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Applicability of Non-Feed Removal Programs to Induce Molting Instead of the Conventional Feed Withdrawal Method in Brown Laying Hens

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ABSTRACT

This study was conducted to compare the applicability of non-feed removal (NFR) programs to induce molting in brown laying hens by feedusing alfalfa meal and barley grain on molting of instead of feed withdrawal in terms of performance, egg quality and profitability. A total of 240, 75-week-old Hy-Line brown laying hens were randomly divided into three groups as conventional feed withdrawal (CONV), and two non-feed removal programs using alfalfa meal (A+F) or barley grain (B+F), each containing 80 hens with 20 replicates (4 hens x 20 replicates = 80 hens). After 10 days of the induced molting the lowest body weight loss (20.01%) was found in the B+F method ($p<0.01$). In the second cycle, onset of egg production days were significantly different between groups ($p<0.001$) and hens of NFR groups (A+F and B+F) reached 50% egg production earlier than CONV group ($p<0.05$). Most of the performance (average egg production, daily feed intake, feed conversion ratio and mortality) and egg quality parameters (egg weight, specific gravity, shell thickness and breakage) of NFR groups were similar to the CONV group ($p>0.05$). Haugh unit of CONV group was better than NFR groups, whereas molting by NFR groups improved egg yolk color ($p<0.001$). Despite higher feed cost of NFR programs, egg income and profit was better than CONV group ($p<0.001$). In conclusion, molting with alfalfa meal and barley grain of brown layers may be used as non-feed removal programs, without negative effects on the performance and egg quality parameters. Besides, these non-feed removal programs have higher income and profitability.

INTRODUCTION

In many countries, induced molting is a common economic concern of egg producers. It is a critical management decision flocks instead of buying replacement pullets. Due to expensive cost of replacement, sometimes producers apply different molting programs to extend the egg production period of older flocks. In practice, several molting programs have been applied in poultry farms. As an alternative to the conventional molting method, which applies feed withdrawal with or without water/light restriction, dietary mineral levels are manipulated, and feeds containing insufficient Ca, Na, or Al or excessive Cu or Zn, are supplied (Keshavarz & Quimby, 2002; Baker *et al.* 1983; Koelkebeck & Anderson, 2007; Breeding *et al.* 1992; Yousaf & Ahmad 2006). The dietary supplementation of drugs or hormones, such as gonadotrophin-releasing hormone (GnRH), melengestrol acetate, and thyroxine have also been applied (Dickerman & Bahr, 1989; Koch *et al.* 2007; Onbaşılar & Erol, 2007). However, these studies showed that the dietary manipulation of mineral levels, and the addition of drugs and hormones addition to layer feeds to induce molting have some disadvantages, such as promoting poorer performance, are expensive, and may induce behaviors (cannibalism) in the second laying cycyle (Webster, 2003; Onbaşılar & Erol, 2007; Biggs *et al.* 2004). Due to the strong criticism of conventional programs from the animal welfare point of view, nutrient-restriction non-feed removal (NFR) may be an alternative method to induce molting.

On farms, readily available and cheap feed ingredients, such as barley grain (Onbaşılar & Erol, 2007; Petek *et al.* 2008; Aygun & Yetisir, 2009; Petek & Alpay, 2008) and alfalfa meal (Aygün & Olgun, 2010; Mcreynolds *et al.* 2006; Elouun, 2009; Landers *et al.* 2005b) have been used for induced molting instead of the conventional feed removal program. Barley grain contains 11.0 crude protein, 5.50% crude fiber and 2,640 kcal/kg metabolizable energy (ME) (NRC, 1994). Alfalfa is a high-quality feedstuff, presents slow passage through the digestive system, and contains moderate crude protein (17.5%), high crude fiber (24.1%), and low ME value (1,200 kcal/kg) (NRC, 1994).

There are few studies on the use of both alfalfa meal and barley grain to induce molting in layers (Petek & Alpay, 2008; Petek *et al.*, 2008). In addition, there are no reports on the economic evaluation of these alternative programs.

The aim of this study was to evaluate the applicability of non-feed removal programs by feeding alfalfa meal and barley grain to induce molting in brown laying hens instead of conventional feed withdrawal in terms of performance, egg quality and profitability.

