Effect of Molting Method and Dietary Energy on Postmolt Performance, Egg Components, Egg Solid, and Egg Quality in Bovans White and Dekalb White Hens During Second Cycle Phases Two and Three

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ABSTRACT Two experiments of 4 × 2 × 2 factorial arrangements of 4 dietary energy levels, 2 molting methods (feed withdrawal and no salt diet), and 2 strains (Bovans White and Dekalb White) were conducted to determine the effect of dietary energy and molting method on long-term postmolt performance of 2 strains of commercial Leghorns. In experiments 1 and 2, Bovans White hens (n = 576) and Dekalb White hens (n = 576) were randomly divided into 16 treatments (6 replicates of 12 birds per treatment). Experiment 1 lasted from 86 to 96 wk of age, and experiment 2 lasted from 100 to 110 wk of age. Bovans White hens had significantly higher egg production than Dekalb White hens, whereas Bovans White hens had significantly lower egg weight, percentage of eggshell, and egg specific gravity than Dekalb White hens. Based on improved feed conversion, dietary energy of 2,846 kcal of ME/kg appeared to be enough for optimal performance during second cycle phase 2. Based on BW of hens, dietary energy level for optimal performance should be less than 2,936 kcal of ME/kg during second cycle phase 3. There can be no fixed ideal dietary energy level for optimal profits for postmolt egg production. Molting method had no effect on egg production and egg mass during the early and middle stages of the postmolt production period. However, hens molted by feed withdrawal had significantly higher egg production and egg mass during the later stage of the postmolt production period compared with hens molted by a no salt diet. There was no significant difference in egg specific gravity due to molting method. Feeding a no salt diet resulted in reasonable long-term postmolt performance and eggshell quality, rather than optimal performance and eggshell quality.

Key words: strain, dietary energy, molting method, laying hen

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INTRODUCTION

Induced molting, an important management tool, has been widely used to rejuvenate laying hens for a second or third cycle of egg production by the egg industry in the United States. Induced molting not only improved performance and eggshell quality, but also increased profits by optimizing the use of replacement pullets on commercial layer farms (Lee, 1982; Barker et al., 1983; Bell, 2003). Forty-seven percent more hens would be required to keep houses full with the 1-cycle egg production (Bell, 2003). The combination of feed withdrawal and light reduction was most widely used to induce molting in the US egg industry in the past. Most producers used some form of feed withdrawal for periods of 5 to 14 d (Bell and Kuney, 2004). The United Egg Producers (**UEP**) Scientific Advisory Committee on Animal Welfare urged researchers and producers to work together to develop alternatives to feed withdrawal for molting (UEP, 2002). Large egg consumers such as McDonald's, Wendy's, and Burger King stated that they would not purchase eggs from producers that use feed withdrawal in their molting programs (Egg Industry, 2000; Smith, 2002). Since January 1, 2006, all egg producers enrolled in the UEP animal care program (most US shell egg producers) have been using no-fast molts. To optimize production and profits, egg producers need more information on nonfeed removal molting methods.

The effectiveness of several nonfeed removal molting diets including low-sodium diets (Whitehead and Shannon, 1974; Begin and Johnson, 1976; Nesbeth et al., 1976a,b; Whitehead and Sharp, 1976; Monsi and Enos, 1977; Ross and Herrick, 1981; Harms 1981, 1983; Naber et al., 1984; Said et al., 1984), low-calcium diets (Gilbert et al., 1981), high-zinc diets (Shippee et al., 1979; Berry and Brake, 1985; Bar et al., 2003), and low protein and low energy diets (Koelkebeck et al., 2001; Biggs et al., 2003) has been evaluated. Naber et al. (1984) and Said et al. (1984) reported that low sodium diets can be effective in recycling hens for a second period of egg production. However, feeding the low-salt diets subsequently resulted in decreased egg production and eggshell thickness in postmolt hens (Ross and Herrick, 1981). Different

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strains showed different performance after molt, whereas different strains showed no difference in performance after conventional feed withdrawal (Said et al., 1984). In addition, there is little research on the effect of low-salt diets (diets without added salt) on postmolt egg composition and egg solids, which are important factors influencing profits of breaker egg market. Unpublished observations from our laboratory showed that there was no significant difference in performance, egg composition, egg solids, and egg quality between hens molted by feed withdrawal and hens molted by no salt diet during the early stage of postmolt egg production (wk 70 to 81). However, molting method may affect long-term performance, egg composition, egg solids, and egg quality. Therefore, it is necessary to have more knowledge on the effect of the no salt diet on long-term performance, egg quality, egg components, and egg solids in current strains of commercial Leghorns (Bovans and Dekalb) to determine acceptable alternatives to the feed withdrawal method to obtain optimal performance and profits.

