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Effect of Dietary Energy and Protein on Performance, Egg Composition, Egg Solids, Egg Quality and Profits of Hy-Line W-36 Hens During Phase 2

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Abstract: A 4×3 factorial experiment with four added dietary energy (fat) levels (0.00 (0.00), 0.33 (16.7), 0.67 (33.5) and 1.00 (50.4) MJ ME/kg (g fat/kg)) and three protein levels (173.9, 166.5 and 160.7 g protein/kg) was conducted to determine the effect of dietary energy on performance, egg composition, egg solids, egg quality and profits of Hy-line W-36 hens at different protein levels. Hy-line W-36 hens (n = 1080) in Phase II (40 weeks of age) were randomly divided into 12 treatments (6 replicates of 15 birds per treatment) and fed the experimental diets for 12 wks. There was no significant interaction on all parameters between dietary energy and protein. Increasing protein had a significant effect on nutrient intake per g egg, percent albumen and yolk/albumen ratio, but had no effect on performance, egg solids, or egg quality. Hens had the capability to linearly decrease feed intake as dietary energy level increased so that the similar quantities of dietary energy (0.022 to 0.023 MJ/kg) was consumed to produce 1 g egg. Increasing dietary energy by the addition of poultry oil significantly improved nutrient (protein, lysine, or TSAA) utilization. As added dietary energy increased from 0.00 to 0.67 MJ/kg, feed intake linearly decreased and feed conversion linearly improved. However, a further increase of added dietary energy from 0.67 to 1.00 MJ/kg had no additional effect on feed intake and feed conversion. Based on feed intake and feed conversion, increasing 0.67 MJ/kg dietary energy by the addition of 33.5 g poultry oil/kg gave optimal performance in Hy-line W-36 hens from 40 to 51 wk of age. Because feed ingredient prices and egg price vary, there can be no fixed ideal dietary energy level for optimal profits during phase 2 (wk 40 to 51).

Key words: Protein, energy, feed intake, feed conversion

Introduction

Protein and dietary energy are the major nutrients of the diets for laying hens. As much as 85% of total costs of the diet come from protein and energy ingredients. Liu *et al*. (2004; 2005) and Wu *et al*. (2005a) reported that increasing protein level significantly affected egg production, egg weight, egg mass, feed consumption, feed conversion, egg specific gravity and body weight of hens. Although feeding high protein diets can optimize performance, the cost of high protein diets and egg prices determine the level needed for optimal profits. Several protein levels ranging from 160 to 180 g/kg are currently used by egg producers during phase 2. Increasing dietary energy by the addition of fat significantly decreased feed intake (Grobas *et al*., 1999; Harms *et al*., 2000; Bohnsack *et al*., 2002; Wu *et al*., 2005b, c, d) and improved feed conversion (Wu *et al*., 2005b, c, d, e). As protein level decreases in corn-soy diets, the diets contain more corn and less soy. Because corn contains more dietary energy than soy, low protein diets contain higher dietary energy than high protein diets. If dietary energy contributed from corn and soy is sufficient for optimal performance of laying hens fed the low protein diets, increasing dietary energy by the addition of fat may have no influence on performance of hens fed the low protein diets. Sohail *et al*. (2003) reported there was an interaction in feed conversion between dietary energy and protein. Increasing dietary energy by the addition of fat decreased feed consumption and improved feed efficiency at two higher protein levels (198 and 187 g/kg) but not at the lower level (174 g/kg) (Sohail *et al*., 2003). However, Wu *et al*. (2005d) reported that increasing dietary energy by the addition of poultry oil had the same effect on performance of laying hens fed different protein levels. Because fat price can very significantly, it is necessary to have better understanding on how to optimize the use of dietary energy at different protein levels.

The liquid egg and breaker egg industry have grown during the last 10 years. Egg components and egg solids might be changed by the manipulation of protein (amino acids) and dietary energy. Increasing amino acids such as methionine and lysine could significantly increase percent albumen (Shafer *et al*., 1998: Novak *et al*., 2004) and increasing dietary energy by the addition of poultry oil could significantly increase yolk weight (Wu *et al*., 2005b). Few studies have been conducted to investigate the dietary energy and protein effect on egg composition and egg solids of Hy-line W-36 hens during phase 2. It is beneficial for the egg processing industry to know how to manipulate protein and dietary energy to improve the final products of liquid egg and dried egg production.

