependent egg component synthesis, which is dependent on stimulation from ovarian steroids (Berry and Brake, 1985). The most common ovarian steroids are the estrogens whose target organ is the liver where yolk phospholipoprotein synthesis occurs and is dependent primarily on estrogens (Berry and Brake, 1985). With a higher energy concentration due to increased percentage of layer ration, hens on A70 were apparently able to retain liver functionality more like that of FF birds than were birds fed other alfalfa dietary combinations, which were significantly lower in energy. This increase in energy density availability for the A70 birds would explain their increased liver weights.

Feed Intake

All treatments exhibited differences ($P < 0.05$) in feed intake during the molt. FF-treated birds exhibited the greatest feed intake (736.4 g/bird over the 9-d molt), whereas birds on A70 and A90 ingested 409.4 g/bird and 272.4 g/bird, respectively (Table 3). Birds on A100 ate the least feed (82 g/bird). The reduction in feed intake could have been due to several factors, including appetite suppression in conjunction with the natural molting process (Mrosovsky and Sherry, 1980), low palatability of alfalfa by hens (Sen et al., 1998), or decreased feeding stimulation with reduced daylight hours (Andrews et al., 1987b). Furthermore, alfalfa contains saponins, which may be a factor in the suppression of feed intake and growth (Matsushima, 1972). The slow passage rate of alfalfa may also influence feed intake by giving hens a feeling of satiety and thus causing them to refrain from eating (Sibbald, 1979). Ueda et al. (2002) suggested that decreased feed intake is due to delayed emptying of the crop. Increased percentages of alfalfa in the diet tended to decrease feed consumption, as feed consumption of hens on A100 was significantly lower than for hens on A90 or A70. This trend suggested that as diets became more diluted with layer ration, feed consumption increased. Feed intake was also measured for 3 wk following the molt. No significant differences were observed among any treatments during the first 2 wk after the molt. However, 3 wk after molt, FF hens exhibited significantly

TABLE 4. Effect of alfalfa, alfalfa-layer ration, feed withdrawal molt diets and a nonmolt diet on post molt organ weights (as % of body weight)[1]

Treatment[2]	Ovary (%)	Oviduct (%)	Intestine (%)	Kidney (%)	Heart (%)	Liver (%)	Spleen (%)
				(%)			
FF	2.17 ± 0.21[a]	3.98 ± 0.30[a]	3.52 ± 0.20[a]	0.43 ± 0.02[a]	0.48 ± 0.01	2.25 ± 0.05[a]	0.09 ± 0.006
FW	0.55 ± 0.07[b]	1.53 ± 0.07[b]	2.71 ± 0.12[b]	0.35 ± 0.01[b]	0.46 ± 0.01	1.49 ± 0.03[d]	0.11 ± 0.007
A100	0.71 ± 0.09[b]	1.73 ± 0.08[b]	2.85 ± 0.09[b]	0.37 ± 0.02[b]	0.46 ± 0.01	1.60 ± 0.05[cd]	0.10 ± 0.005
A90	0.60 ± 0.04[b]	1.77 ± 0.06[b]	3.11 ± 0.12[ab]	0.39 ± 0.01[b]	0.46 ± 0.01	1.69 ± 0.05[bc]	0.10 ± 0.005
A70	0.48 ± 0.5[b]	1.69 ± 0.14[b]	3.46 ± 0.12[a]	0.45 ± 0.05[a]	0.46 ± 0.01	1.80 ± 0.08[b]	0.11 ± 0.008

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

[1]Relative organ weight (%) = (organ weight/100 g of body weight) × 100.