Feed intake (Grobas et al., 1999; Harms et al., 2000; Wu et al., 2005a) significantly decreased with increasing dietary energy or supplemental fat. However, Summers and Leeson (1993) and Jalal et al. (2006) reported that there was no significant effect of dietary energy on feed intake. Decreased feed intake might have a big impact on cost of production. If feed intake cannot be linearly decreased by increased energy, increasing dietary energy by the addition of fat may not be economical. In addition, egg weight increased with increasing dietary energy (Keshavarz, 1995; Keshavarz and Nakajima, 1995; Harms et al., 2000; Bohnsack et al., 2002; Sohail et al., 2003; Wu et al., 2005a). However, Jalal et al. (2006) reported that there was no response of egg weight to increasing dietary energy by the addition of fat. Egg weight is also an important factor that can affect profits. There is very limited literature on the effect of dietary energy on performance, egg composition, egg solids, egg quality, and profits in postmolt egg production. It is necessary to have a better understanding on how to optimize the use of dietary energy to get optimal performance and profits of postmolt laying hens.

The objective of this study is to determine the effect of molting method and dietary energy on performance, egg components, egg solids, egg quality, and profits in Bovans White and Dekalb White hens in long-term postmolt production period.

MATERIALS AND METHODS

Two experiments of 4 × 2 × 2 factorial arrangement of 4 dietary energy levels, 2 molting methods (feed withdrawal and low salt diet), and 2 strains (Bovans White and Dekalb White) were conducted. Experiment 1 lasted from wk 86 to 96, and experiment 2 lasted from wk 100 to 110. All hens were fed the same diet between the trials. Ingredients and nutrient composition of experimental diets were shown in Table 1.

Before molt, Bovans hens or Dekalb hens were randomly divided into 2 groups. Feed was withdrawn from half of the hens (66 wk of age) for 9 d. Bovans and Dekalb hens lost 32.8 and 32.9% BW, respectively. A molt feed was fed from d 10 to 28 (Table 1). The other half of hens was fed a low salt diet for 28 d (Table 1). Bovans and Dekalb hens lost 16.4 and 17.8% BW at the end of molt, respectively. Hens molted by feed withdrawal stopped laying by d 4, whereas hens molted by no salt diet did not stop laying until d 17. In both experiments, Bovans White hens (n = 576) and Dekalb White hens (n = 576) were randomly divided into 16 treatments (6 replicates of 12 birds per treatment). Replicates were equally distributed into upper and lower cages to minimize cage level effect. Three hens were housed in a 40.6 × 45.7 cm^2 cage and 4 adjoining cages consisted of a replicate. All hens were housed in an environmentally controlled house with temperature maintained at approximately 25.6°C. The light period was reduced from 16 to 8 h daily from d 1. On d 29, the light period was returned to 16 h daily. All hens were supplied with feed and water for ad libitum consumption. Egg production was recorded daily; feed consumption was recorded weekly; egg weight was recorded biweekly; and egg specific gravity was recorded monthly. Egg weight and egg specific gravity were measured using all eggs produced during 2 consecutive days. Egg specific gravity was determined using 11 gradient saline solutions varying in specific gravity from 1.060 to 1.100 with 0.005-unit increments (Holder and Bradford, 1979). Mortality was determined daily, and the feed consumption was adjusted accordingly. Body weight was obtained by weighing 3 hens per replicate at the end of the experiment. Egg mass and feed conversion (g of feed/g of egg) were calculated from egg production, egg weight, and feed consumption.

Egg components, albumen solids, and yolk solids were measured using 2 eggs from each replicate in the middle (wk 5) and the end (wk 10) of experiment. Two eggs from each replicate were collected to measure whole egg solids in the middle and the end of the experiment. The procedures for measuring egg components, whole egg solids, and albumen and yolk solid were the same as those of Wu et al. (2005a). Yolk color and Haugh units were measured (3 eggs of each replicate) at the end of experiment by egg multitester EMT-5200 (Robotmation Co. Ltd., Tokyo, Japan).