Table 1: Ingredient and nutrient content of the experimental diets

Ingredient (g/kg)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	Diet 7	Diet 8	Diet 9	Diet 10	Diet 11	Diet 12
Corn	628.0	609.8	591.4	572.9	646.2	627.9	609.6	591.1	660.7	642.4	624.1	605.6
Soybean meal	256.4	257.9	259.4	260.8	238.3	239.8	241.2	242.7	223.8	225.3	226.7	228.2
$CaCO_3$	51.1	51.1	51.1	51.0	51.2	51.1	51.1	51.1	51.2	51.2	51.1	51.1
Hardshell[1]	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Dicalcium phosphate	14.9	14.9	15.0	15.1	15.0	15.0	15.1	15.2	15.0	15.1	15.2	15.3
Poultry oil	0.0	16.7	33.5	50.4	0.0	16.7	33.5	50.4	0.0	16.7	33.5	50.4
NaCl	3.6	3.6	3.6	3.7	3.6	3.6	3.6	3.7	3.6	3.6	3.6	3.7
Vitamin Premix[2]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Mineral premix[3]	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
DL-Methionine	1.0	1.0	1.1	1.1	0.8	0.8	0.9	0.9	0.6	0.7	0.7	0.8
Calculated analysis												
CP (g/kg)	173.9	173.2	172.4	171.7	166.5	165.8	165.1	164.3	160.7	159.9	159.2	158.4
ME (MJ/kg)	11.55	11.88	12.22	12.55	11.62	11.96	12.29	12.62	11.69	12.01	12.35	12.68
Ca (g/kg)	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0	40.0
Available phosphorus (g/kg)	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8	3.8
Methionine (g/kg)	3.8	3.8	3.9	3.9	3.6	3.6	3.6	3.6	3.3	3.4	3.4	3.4
Metionine+Cystine (g/kg)	6.9	6.9	6.9	6.9	6.5	6.5	6.5	6.5	6.2	6.2	6.2	6.2
Lysine (g/kg)	9.2	9.2	9.2	9.2	8.7	8.7	8.7	8.7	8.3	8.3	8.3	8.3

[1]Hardshell = large particle (passing US mesh #4 and retained by US mesh #6) $CaCO_3$ supplied by Franklin Industrial Minerals, Lowell, Florida,
[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, 65 mg; iodine, 1 mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg; selenium, 0.3 mg

The objective of this study was to determine the effect of dietary energy on performance, egg composition, egg solids, egg quality and profits at different protein levels in Hy-line W-36 hens during phase 2 (from wk 40 to 51).

Materials and Methods

Diets: Four added dietary energy (fat) levels (0.00 (0.00), 0.33 (16.7), 0.67 (33.5) and 1.00 (50.4) MJ ME/kg (g fat/kg)) and three protein levels (173.9, 166.5 and 160.7 g protein/kg) in a 4×3 factorial arrangement were used in this experiment. Ingredients and nutrient composition of experimental diets were shown in Table 1.

Animals and housing: In this experiment, Hy-line W-36 hens (n = 1080) in phase 2 (40 wk of age) were randomly divided into 12 treatments (6 replicates of 15 birds per treatment) and fed the experimental diets for 12 wks. 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 five adjoining cages consisted of a replicate. All hens were housed in an environmentally-controlled house with temperature maintained at approximately 25.6°C. The house had controlled ventilation and lighting (16 h/d). All hens were supplied with feed and water *ad libitum*.

Experimental procedures: Egg production was recorded daily, feed consumption and egg weight were recorded weekly and egg specific gravity was recorded monthly. Egg weight and egg specific gravity were measured using all eggs produced during two 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 feed/g egg) were calculated from egg production, egg weight and feed consumption. Three eggs from each replicate were collected at middle of the end of experiment for measuring egg components. Three eggs from each replicate were collected to measure whole egg solids in the middle and the end of experiment. Albumen and yolk solids were measured by using three eggs from each replicate in the middle and the end of experiment. The procedures for measuring egg components, whole egg solids and albumen and yolk solids were the same as those of Wu *et al.* (2005b). Yolk color and Haugh unit were measured (3 eggs of each replicate) at the end of experiment by egg multi-tester EMT-5200 (Robotmation, Co., Ltd, Japan).