MATERIAL AND METHODS

Housing, Management and Nutrition

A total of 240 75-week-old Hy-Line brown laying hens were used in the study. Hens were divided into three treaments with 20 replicates of four birds each, totaling 80 birds per treatment. The following treatments to induce molting were applied: (1) conventional feed withdrawal (CONV; hens received no feed for 10 days, were fed barley grain for 17 days (days 11-28), and then fed a commercial diet for 77 days (days 29-105); (2) alfalfa meal (A+F; hens were fed alfalfa meal for 10 days and then a commercial feed from days 11-105 days); and (3) barley grain (B+F; hens were fed barley grain for 10 days and then a commercial feed from days 11-105 days). The experiment was lasted for 105 days. In practice, generally after the 10th day of fasting of conventional molting programs, whole, cracked, or ground cereal grains, such as corn and barley, are fed between days 11 to 28 (Hambree *et al,* 1980; Kara & Güçlü, 2012; Onbaşılar & Erol, 2007; Sarıözkan *et al.,* 2013).

Four hens were housed per a wire cage (50x40x40 cm), which provided a space of 500 cm^2/hen. Hens were equally distributed in upper and lower cage decks to minimize the cage floor effect. Each cage was equipped with individual feeders and nipple drinkers.

The experimental procedures applied in this experiment were approved by the Ethical Committee of Erciyes University (20.03.2007/11).

The implemented molting programs in the study are presented in Table 1.

Feed and water were provided as *ad libitum* to hens. A lighting program of 16 h light and 8 h darkness (16L:8D) per day was applied. Environmental temperature and air relative humidity were maintained at 20-24 ºC and 60-70%, respectively. The chemical analysis of commercial laying diet was performed according to the standard procedures of the AOAC (1984). Dietary metabolizable energy (ME) levels was calculated. Ingredients and nutrient composition of the diets are given in Table 2.

Table 1 – Molting programs used in the study

Molting Program	Days	Feeds	Water	Lighting program
1. Conventional Feed Withdrawal (CONV)	1 to 10	-	*Ad libitum*	16 h /day
	11 to 28	Barley grain		
	29 to 105	Commercial laying diet		
2. Alfalfa Meal (A+F)	1 to 10	Alfalfa meal	*Ad libitum*	16 h /day
	11 to 105	Commercial laying diet		
3. Barley Grain (B+F)	1 to 10	Barley grain	*Ad libitum*	16 h /day
	11 to 105	Commercial laying diet		

Table 2 – Ingredients and nutrient composition of commercial laying diet

Items	%
Corn	44.05
Full fat soybeans	15.00
Sunflower meal (36% crude protein)	12.65
Wheat	10.00
Limestone	9.12
Barley	5.05
Meat and bone meal (32% crude protein)	2.50
Dicalcium phosphate	0.50
Soy bean meal (46% crude protein)	0.40
Salt	0.30
Methionine	0.08
Enzyme (Phytase)	0.06
Vitamin and mineral premix*	0.25
Lysine HCl	0.04
Chemical composition	
Dry matter	90.20
Crude protein	17.00
Calcium	3.99
Phosphorus (available)	0.43
Methionine	0.36
Lysine	0.76
Linoleic acid	2.21
Metabolizable energy (kcal/kg)	2654

*Provided per 2.5 kilogram of vitamin and mineral premix: Vitamin A 12000,000 IU; Vitamin D_3 2,400,000 IU; Vitamin E 30,000 mg; Vitamin K_3 2,500 mg; Vitamin B_1 3,000 mg; Vitamin B_2 7,000 mg; Vitamin B_6 4,000 mg; Vitamin B_{12} 15 mg; Niacin 40,000 mg; Calcium-D-Pantothenate 8,000 mg; Folic acid 1,000 mg; D-Biotin 45 mg; Vitamin C 50,000 mg; Choline chloride 125,000 mg; Canthaxanthin 1,500 mg; Apo-Carotenoic acid ester 500 mg; Manganese 80,000 mg; Iron 40,000 mg; Zinc 60,000 mg; Copper 5,000 mg; Iodine 400 mg; Cobalt 100 mg; Selenium 150; Antioxidant 10,000 mg.

Data Collection

Hens were weighed on experimental days 1, 10, 28, and 105 (final day) to determine body weight (g) and body weight changes (%). Feed intake and egg weight were weekly recorded. Daily feed intake (g/hen) was calculated. Feed conversion ratio (FCR) was calculated as feed intake per kg of egg mass.

The number of eggs produced was daily recorded and egg production ratio (%) was determined on hen/day basis. The days when the first and 50% of the eggs were produced were recorded. Mortality rate of hens was recorded per cage. Egg weight and egg specific gravity were determined per replicate using all eggs produced on a single day. Egg specific gravity (g/cm^3) was determined monthly using Archimedes' method (Wells, 1968), and then egg weight (g) was measured after 24 h storage at standard room temperature (20-22°C).