Data were analyzed by PROC MIXED procedures of the Statistical Analysis System (SAS Institute, 2000) for a randomized complete block with a factorial treatment design. Dietary energy, molting method, and strain were fixed, whereas blocks were random. The model used to analyze data was as follows:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\beta\gamma)_{jk} + (\alpha\gamma)_{ik} + (\alpha\beta\gamma)_{ijk} + P_l + \varepsilon_{ijkl},$$

where Y_{ijkl} = individual observation; μ = experimental mean; α_i = dietary energy effect; β_j = molting method; γ_k = layer strain effect; $(\alpha\beta)_{ij}$ = interaction between dietary

Table 1. Ingredients and nutrient composition of experimental diets

Ingredient (%)	No salt diet	Molt diet following feed withdrawal	Postmolt diet: Experiment 1 (wk 86 to 95) Diet 1	Diet 2	Diet 3	Diet 4	Diet between trials	Experiment 2 (wk 101 to 110) Diet 1	Diet 2	Diet 3	Diet 4
Corn (8.5% CP)	73.12	72.78	65.41	64.50	63.57	62.65	64.09	67.62	66.52	65.43	64.34
Soybean meal (48.5% CP)	20.02	20.51	22.43	22.51	22.58	22.66	23.45	20.59	20.68	20.77	20.85
$CaCO_3$	0.00	4.02	5.83	5.83	5.82	5.82	5.12	5.70	5.69	5.69	5.69
Hardshell[1]	4.13	0.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Dicalcium phosphate	1.39	1.38	1.40	1.40	1.41	1.41	1.51	1.19	1.19	1.20	1.20
Poultry oil	0.25	0.25	0.00	0.84	1.68	2.53	0.80	0.00	1.00	2.00	3.00
NaCl	0.00	0.38	0.36	0.36	0.36	0.36	0.46	0.36	0.36	0.36	0.36
Vitamin premix[2]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix[3]	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.19	0.05	0.07	0.07	0.07	0.07	0.05	0.05	0.05	0.05	0.05
Calculated analysis[4]											
Crude protein (%)	15.90	15.77	16.04	16.00	15.97	15.93	16.82	15.32	15.28	15.23	15.19
ME (kcal/kg)	2,989	2,996	2,767	2,806	2,846	2,885	2,809	2,797	2,843	2,890	2,938
Linoleic acid (%)	1.48	1.48	1.30	1.47	1.65	1.83	1.46	1.33	1.54	1.75	1.96
Ca (%)	2.00	2.00	4.25	4.25	4.25	4.25	4.00	4.15	4.15	4.15	4.15
Available phosphorus (%)	0.36	0.36	0.36	0.36	0.36	0.36	0.38	0.32	0.32	0.32	0.32
Sodium (%)	0.02	0.18	0.17	0.17	0.17	0.17	0.20	0.17	0.17	0.17	0.17
Methionine (%)	0.47	0.44	0.33	0.33	0.33	0.33	0.36	0.31	0.31	0.31	0.31
Methionine + cysteine (%)	0.73	0.73	0.62	0.62	0.62	0.62	0.65	0.58	0.58	0.58	0.58
Lysine (%)	0.80	0.79	0.83	0.83	0.83	0.83	0.87	0.78	0.78	0.78	0.78

[1]Hardshell = large particle (passing US mesh #4 and retained by US mesh #6) $CaCO_3$ supplied by Franklin Industrial Minerals, Lowell, FL.

[2]Provided per kilogram of diet: vitamin A (as retinyl acetate), 8,000 IU; cholecalciferol, 2,200 ICU; vitamin E (as DL-α-tocopheryl acetate), 8 IU; vitamin B_{12}, 0.02 mg; riboflavin, 5.5 mg; D-calcium pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; folic acid, 0.5 mg; vitamin B_1 (thiamin mononitrate), 1 mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; vitamin K (menadione sodium bisulfate complex), 2 mg.

[3]Provided per kilogram of diet: manganese ($MnSO_4 \cdot H_2O$), 65 mg; iodine [$Ca(IO_3)_2 \cdot H_2O$], 1 mg; iron ($FeSO_4 \cdot 7H_2O$), 55 mg; copper ($Cu\text{-}SO_4 \cdot 5H_2O$), 6 mg; and zinc ($ZnSO_4 \cdot 7H_2O$), 55 mg.

[4]The analyzed value of ME used for corn, soybean meal, and poultry oil were 3,399, 2,396, and 8,195 kcal of ME/kg, respectively, and the analyzed value of Na used for corn, soybean meal, and salt were 0.03, 0.034, and 39.4%, respectively.

energy and molting method; $(\beta\gamma)_{jk}$ = interaction between molting method and strain; $(\alpha\gamma)_{ik}$ = interaction between dietary energy and strain; $(\alpha\beta\gamma)_{ijk}$ = interaction among dietary energy, molting method, and strain; P_k = effect of block; and ε_{ijkl} = error component.

If differences in treatment means were detected by ANOVA, Duncan's multiple range test was applied to separate means. A significance level of $P \leq 0.05$ was used during analysis.