[2]FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

TABLE 5. Effect of alfalfa, alfalfa-layer ration, feed withdrawal molt diets and a nonmolt diet on external egg quality postmolt[1]

Treatment[2]	Weight (g)	Length (mm)	Specific gravity	Shell breakage (kg)
FF	67.78 ± 0.30[b]	60.46 ± 0.24[b]	1.076 ± 0.00[b]	2.97 ± 0.07[b]
FW	70.05 ± 0.35[a]	61.09 ± 0.13[a]	1.077 ± 0.00[a]	2.98 ± 0.05[b]
A100	67.74 ± 0.21[b]	60.28 ± 0.11[b]	1.076 ± 0.00[b]	2.94 ± 0.06[b]
A90	70.68 ± 0.41[a]	61.26 ± 0.14[a]	1.078 ± 0.00[a]	3.22 ± 0.05[a]
A70	70.78 ± 0.42[a]	61.13 ± 0.15[a]	1.076 ± 0.00[b]	2.97 ± 0.07[b]

[a,b]Means within a column with no common superscripts differ significantly ($P < 0.05$).

[1]Means from wk 3 through 39 postmolt.

[2]FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

lower feed intake when compared with all other treatments (data not shown).

Interior and Exterior Egg Quality

Interior and exterior egg qualities were examined in this study to determine if the different levels of alfalfa would alter postmolt quality of eggs. Treatment differences ($P < 0.05$) were identified for external parameters, including egg weight, egg length, specific gravity (which indicated shell thickness), and shell breakage strength (Table 5). Egg weights and lengths were significantly higher for FW, A90, and A70 treatments when compared with FF and A100 treatments. This finding did not agree with results reported previously by Landers et al. (2005) in which egg weights from hens molted by A100 were not significantly different from FW hens. Specific gravity and shell breakage showed significant differences with treatments FW and A90 being significantly higher than all other treatments. Higher specific gravity values are related to thicker eggshells, which is a desirable characteristic for the egg industry (DeKetelaere et al., 2002; Keshavarz and Quimby, 2002). Mabe et al. (2003) reported that 80 to 90% of eggs that ended up being downgraded were due to cracked or broken eggshells. These defects result in a loss in profits for the producer and can affect consumer safety, as eggshells are a barrier to microorganisms, such as *Salmonella* (Mabe et al., 2003). It would appear that the A90 treatment represented the optimal dietary mixture to minimize shell breakage.

Interior quality parameters such as yolk diameter, yolk height, albumen height, and Haugh units also proved to be significantly different due to treatment (Table 6). Yolk diameters of A90 hens were ($P < 0.05$) higher than those of FW hens. Yolk heights were significantly higher for A70 and FW-treated hens when compared with those of FF-treated hens. The FF albumen heights were significantly lower when compared with all other treatments indicating a decrease in internal egg quality. Similar results were observed when grape pomace was used as an alternative to feed deprivation for the induction of molt (Keshavarz and Quimby, 2002). Landers et al. (2005) reported albumen heights significantly lower than current study results; the difference can be explained by a longer postmolt period (39 wk) in the current study and a shorter 12-wk postmolt period in Landers et al. (2005). Haugh units were significantly lower for FF-treated hens when compared with all molt treatments. These measurements (Haugh units) were comparable to those reported by Silversides et al. (1993). Interior quality decreases as hen age increases; however, after a complete molt egg quality is equivalent to that of a 10- to 12-mo-old pullet (Bell, 1987). When quality increases, more eggs are saleable, which increases profits for producers and keeps supply equivalent to customer demand thus maintaining reasonable prices for consumers (McDaniel and Aske, 2000).

Egg Production and Date of Reentry

On average nonmolted hens fed a layer ration (60.94%) and A70 treatment hens (61.14%) had significantly lower

TABLE 6. Effect of alfalfa, alfalfa-layer ration, feed withdrawal molt diets and a nonmolt diet on internal egg quality post molt (wk 3 to 39)[1]

Treatment[2]	Yolk diameter (mm)	Yolk height (mm)	Albumen height (mm)	Haugh units
FF	41.78 ± 0.11[ab]	18.17 ± 0.08[c]	7.01 ± 0.14[c]	77.89 ± 3.24[b]
FW	41.48 ± 0.15[b]	18.88 ± 0.07[a]	8.57 ± 0.10[a]	87.11 ± 1.95[a]
A100	41.73 ± 0.11[ab]	18.53 ± 0.08[b]	7.79 ± 0.10[b]	84.27 ± 2.14[a]
A90	41.91 ± 0.16[a]	18.31 ± 0.07[bc]	7.60 ± 0.11[b]	85.08 ± 1.68[a]
A70	41.57 ± 0.10[ab]	18.97 ± 0.08[a]	8.31 ± 0.11[a]	85.02 ± 1.93[a]

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

[1]Means from wk 3 to 39 postmolt.