Statistical analyses: Data were analyzed by proc mixed procedures of Statistical Analysis System (SAS Institute, 2000) for a randomized complete block with a factorial treatment design. Dietary energy and protein were fixed, while blocks were random. The factorial treatment arrangement consisted of 4 dietary energy levels and 3 protein levels. The following model used to analyze data was as follows:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + (\alpha\beta)_{ij} + P_k + \epsilon_{ijk}$$

Where Y_{ijk} = individual observation, μ = experimental mean, α_i = dietary energy effect, β_j = protein effect $(\alpha\beta)_{ij}$ = interaction between dietary energy and protein, P_k = effect of block, ϵ_{ijk} = error component.

Table 2: Effect of protein and dietary energy on performance of Hy-line W-36 during phase 2 (from 40 to 51 wk of age)

Protein (g/kg)	Added dietary energy (MJ/kg)	Feed intake (g/hen/day)	Egg Production (%)	Egg weight (g)	Egg mass (g)	Feed conversion (g feed/g egg)	Body weight of hens (kg)	Total mortality (%)
173.9		96.52	87.16	61.02	53.19	1.82	1.65	1.11
166.5		96.61	86.45	60.90	52.65	1.84	1.60	0.56
160.7		97.24	85.67	60.88	52.17	1.87	1.61	1.11
	0.00	97.89^{ab}	85.45	61.02	52.13	1.88^{a}	1.59	1.11
	0.33	98.78^{b}	86.32	61.00	52.65	1.88^{a}	1.66	1.11
	0.67	95.81^{bc}	87.03	60.72	52.85	1.81^{b}	1.66	0.74
	1.00	94.68^{c}	86.92	61.01	53.04	1.79^{b}	1.58	0.74
Pooled SEM		1.35	1.32	0.45	0.76	0.04	0.10	1.06
				-------------- Probability --------------				
Main effect and interaction								
Protein		NS	NS	NS	NS	NS	NS	NS
Energy		0.0039	NS	NS	NS	0.0116	NS	NS
Protein×Energy		NS	NS	NS	NS	NS	NS	NS
Contrast								
Energy linear		0.0014	NS	NS	NS	0.0019	NS	NS
Energy quadratic		NS	NS	NS	NS	NS	NS	NS

$^{a-c}$Means within a column and under each main effect with no common superscripts differ significantly

Table 3: Effect of protein and dietary energy on nutrient intake of Hy-line W-36 during phase 2 (from 40 to 51 wk of age)

		-------------- Nutrients used to produce one gram egg --------------			
Protein (%)	Added dietary energy (MJ/kg)	Dietary energy (MJ)	Protein (g)	TSAA (mg)	Lysine (mg)
173.9		0.022	0.31^{a}	12.53^{a}	16.70^{a}
166.5		0.022	0.30^{b}	12.00^{b}	15.97^{b}
160.7		0.023	0.30^{b}	11.57^{c}	15.48^{c}
	0.00	0.022	0.31^{a}	12.35^{a}	16.40^{a}
	0.33	0.023	0.31^{a}	12.26^{a}	16.39^{a}
	0.67	0.022	0.30^{b}	11.84^{b}	15.83^{b}
	1.00	0.023	0.29^{b}	11.67^{b}	15.59^{b}
Pooled SEM		0.0011	0.006	0.24	0.32
			-------------- Probability --------------		
Main effect and interaction					
Protein		NS	0.0020	0.0001	0.0001
Energy		NS	0.0019	0.0048	0.0086
Protein × Energy		NS	NS	NS	NS
Contrast					
Energy linear		NS	0.0002	0.0006	0.0013
Energy quadratic		NS	NS	NS	NS

$^{a-b}$Means within a column and under each main effect with no common superscripts differ significantly

If differences in treatment means were detected by ANOVA, Duncan's Multiple Range Test was applied to separate means. Contrast statements were utilized to test for linear or quadratic dietary energy effects. A significance level of $p \leq 0.05$ was used during analysis.

Results

There was no significant interaction on all parameters between protein and dietary energy (Table 2, 3 and 4). There was no significant protein effect on feed intake, egg production, egg weight, egg mass, feed conversion, body weight of hens, or mortality (Table 2). Increasing dietary energy by the addition of poultry oil had no effect on egg production, egg weight, egg mass, body weight of hens, or mortality. Increasing dietary energy by the addition of poultry oil had a linear effect on feed intake. As added dietary energy increased from 0.00 to 1.00 MJ/kg, feed intake linearly decreased from 97.89 to 94.68 g/hen per day, resulting in a 3.3% decrease of feed intake. An increase of 71.8 kcal of ME/kg decreased feed intake by 1%. There was a linear effect of dietary energy on feed conversion. With increasing dietary energy feed conversion significantly improved from 1.88 to 1.79, resulting in a 4.8% improvement of feed conversion.