RESULTS AND DISCUSSION

There were no interactions among strain, dietary energy, and molting method in all parameters during second cycle phase 2 (86 to 96 wk of age) and phase 3 (100 to 110 wk of age) (Tables 2, 3, 4, and 5). Bovans hens had significantly greater egg production than Dekalb hens during second cycle phases 2 and 3 (Tables 2 and 4). Egg mass and feed conversion of Bovans hens were significantly better than Dekalb hens during second cycle phase 2. Bovans hens used significantly less dietary energy to produce 1 g of egg compared with Dekalb hens. Dekalb hens had significantly higher egg weight during second cycle phase 2 and higher egg weight ($P \leq 0.089$) during second cycle phase 3 than Bovans hens. Dekalb hens had significantly higher percentage of eggshell and egg specific gravity than Bovans hens during second cycle phases 2 and 3 (Tables 3 and 5). These results were in agreement with those Wu et al. (2005a,b), who reported Bovans hens had significantly higher egg production and egg mass, and lower egg weight than Dekalb hens. There was no significant difference in percentage of yolk and albumen, percent of whole solid, Haugh unit and yolk color between Bovans hens and Dekalb hens during second cycle phases 2 and 3 (Tables 3 and 5). Breaker egg industry may get more total egg solids in Bovans hens because of higher egg yield of Bovans hens.

Increasing dietary energy by the addition of poultry oil had no significant effect on feed intake during second cycle phase 2 (wk 86 to 96 of age) and phase 3 (100 to 110 wk of age; Tables 2 and 4). Similarly, unpublished data from our laboratory showed that there was no effect of dietary energy on feed intake during second cycle phase 1 (70 to 82 wk of age). However, other results from our laboratory have been inconsistent with that of Wu et al. (2005a), who reported that feed intake linearly decreased as dietary energy increased. This might be due to the smaller gap between 2 levels of dietary energy (approximately 40 and 46 kcal of ME/kg in second cycle phases 2 and 3, respectively), compared with that (approximately 80 kcal of ME/kg) of Wu et al. (2005a). Dietary energy had no effect on egg production, egg mass, and mortality in second cycle phases 2 and 3 (Table 2 and 4). These results were in agreement with those of Wu et al. (2005a,b) and Jalal et al. (2006), who reported that there was no significant effect of dietary energy level on egg production.

Dietary energy had no significant effect on egg weight during second cycle phase 2 (86 to 96 wk of age) and

Table 2. Influence of dietary energy and molting method on postmolt performance of Bovans White and Dekalb White hens during second cycle phase 2 (86 to 96 wk of age; experiment 1)[1]

Factor		Feed intake (g·hen^{-1}·d)	Egg production (%)	Egg weight (g)	Egg mass (g of egg/hen per d)	Feed conversion (g of feed/g of egg)	Energy intake (kcal of ME/g of egg)	BW (kg)	Mortality (%)
Strain	Bovans	96.80	78.31[a]	66.10[b]	51.76[a]	1.87[b]	5.22[b]	1.75	2.01
	Dekalb	96.83	74.46[b]	67.28[a]	50.10[b]	1.94[a]	5.54[a]	1.73	3.09
Dietary	2,767	98.79	75.50	66.62	50.31	1.97[a]	5.51	1.73	3.93
energy	2,806	96.16	76.12	66.68	50.73	1.90[ab]	5.33	1.71	2.78
(kcal/kg)	2,846	95.85	76.62	66.57	50.99	1.88[b]	5.36	1.76	2.50
	2,886	96.46	77.28	66.88	51.68	1.87[b]	5.31	1.78	1.00
Molt regimen[2]	NSD	95.65	75.36	66.86	50.25	1.91	5.39	1.74	1.87
	FW	97.99	77.40	66.52	51.61	1.90	5.38	1.74	3.23
Pooled SEM		2.45	2.29	0.69	1.54	0.05	0.14	0.15	2.00
Main effects and interactions		Probability							
Strain		NS[3]	0.0012	0.0010	0.0386	0.0223	0.0001	NS	NS
Dietary energy		NS	NS	NS	NS	0.0497	NS	NS	NS
Molt method		0.0625	0.0782	NS	0.0873	NS	NS	NS	NS
Strain × Energy		NS	NS	NS	NS	NS	NS	NS	NS
Strain × Molt		NS	NS	NS	NS	NS	NS	NS	NS
Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS
Strain × Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS

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

[1]Data represent means of 6 replicates of 12 hens.

[2]NSD = no salt diet; FW = feed withdrawal.