[2]FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

TABLE 7. Average percentages of hen-day egg production after induced molt of hens on alfalfa, alfalfa-layer ration, and feed withdrawal molt diets and a nonmolt diet (wk 1 to 39)

Treatment[1]	Average egg production[2]
FF	60.94 ± 1.55^{c}
FW	74.29 ± 1.31^{a}
A100	69.53 ± 1.42^{b}
A90	73.08 ± 1.26^{ab}
A70	61.14 ± 1.48^{c}

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

[1]FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

[2]Egg production was measured daily, and 100% represents one egg per day.

($P < 0.05$) egg production when compared with all other treatments after 39 wk postmolt (Table 7). FW hens (74.29%), not surprisingly, had significantly higher egg production than all treatments except A90 treatment hens (73.08%). A100 treatment hens (69.53%) exhibited significantly lower postmolt egg production than FW (74.29%) but were not significantly different from A90 hens with 69.53% postmolt production. Overall egg production from the premolt acclimation period to 39 wk postmolt is shown in Figure 1. The lower egg production rate of the A70 hens after 39 wk postmolt is most likely due to an incomplete molt, which is an effect of the high-energy concentration present in the diet in conjunction with its relatively higher layer ration percentage. Other alfalfa diets, especially A90, proved to be comparable with the FW treatment for postmolt egg production. The goal of a viable molting program is to increase post molt egg production and quality. After the molting period, hens improve their egg production due to the rejuvenation of the reproductive organs and overall BW loss (Alodan and Mashaly, 1999). Increased egg production can relate to profits for the industry depending on bird prices, feed prices, and egg demand (Bar et al., 2001). A change in supply as small as 1% can result in a 6% opposite change in egg prices, which can cost or make a producer with a typical operation $1.46 million annually (McDaniel and Aske, 2000).

There were no significant differences found among any treatments when days to first egg, days to tenth egg, and days between the first and tenth egg were measured. In addition, no significant differences were found among treatments when examining days to return to 50 to 60% egg production (Table 8). Hens molted by A100 returned to production 14.8 d after molt induction, which is consistent with the observation by Landers et al. (2005) who also reported that hens fed alfalfa meal during molt return to production 14 d after induction. There were significant differences found from the start of the molt to the first day out of production. On average A70-treated hens took significantly longer (5.75 d) to cease production than FW birds (4.42 d). A100 hens (5.25 d) and A90 hens (4.92 d) were not significantly different from FW or A70 hens. The sooner hens enter the rest period and cease production, the quicker they will return to production and reach their peak production, which occurs within a month of the molting period (North and Bell, 1990). The peak production of a hen during the second cycle after being molted at 65 wk is 75 to 85%, which is equivalent to that of birds in a 40- to 50-wk-old flock (Bell, 2003).

In conclusion, use of alfalfa mixed with layer ration proved to be effective in molt induction, increasing postmolt egg quality and postmolt egg production when com-