As protein level increased from 160.7 to 173.9 g/kg, dietary energy intake per g egg did not change, but nutrient intake such as protein, TSAA and lysine per g egg linearly increased (Table 3). Increasing dietary energy by the addition of poultry oil had no significant effect on dietary energy intake per g egg, but linearly decreased nutrient intake such as protein, TSAA and lysine per g egg.

There was no significant effect of protein on percent yolk and percent shell (Table 4). As protein increased from 160.7 to 173.9 g/kg, percent albumen linearly increased

Table 4: Effect of protein and dietary energy on egg components, egg solids and egg quality of Hy-line W36 during phase 2 (from 40 to 51 wk of age)

	Added dietary	% of egg components			Yolk/	% of egg solids			Egg quality		
Protein (%)	energy (MJ/kg)	Yolk	Albumen	Shell	alb ratio	Whole egg	Yolk	Albumen	Egg specific gravity (unit)	Yolk color	Haugh unit
173.9		28.64	62.95[a]	8.41	0.46[b]	24.78	48.34	12.61	1.0803	5.72	72.25
166.5		29.16	62.32[ab]	8.53	0.47[ab]	24.85	48.35	12.69	1.0804	5.72	73.76
160.7		29.67	61.81[b]	8.52	0.48[a]	25.08	48.03	12.72	1.0801	5.91	72.54
	0.00	29.28	62.40	8.07	0.47	24.82	48.35	12.45	1.0806	5.68	71.81
	0.33	28.63	62.73	8.65	0.46	25.11	48.34	12.80	1.0801	5.72	73.77
	0.67	29.21	62.41	8.47	0.47	25.84	48.27	12.68	1.0803	5.96	74.04
	1.00	29.52	61.90	8.48	0.48	25.85	47.99	12.75	1.0800	5.77	71.78
Pooled SEM		0.58	0.61	0.56	0.01	0.28	0.44	0.17	0.0004	0.13	1.86
					-------------- Probability --------------						
Main effect and interaction											
Protein		0.0610	0.0488	NS	0.0492	NS	NS	NS	NS	NS	NS
Energy		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Protein×Energy		NS	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

and yolk/albumen ratio linearly decreased. Protein had no effect on percent whole egg solids, percent yolk solid, percent albumen solids, egg specific gravity, Haugh unit, or yolk color. Increasing dietary energy by the addition of poultry oil had no significant effect on percent yolk, percent albumen, percent shell, yolk/albumen ratio, percent whole egg solids, percent yolk solids, percent albumen solids, egg specific gravity, Haugh unit, or yolk color.

Discussion

There was no significant interaction between protein and dietary energy on feed intake, egg production, egg weight, egg mass, feed conversion, body weight of hens and mortality (Table 2). These results were in agreement with that of Wu *et al.* (2005d), who reported that there was no significant interaction on performance between protein and dietary energy in Hy-line W-36 hens. However, Sohail *et al.* (2003) reported there was an interaction on feed intake and feed conversion between dietary energy and protein. Increasing dietary energy by the addition of fat decreased feed consumption and improved feed efficiency at the two higher protein levels (198 and 187 g/kg) but not at the lower level (174 g/kg) (Sohail *et al.*, 2003). The differences among studies might be due to different energy spread between dietary energy levels in different protein levels. Dietary energy gap between dietary energy levels were the same at different protein levels in this experiment and the experiment of Wu *et al.* (2005d) while dietary energy spread between dietary energy levels at higher protein levels was bigger than that at lower protein levels in the experiment of Sohail *et al.* (2003).