[3]Not significant at $P > 0.05$.

phase 3 (100 to 110 wk of age; Tables 2 and 4). Similarly, unpublished observations from our laboratory showed that there was no significant effect of egg weight to increasing dietary energy during second cycle phase 1 (70 to 82 wk of age). However, Wu et al. (2005a) reported that egg weight linearly increased with increasing dietary energy from 21 to 36 wk of age and suggested that the increase of egg weight was mainly due to increased yolk weight for young hens. There was no response of percentage of yolk to increasing dietary energy during second cycle phases 2 and 3 (Tables 3 and 5). Young hens might not have enough ability to produce enough lipoprotein and need more exogenous fat to supply lipids for egg yolk development in the early stage of egg production (Sell et al., 1987), but hens during later egg production might already have enough ability to produce lipoprotein.

Table 3. Influence of dietary energy and molting method on egg component, egg solids, and egg quality in postmolt Bovans White and Dekalb White hens during second cycle phase 2 (86 to 96 wk of age; experiment 1)[1]

Factor		% of egg component			% of egg solids			Egg quality		
		Yolk	Albumen	Shell	Whole egg	Yolk	Albumen	Egg specific gravity	Haugh unit	Yolk color
Strain	Bovans	26.12	65.01	8.81[b]	22.88	50.85	11.42	1.0807[b]	72.55	5.98
	Dekalb	25.69	65.15	9.17[a]	22.84	50.58	11.59	1.0831[a]	72.60	5.94
Dietary	2,767	25.83	65.16	8.88	22.92	50.81	11.37	1.0824	73.37	6.08
energy	2,806	25.89	65.18	8.93	22.48	51.01	11.49	1.0820	71.20	5.87
(kcal/kg)	2,846	25.75	65.19	9.06	22.72	50.62	11.58	1.0821	73.23	5.93
	2,886	26.15	64.78	9.08	23.32	50.41	11.60	1.0810	72.50	5.95
Molt regimen[2]	NSD	25.47[b]	65.60[a]	8.93	22.79	50.72	11.54	1.0815	72.80	6.01
	FW	26.34[a]	64.56[b]	9.05	22.93	50.71	11.48	1.0823	72.35	5.90
Pooled SEM		0.80	0.93	0.25	0.38	0.24	0.37	0.0008	2.25	0.15
Main effects and interactions		Probability								
Strain		NS[3]	NS	0.0057	NS	NS	NS	0.0001	NS	NS
Dietary energy		NS	NS	NS	NS	NS	NS	0.0788	NS	NS
Molt method		0.0330	0.0280	NS	NS	NS	NS	0.0563	NS	NS
Strain × Energy		NS	NS	NS	NS	NS	NS	NS	NS	NS
Strain × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS
Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS
Strain × Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS

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

[1]Data represent means of 6 replicates of 12 hens.

[2]NSD = no salt diet; FW = feed withdrawal.

[3]Not significant at $P > 0.05$.

Table 4. Influence of dietary energy and molting method on postmolt performance of Bovans White and Dekalb White hens during second cycle phase 2 (100 to 110 wk of age; experiment 2)[1]

Factor		Feed intake ($g \cdot hen^{-1} \cdot d$)	Egg production (%)	Egg weight (g)	Egg mass (g of egg/hen per d)	Feed conversion (g of feed/g of egg)	Energy intake (kcal of ME/g of egg)	BW (kg)	Mortality (%)
Strain	Bovans	103.78	72.91[a]	66.48	48.47	2.15	6.07[b]	1.77	1.93
	Dekalb	102.54	70.01[b]	67.09	46.95	2.19	6.38[a]	1.73	2.53
Dietary	2,797	103.84	70.56	66.26	46.75	2.23	6.35	1.71[a]	2.51
energy	2,844	103.20	70.70	66.43	46.94	2.21	6.28	1.72[a]	2.54
(kcal/kg)	2,890	103.61	72.75	67.19	48.87	2.13	6.15	1.73[a]	1.74
	2,936	102.01	71.83	67.25	48.29	2.12	6.12	1.83[b]	2.12
Molt regimen[2]	NSD	102.57	69.79[b]	66.95	46.65[b]	2.21[a]	6.34[a]	1.74	2.45
	FW	103.76	73.13[a]	66.62	48.78[a]	2.13[b]	6.11[b]	1.75	2.01
Pooled SEM		1.87	2.80	0.71	1.98	0.08	0.22	0.14	1.74
Main effects and interactions		Probability							
Strain		NS[3]	0.0414	0.0897	NS	NS	0.0064	NS	NS
Dietary energy		NS	NS	NS	NS	0.0949	NS	0.0380	NS
Molt method		NS	0.0197	NS	0.0396	0.0483	0.0462	NS	NS
Strain × Energy		NS	NS	NS	NS	NS	NS	NS	NS
Strain × Molt		NS	NS	NS	NS	NS	NS	NS	NS
Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS
Strain × Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS

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

[1]Data represent means of 6 replicates of 12 hens.