Eggshell thickness (mm) was determined by using the average of samples taken from three parts of the broken eggs after the removal of shell membranes.

Four eggs per replicate were monthly collected, weighed, and cracked on a glass table at room temperature, and albumen height was measured 10 minutes later to minimize the differences between measurements by using a micrometer. Haughs unit (HU) were calculated according to the following equation (Haugh, 1937);

HU=100 Log (Albumen height + 7.57-1.7 Egg weight$^{0.37}$)

Egg yolk color was evaluated using Hoffman La Roche color scale.

Financial Analysis

Profit per hen housed was calculated by subtracting feed costs from egg income, adapted from Roland *et al.* (1998). The mean weight of eggs produced throughout the experimental period was used to calculate egg sales revenue. Prices were set according to the obtained egg weights as well as the average egg prices practiced in 2015. Egg income, feed cost, and profit were calculated according to the following formulas:

Egg income (₺) = number of eggs produced (units) x egg price according to weight (₺)

Feed cost (₺) = [total intake of commercial feed (kg) x commercial feed price (₺)] + [intake of feed ingredients (g) x feed ingredient price (₺)]

Profit (₺) = egg income (₺) – feed cost (₺)

Egg and feed prices used in the analysis are given in Table 3.

Table 3 – Feed and egg prices used for the calculations

Cost item	Description	Price (₺)
Egg (piece)	58-61.9 (g)	0.205
	62-64.9 (g)	0.215
	≥ 65 (g)	0.225
Feed	Commercial Feed (kg)	0.9
	Alfalfa Meal (kg)	0.6
	Barley (kg)	0.7

2,6 ₺ (Turkish Lira) = 1 US$

Statistical Analyses

Statistical analyses were performed using SPSS 15.0 software package (SPSS Inc., Chicago, IL, USA). Analysis of variance (ANOVA) was used to evaluate the effects of treatments. Homogeneity of variances was tested by Levene's test. When variances were equal, Tukey's HSD post-hoc test was applied to detect the source of differences among treatment means. When variances were unequal, Tamhane's T2 procedure was applied. Data are expressed as means ± SEMs. Differences between the groups were considered significant at $p<0.05$ level.

RESULTS

At the beginning of the study, the body weights of CONV and NFR hens was similar ($p>0.05$). Body weight losses in the CONV and A+F groups were higher than those of the B+F group ($p<0.05$) on day 10. However, between days 1 and 28, body weight losses in both A+F and B+F groups were significantly lower compared with the CONV group ($p<0.001$). In the first 10 days of molting, mortality rates were similar among groups ($p>0.05$; Table 4).

The day egg production resumed was different among groups ($p<0.001$) and the earliest egg production was determined in B+F hens (day 23.5). The hens in the NFR groups (B+F and A+F) achieved 50% egg production earlier compared with thise in the CONV group ($p<0.05$). Induced-molting method did not affect ($p>0.05$) average egg production percentage, daily feed intake, feed conversion ratio or and mortality rates (Table 5).

There were no differences among groups ($p>0.05$) in terms of external quality parameters of eggs after molting, such as egg weight, egg specific gravity, or eggshell thickness and percentage of cracked eggshells. However, higher Haugh units and lower egg yolk color values were determined in the CONV group compared with the NFR groups ($p<0.001$; Table 6).

Financial results showed that, feed costs and egg income per hen housed were higher in both alternative NFR groups ($p<0.001$). The A+F and B+F methods resulted in higher profits compared with the CONV method ($p<0.001$; Table 7).

Table 4 – Effect of molting programs on body weight (BW), BW loss, and mortality rate (mean ± SE)

Molting method	Initial BW (g)	BW (g) Day 10	BW (g) Day 28	BW (g) Day 105	BW loss, % (1-10 d)	BW loss, % (1-28 d)	Mortality* (%)
CONV	1894.8±24.9	1365.4±21.4^{b}	1529.0±20.9^{b}	1814.7±19.7	26.57±1.77^{a}	17.75±1.92^{a}	11.7±3.4
A+F	1857.1±24.5	1380.9±26.7^{b}	1863.6±24.8^{a}	1823.3±24.7	25.59±1.79^{a}	+1.48±1.81^{b}	9.4±3.0
B+F	1903.2±23.0	1518.4±22.3^{a}	1891.4±22.1^{a}	1843.2±22.3	20.01±1.39^{b}	1.44±1.97^{b}	11.7±3.8
p value	0.390	<0.001	<0.001	0.625	0.009	<0.001	0.858