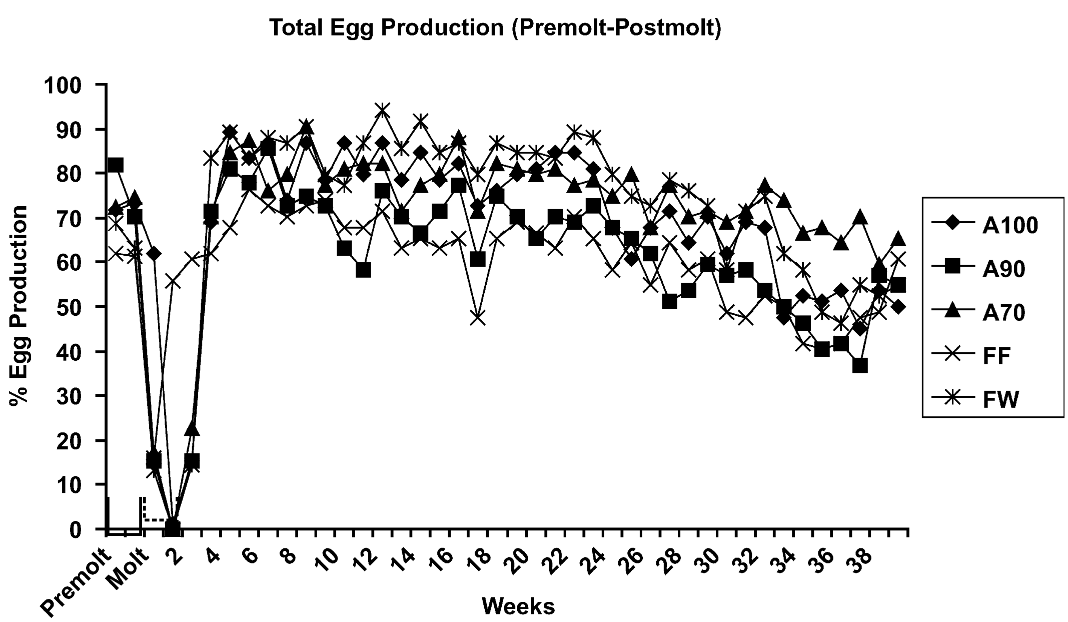

FIGURE 1. Percentage of hen-day egg production by 5 treatments on a weekly basis during molt and postmolt of hens on the following treatments: FF = full feed; FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet. Egg production was measured daily, and 100% represents one egg per day.

TABLE 8. Effects of alfalfa, alfalfa-layer ration, and feed withdrawal molt diets and a nonmolt diet on egg production parameters during and after molting

Parameter	FW[1]	A100[1]	A90[1]	A70[1]
First day out of production from start of treatments	4.42 ± 0.48[b]	5.25 ± 0.28[ab]	4.92 ± 0.15[ab]	5.75 ± 0.33[a]
Days to first egg postmolt	15.2 ± 0.44	14.8 ± 0.95	15.8 ± 1.64	14.5 ± 0.60
Days to tenth egg postmolt	25.6 ± 0.48	26.4 ± 0.77	27.8 ± 2.50	27.8 ± 1.41
Days from first to tenth egg	10.4 ± 0.19	11.7 ± 0.38	11.9 ± 0.94	13.3 ± 1.74
Days to return to 50 to 60% egg production	15	16	15	15

[a,b]Means within a row with no common superscript differ significantly ($P < 0.05$); n = 12.

[1]FW = feed withdrawal; A100 = 100% alfalfa; A90 = 90% alfalfa and 10% layer diet; A70 = 70% alfalfa and 30% layer diet.

pared with conventional FW methods. Alfalfa-induced molting offers advantages in that it is readily available across the United States as a common feed for dairy cattle and horses. Furthermore, its in vitro fermentability is comparable with other feeds that have been shown to inhibit the growth of enteric pathogens, such as *Salmonella* Enteritidis. As animal welfare concerns rise, the industry will continue to seek alternatives to FW. Molt diets consisting of alfalfa mixed with layer ration will need to be further investigated to determine the best ratio for molt induction and performance. Based on the results of this study, A100 and A90 appear to be the best alternatives to FW molting methods and yield comparable results. The A70 treatment may also be a viable alternative; however, molts induced by the A70 treatment may not be sufficiently complete due to the higher energy concentration of the A70 diet. Further research will be conducted to determine an optimal combination of alfalfa and layer ration intermediate to the A70 and A90 regimens, for maximizing molt induction and postmolt egg quality. In addition, the commercial egg industry will require more research to determine long-term effects on alfalfa and the effect on hens after longer molting periods common in industry.

ACKNOWLEDGMENTS

This research is supported by Hatch grant H8311 administered by the Texas Agricultural Experiment Station, USDA-NRI grant number 2002-02614 and US Poultry and Egg Association grant 485.

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