[2]NSD = no salt diet; FW = feed withdrawal.

[3]Not significant at $P > 0.05$.

In addition, both strains produced very large eggs in this study. The genetic maximum for egg weight might have been attained so that egg weight was unable to respond to dietary energy manipulation. Linoleic acid content of all experimental diets in this study was more than 1.3%. Grobas et al. (1999) reported that linoleic acid content (more than 1.15%) in the diet had no effect on egg weight, and NRC (1994) recommended that the linoleic acid requirement for laying hens was 1.0%. Therefore, linoleic acid might have no effect on egg weight in this study.

Increasing dietary energy by the addition of poultry oil had a linear effect on feed conversion during second cycle phase 2 (wk 86 to 96; Table 2). Increasing dietary energy from 2,767 to 2,846 kcal of ME/kg improved feed conversion from 1.97 to 1.88, resulting in a 4.6% improvement in feed conversion. Further increasing dietary en-

Table 5. Influence of dietary energy and molting method on egg component, egg solids, and egg quality in postmolt Bovans White and Dekalb White hens during second cycle phase 2 (100 to 110 wk of age; experiment 2)[1]

		% of egg component			% of egg solids			Egg quality		
Factor		Yolk	Albumen	Shell	Whole egg	Yolk	Albumen	Egg specific gravity	Haugh unit	Yolk color
Strain	Bovans	28.10	63.28	8.62	24.17	50.35	11.95	1.0789[b]	68.14	6.34
	Dekalb	27.94	62.84	9.22	23.82	50.19	12.08	1.0816[a]	69.61	6.55
Dietary	2,797	27.66	63.24	9.10	23.98	49.88	12.02	1.0809	69.02	6.38
energy	2,844	28.36	62.68	8.96	24.00	50.57	11.94	1.0802	68.48	6.41
(kcal/kg)	2,890	28.03	63.30	8.68	23.98	50.30	12.14	1.0797	70.98	6.57
	2,936	28.03	63.01	8.97	24.01	50.30	11.98	1.0802	67.02	6.41
Molt regimen[2]	NSD	27.81	63.44	8.75	23.92	50.34	11.92	1.0800	69.03	6.45
	FW	28.22	62.69	9.09	24.07	50.20	12.11	1.0804	68.72	6.44
Pooled SEM		0.71	0.82	0.38	0.52	0.38	0.24	0.0009	2.25	0.15
Main effects and interactions		Probability								
Strain		NS[3]	NS	0.0024	NS	NS	NS	0.0001	NS	NS
Dietary energy		NS	NS	NS	NS	NS	NS	NS	NS	NS
Molt method		NS	0.0691	0.0734	NS	NS	NS	NS	NS	NS
Strain × Energy		NS	NS	NS	NS	NS	NS	NS	NS	NS
Strain × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS
Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS
Strain × Energy × Molt		NS	NS	NS	NS	NS	NS	NS	NS	NS

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

[1]Data represent means of 6 replicates of 12 hens.

[2]NSD = no salt diet; FW = feed withdrawal.

[3]Not significant at $P > 0.05$.

Table 6. Influence of dietary energy and poultry oil price on profits[1,2] in experiment 1 (86 to 95 wk of age)

Item	Dietary energy content (kcal of ME/kg)			
	2,767	2,806	2,846	2,886
	Return[3] (cents/dozen)			
High fat price ($0.40/kg)	0.196	0.198	0.195	0.193
Low fat price ($0.26/kg)	0.196	0.200	0.198	0.198

[1]Corn price = $0.09/kg; soy price = $0.19/kg; $CaCO_3$ = $0.03/kg; hard shell = $0.03/kg; dicalcium phosphate = $0.27 cents/kg; salt = $0.06/kg, vitamin premix = $2.67/kg; mineral premix = $0.59/kg; and DL-methionine = $2.59/kg.

[2]The egg price spread between medium and large eggs was 11 cents.

[3]Return (R) was calculated using the equation: R = UBEP – NR – PC– FdC, where UBEP = Urner Barry Egg Price, NR = nest run into package product delivered, PC = production cost, and FdC = feed cost, as described by Roland et al. (1998, 2000).