$^{a-b:}$ Values within the same column with different superscripts differ significantly ($p<0.05$). *: first 10 days of molting
CONV = Conventional feed withdrawal; A+F = Alfalfa Meal; B+F = Barley Grain; P: Probability

Table 5 – Effect of molting methods on some performance traits (mean ± SE)

Molting method	Onset of egg production, day#	50% egg production, day#	Egg production (%)	Feed intake* (g/hen/day)	Feed conversion ratio* (kgfeed/kgegg)	Mortality rate** (%)
CONV	36.7±0.4^{c}	43.0±0.5^{b}	75.6±1.4	113.7±1.6	2.3±0.1	3.5±1.9
A+F	26.2±0.2^{b}	30.5±0.5^{a}	74.2±2.0	110.6±2.7	2.2±0.1	7.5±2.9
B+F	23.5±0.3^{a}	28.2±0.4^{a}	71.5±1.6	112.1±2.2	2.4±0.1	4.7±2.2
p value	<0.001	0.019	0.210	0.607	0.375	0.482

#: From day 1 of the experiment; *: Second laying cycle (post-molting period); $^{a-c:}$ Values within the same column with different superscripts differ significantly ($p<0.05$) and letters indicate from best to worst results in alphabetical order **: Post-molting period
CONV = Conventional feed withdrawal; A+F = Alfalfa Meal; B+F = Barley Grain; P: Probability

Table 6 – Effect of molting methods on some external and internal egg quality parameters (mean ± SE)

Molting Program	External quality				Internal quality	
	Egg weight (g)	Egg specific gravity (g/cm^{3})	Eggshell thickness (mm)	Cracked eggshells (%)	Haugh units	Egg yolk color
CONV	64.40±0.23	1.0836±0.0008	0.336±0.002	3.23±0.59	74.9±1.0^{a}	9.5±0.1^{b}
A+F	65.05±0.32	1.0835±0.0007	0.343±0.002	3.06±0.57	70.5±1.2^{b}	10.4±0.1^{a}
B+F	65.72±0.25	1.0829±0.0005	0.344±0.003	4.08±0.49	69.4±1.1^{b}	10.2±0.1^{a}
P value	0.218	0.714	0.115	0.374	<0.001	<0.001

$^{a-c:}$ Values within the same column with different superscripts differ significantly ($p<0.05$).
CONV = Conventional feed withdrawal; A+F = Alfalfa Meal; B+F = Barley Grain; P: Probability

Table 7 – Effect of molting programs on profitability (Mean ± SE)

Molting Program	Feed Cost* (TL/hen housed)	Egg Income (TL/hen housed)	Profit (TL/hen housed)
CONV	8.62±0.13^{b}	12.39±0.28^{b}	3.77±0.27^{b}
A+F	9.31±0.28^{a}	15.14±0.49^{a}	5.83±0.31^{a}
B+F	9.70±0.17^{a}	14.74±0.38^{a}	5.04±0.37^{a}
p value	<0.001	<0.001	<0.001

*Barley and alfalfa meal costs were added to the commercial feed cost; $^{a-c:}$ Values within the same column with different superscripts differ significantly ($p<0.05$). CONV = Conventional feed withdrawal; A+F = Alfalfa Meal; B+F = Barley Grain

DISCUSSION

There is increasing public awareness on animal welfare of animals and food safety. One of the current concerns is the welfare of layers submitted to complete feed withdrawal to induce molting in order to obtain a second laying cycle. Several alternative methods have been proposed (McReynolds *et al.* 2006; Donalson *et al.* 2005; Landers *et al.* 2005a; Landers *et al.* 2005b; Soe *et al.* 2007; Soe *et al.* 2009). In the present study, the effectiveness two non-feed withdrawal methods (feeding alfalfa meal and barley grain), as alternatives to the conventional method, was investigated.

One of the requirements of a successful molting program is to achieve enough body weight loss to obtain the expected production level in the second laying cycle. In the present study, during first 10 days of molting, desired levels of body weight losses were obtained, and ranged between 20 and 30%, as previously reported (Baker *et al.* 1983; Hussein, 1996; Webster, 2003; Kara & Güçlü, 2012). The higher weight loss achieved with the A+F method, compared with B+F, may be explained by the promotion of satiety in the hens due to the slow passage rate of alfalfa (Sibbald, 1979) and to its poor palatability (Sen *et al.* 1998). The percentage of body weight loss influences egg production rate in second cycle of lay, and some studies reported that low weight loss resulted in lower subsequent egg production (Brake & Traxton, 1979; Landers *et al.* 2005b; Petek & Alpay, 2008). The results of present study confirm earlier findings on the relation of weight loss with average egg production in the second cycle. The lower weight losses in the B+F group resulted in relatively lower subsequent egg production.

In agreement with Sariozkan *et al.* (2013), the onset of egg production occurred earlier in the B+F group, followed by the A+F and CONV groups; in addition, A+F and B+F group reached 50% egg production earlier than the CONV group. The day of first egg production after molting of the A+F group is also consistent with that resported in previous studies (Donalson *et al.* 2005; Landers *et al.* 2005a; Kara & Güçlü, 2012) in which alfalfa was used to induce molting. The possible reason for the early egg production of the A+F group may be related to the achievement of enough body weight loss (25.6%) during the molting period.

Other performance parameters, such as average egg production, daily feed intake, feed conversion ratio, and mortality rate during the second cycle, were not different among groups. As stated above, the performance results are important indicators of the efficiency of molting methods alternative to conventional feed withdrawal. Willis *et al.* (2008) also mentioned that similar egg yield was obtained when molting was induced with alfalfa hay and by feed fasting. In the present study, the egg production rate obtained with the A+F method (74.2%) is consistent with that recorded by Donalson *et al.* (2005), but higher than that reported by Petek & Alpay (2008). On the other hand, Landers *et al.* (2005a) and Kara & Güçlü (2012) reported a significant increase in egg production when molting was induced by feeding alfalfa.

External egg quality parameters, such as egg weight, egg specific gravity, eggshell thickness and percentage of cracked eggs were not negatively affected by the NFR molting methods. Petek *et al.* (2008) also reported that egg specific gravity and eggshell thickness were not affected by NFR molting methods in brown layers.

Considering the effects of the alternative methods on internal egg quality parameters, egg yolk color improved, while Haugh units significantly decreased. The possible reason for the higher Haugh unit in the CONV group was the higher albumen height value obtained. The β-carotene level of alfalfa meal may have promoted the better egg yolk color value in A+F group. The lower Haugh unit value in B+F group may be related to insufficient body weight loss during the molting period in this group.

Total feed cost per hen housed was significantly lower in the CONV group due to 10 days of feed fasting. Egg income and profit were significantly higher both in the A+F and B+F groups. The role of egg weight is important for calculating the income and profit as the price of eggs weighing over ≥ 65 g is higher. The lower profit obtained for the CONV method may be explained by the obtained average egg weight lower than 65 g in this group and by the price paid for smaller eggs, which is approximately 5% lower than those paid for larger eggs.

Molting of layer hens is one of the limited options of egg producers have to increase egg production within a short period of time. In the layer industry, egg price and feed cost relative to the cost of replacement pullets are the most important factors to make the decision to force hens to molt (McDaniel & Aske, 2005). In general, induced molting is applied when egg prices are low and feed costs are high. Due to inelastic structure of egg demand, instability and small changes in egg production lead to major fluctuations in egg prices (Miller & Masters, 1973). Extra egg-production cycles are achieved by molting programs, which allow for the spread of the fixed cost over a long time period.

The performance, egg quality, and financial findings of the present study may be different from those of previous studies on induced molting. The results depend on many factors, such as layer age and strain, egg production period (first or second cycle), type and duration of the molting method, diet composition, and management conditions (cage density, temperature, light, etc.).

The ultimate aim of egg producers is to increase their income, reduce costs and maximize profits. In the present study, higher profit was obtained with more humane and non-feed removal methods for inducing molting in layers that the conventional one.

In conclusion, inducing molting of hens using non-feed removal methods can could be effectively used instead of conventional feed withdrawal because:

- Targeted body weight losses (20-30%) were successfully achieved in laying hens which molting was induced by feeding alfalfa meal and barley, not by fasting, for 10 days.
- The performance (average egg yield, daily feed intake, feed conversion ratio, mortality rate), egg quality (egg weight, egg specific gravity, shell thickness, cracked egg percentage, and egg yolk color), and profitability of hens molted using alfalfa meal and barley grain were comparable to those obtained with the feed removal method.
- The onset of egg production and 50% egg production were achieved earlier and higher profits were obtained with both A+F and B+F methods compared with CONV method.
- The feeding of alfalfa meal and barley instead of fasting to induce molting of laying hens has a great potential as an alternative to fasting programs.

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