Table 7. Influence of dietary energy and poultry oil price on profits[1,2] in experiment 2 (101 to 110 wk of age)

Item	Dietary energy content (kcal of ME/kg)			
	2,797	2,844	2,890	2,936
	Return[3] (cents/dozen)			
High fat price ($0.40/kg)	0.143	0.140	0.142	0.137
Low fat price ($0.26/kg)	0.143	0.142	0.146	0.144

[1]Corn price = $0.09/kg, soy price = $0.24/kg, $CaCO_3$ = $0.03/kg, hard shell = $0.03/kg, dicalcium phosphate = $0.27 cents/kg, salt = $0.06/kg, vitamin premix = $2.67/kg, mineral premix = $0.59/kg, DL-methionine = $2.59/kg.

[2]The egg price spread between medium and large eggs was 11 cents.

[3]Return (R) was calculated using the equation: R = UBEP – NR – PC – FdC, where UBEP = Urner Barry Egg Price; NR = nest run into package product delivered; PC = production cost; and FdC = feed cost, as described by Roland et al. (1998, 2000).

ergy from 2,846 to 2,886 kcal of ME/kg had no improvement in feed conversion. This suggested dietary energy of 2,846 kcal of ME/kg might be enough for optimal performance during second cycle phase 2 (86 to 96 wk of age). Similarly, Wu et al. (2005a) reported that hens fed the diet containing dietary energy of 2,877 kcal of ME/kg obtained optimal performance during phase 1. Dietary energy had no significant effect on feed conversion in second cycle phase 3 (100 to 110 wk of age; Table 4). Hens fed the diet containing 2,936 kcal of ME/kg had significantly higher BW than hens fed the diets with other dietary energy levels. This suggested that dietary energy level of 2,936 kcal of ME/kg might provide more dietary energy than the optimal energy level for performance. Because egg mass (approximately 48 g per hen daily) of hens during second cycle phase 3 (100 to 110 wk of age) was less than that (approximately 52 g per hen daily) of hens during second cycle phase 2 (86 to 96 wk of age), less energy was used to produce egg so that excess energy might be used to produce body fat. This might explain why BW of hens fed 2,936 kcal of ME/kg was significantly higher than that of hens fed other dietary levels. The dietary energy level for optimal performance should be less than 2,936 kcal of ME/kg for hens during second cycle phase 3 (100 to 110 wk of age).

An Economic Feeding and Management Program developed by Roland et al. (1998, 2000) was used to calculate profits of different dietary energy levels at poultry oil prices. Maximum profits per dozen eggs were obtained in hens fed the diet containing 2,806 kcal of ME/kg of dietary energy in both poultry oil prices during second cycle phase 2 (86 to 96 wk of age; Table 6). When poultry oil price was $0.26/kg, maximum profits per dozen eggs were obtained in hens fed the diet containing 2,890 kcal of ME/kg of dietary energy during second cycle phase 3 (100 to 110 wk of age; Table 7). However, when poultry oil price increased to $0.40/kg, maximum profits was obtained in hens fed the diet containing 2,797 kcal of ME/kg of dietary energy during second cycle phase 3. Because feed ingredient prices and egg price often vary, there can be no fixed ideal dietary energy level for optimal profits for postmolt hens.

Although there was no linear response of feed intake to increasing dietary energy, hens did adjust feed intake to achieve a constant energy intake so that the similar quantities of dietary energy (5.3 to 5.5 kcal in second cycle phase 2 and 6.1 to 6.4 kcal in second cycle phase 3, respectively) were used to produce to 1 g of egg (Tables 2 and 4). Increasing dietary energy had no effect on percentage of yolk, albumen, and shell; percent of whole egg solids, yolk solid, and albumen solid; egg specific gravity; Haugh unit; and yolk color in second cycle phase 2 (86 to 96 wk of age) and phase 3 (wk 100 to 110 of age). Similarly, unpublished data from our laboratory showed that there was no significant effect of dietary energy on egg composition, egg solids, and egg quality during second cycle phase 1 (70 to 81 wk of age).

There was no significant difference in feed intake and egg weight between hens molted by feed withdrawal and hens molted by no salt diet during second cycle phase 2 (wk 86 to 95 of age) and phase 3 (100 to 110 wk of age; Tables 2 and 4). Similarly, unpublished observations from our laboratory showed that molting method had no significant effect on feed intake and egg weight during second cycle phase 1 (70 to 82 wk of age). These results were consistent with Ross and Herrick (1981), Said et al. (1984), and Naber et al. (1984), who reported that there was no significant difference in feed intake and egg weight, due to molting method. Hens molted with feed withdrawal had higher egg production and egg mass ($P \leq 0.0782$ and $P \leq 0.0873$, respectively) than hens molted by no salt diet during second cycle phase 2 (86 to 96 wk of age). Hens molted by feed withdrawal had significantly higher egg production and egg mass than hens molted by no salt diet during second cycle phase 3 (100 to 110 wk of age). Unpublished observations from our laboratory showed that there was no significant difference in egg production and egg mass during second cycle phase 1 (70 to 82 wk of age), due to molting method. These results and unpublished data from our laboratory suggested that molting method had no effect on egg production and egg mass during the early and middle stages of postmolt egg production. However, hens molted by feed withdrawal had higher egg production and egg mass during the later stage of postmolt egg production, compared with hens molted by no salt diet. Similarly, difference in egg production between hens molted by no salt diet or low nutrient diet and hens molted by feed withdrawal increased with age (Ross and Herrick, 1981; Biggs et al., 2003). This might be due to different BW loss of hens molted by different molting methods, which leads to different ovarian regression. Hens molted by feed withdrawal lost 32.9% BW, whereas hens molted by no salt diet lost 17.1% BW during molting. Although hens molted by feed withdrawal lost a greater percentage of their BW than hens molted by no salt diet, there was no significant difference in egg weight (69.2 vs. 69.2 g) and hen BW (1.78 vs. 1.74 kg/hen) between hens molted by feed withdrawal and hens molted by no salt diet in the beginning of experiment 1. Barker et al. (1983) reported that a BW loss of approximately 27 to 31% obtained optimal postmolt performance.

There was no significant difference in feed conversion and energy intake during second cycle phase 2 (86 to 96 wk of age; Table 2). Hens molted by feed withdrawal had significantly better feed conversion and used significantly less dietary energy to produce egg than hens molted by no salt diet during second cycle phase 3 (100 to 110 wk of age; Table 4). The improved feed efficiency of hens molted by feed withdrawal might be due to higher egg production of hens molted by feed withdrawal, compared with that of hens molted by no salt diet. Hens molted by feed withdrawal had significantly higher percentage of yolk and lower percentage of albumen than hens molted by no salt diet during second cycle phase 2 (86 to 95 wk of age). The effect of molting method on egg specific gravity approached significance ($P \leq 0.0563$) during second cycle phase 2. There was no significant difference in egg specific gravity during second cycle phase 3. Unpublished observations from our laboratory showed there was no significant difference in egg specific gravity during second cycle phase 1. Similar results were reported by Ross and Herrick (1981), Naber et al. (1984), and Biggs et al. (2003). Based on the results of this study and Ross and Herrick (1981), Naber et al. (1984), and Biggs et al. (2003), it was concluded that although hens molted by feed withdrawal had numerically higher egg specific gravity than hens molted by hens no salt diet, there was no significant difference in egg specific gravity due to molting method. There was no significant difference in percentage of shell; percentage of whole egg solids, yolk solid, and albumen solid; Haugh units; and yolk color between hens molted by feed withdrawal and hens molted by no salt diet during second cycle phase 2 and 3 (Tables 3 and 4). Similarly, unpublished observations from our laboratory showed that molting method had no effect on egg solids, Haugh unit, and yolk color during second cycle phase 1. These results were in agreement with those of Ross and Herrick (1981), Naber et al. (1984), and Biggs et al. (2003), who reported that molting method had no effect on Haugh unit. Therefore, molting method had no significant effect on egg solids and egg quality during postmolt egg production.

In conclusion, Bovans White hens had significantly higher egg production than Dekalb White hens, whereas Bovans White hens had significantly lower egg weight, percentage of eggshell, and egg specific gravity than Dekalb White hens. Increasing dietary energy had no significant effect on all parameters, except feed conversion, during second cycle phase 2 (86 to 96 wk of age). Increasing dietary energy linearly improved feed conversion. Increasing dietary energy had no effect on all parameters, except BW of hens, during second cycle phase 3 (100 to 110 wk of age). Based on improved feed conversion, dietary energy of 2,846 kcal of ME/kg might be enough for optimal performance during second cycle phase 2 (86 to 96 wk of age). Based on BW of hens, dietary energy level for optimal performance should be less than 2,936 kcal of ME/kg during second cycle phase 3 (100 to 110 wk of age). There can be no fixed ideal dietary energy level for optimal profits for postmolt egg production. Molting method had no effect on egg production and egg mass during the early and middle stages of postmolt production period. However, hens molted by feed withdrawal had significantly higher egg production and egg mass during the later stage of postmolt production period, compared with hens molted by no salt diet. Although hens molted by feed withdrawal had numerically higher egg specific gravity than hens molted by no salt diet, there was no significant difference in egg specific gravity due to molting method. Molting method had no significant effect on whole egg solid, albumen solid, yolk solid, Haugh units, and yolk color. Therefore, feeding no salt diet resulted in reasonable long-term postmolt performance and eggshell quality, rather than optimal performance and eggshell quality.

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