Increasing dietary energy by the addition of poultry oil had no significant effect on egg production, egg weight, or egg mass (Table 2). Similarly, Harms *et al.* (2000), Wu *et al.* (2005 b, c, d, e) and Jalal *et al.* (2006) reported that there was no response of egg production, egg weight and egg mass to increasing dietary energy. Increasing dietary energy linearly decreased protein, TSAA and lysine intake per g egg, but had no significant effect on dietary energy intake per g egg (Table 3). This suggested that hens had the capability to linearly decrease feed intake as dietary energy level increased so that the similar quantities of dietary energy (0.022 to 0.023 MJ) was consumed to produce 1 g egg. Although nutrient intake such as protein and TSAA decreased as dietary energy increased, egg production, egg weight and egg mass did not decrease. Increasing fat content has an effect of slowing passage rate, which lead to increased digestibility of other nutrients such as protein and amino acids (Ewan, 1991). This effect is normally referred as the “extra caloric effect” of fat. Li and Sauer (1994) reported that apparent ileal digestibility of protein and amino acids improved as fat increased in young pigs. Similarly, Reginatto *et al.* (2000) concluded that increasing dietary energy improved protein utilization in broilers. Therefore, increasing dietary energy by the addition of poultry oil significantly improved nutrient (protein, lysine, or TSAA) utilization.

Feed intake can significantly affect the cost of production especially when feed price is high. Manipulating dietary energy by the addition of poultry oil is one of the methods to adjust feed intake. As added dietary energy increased from 0 to 158 kcal/kg, feed intake linearly decreased and feed conversion linearly improved. However, a further increase of added dietary energy from 0.67 to 1.00 MJ/kg had no additional effect on feed intake and feed conversion (Table 2). These results were in agreement with those of Wu *et al.* (2005b, c, d, e) and Grobas *et al.* (1999), who reported that increasing dietary energy linearly decreased feed intake and improved feed conversion. Based on feed intake and feed conversion, increasing 0.67 MJ/kg dietary energy by the addition of 33.5 g poultry oil/kg gave optimal performance in Hy-line W-36 hens from 40 to 51 wk of age.

As protein level increased from 160.7 to 173.9 g/kg, percent albumen linearly increased and yolk/albumen

Table 5: Influence of dietary energy and protein on profits[1,2] at different poultry oil prices from 40 to 51 wk of age

		Added dietary energy (MJ/kg)			
		0.00	0.33	0.67	1.00
			Returns[3]($/dozen)		
High poultry oil price ($0.40/kg)	173.9 g protein/kg	0.133	0.136	0.139	0.136
	166.5 g protein/kg	0.142	0.138	0.153	0.150
	160.7 g protein/kg	0.157	0.156	0.158	0.159
Low poultry oil price ($0.22/kg)	173.9 g protein/kg	0.133	0.141	0.143	0.155
	166.5 g protein/kg	0.142	0.151	0.158	0.157
	160.7 g protein/kg	0.157	0.168	0.162	0.165

[1]Corn price = $0.12/kg, soy price = $0.39/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]Urner Barry egg price: jumbo size = 105 cents, extra large size = 101 cents, large size = 97 cents, medium size = 75 cents and small size = 54 cents; [3]Returns (R) were 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)

ratio linearly decreased. Similarly, Shafer *et al.* (1998) and Novak *et al.* (2004) reported that increasing amino acids such as methionine and lysine significantly increased albumen weight or percent albumen. The results of this experiment, Shafer *et al.* (1998) and Novak *et al.* (2004) suggested that increasing protein or amino acids such as methionine and lysine significantly increased percent albumen or albumen weight, which was beneficial for liquid egg production.

The Economic Feeding and Management Program developed by Roland *et al.* (1998, 2000) was used to calculate profits at different dietary energy and protein levels at different poultry oil prices (Table 5). As protein level increased, profits decreased at four dietary energy levels, regardless of the poultry oil prices. As poultry oil price increased, profits decreased in all diets supplemented with poultry oil. When the poultry oil price was $0.20/kg and protein level was 173.9 g/kg, increasing 1.00 MJ/kg dietary energy by the addition of 50.4 g poultry oil/kg obtained the maximum profit. However, when the poultry oil price was 0.30/kg and protein level was 173.9 g/kg, increasing 0.67 MJ/kg dietary energy by the addition of 33.5 g poultry oil/kg obtained the maximum profit per dozen eggs. Because feed ingredient prices and egg price vary, there can be no fixed ideal dietary energy level for optimal profits during phase 2 (wk 40 to 51).

Conclusions: There was no significant interaction on all parameters between dietary energy and protein. Increasing protein had a significant effect on nutrient intake per g egg, percent albumen and yolk/albumen ratio, but had no effect on performance, egg solids, or egg quality. Hens had the capability to linearly decrease feed intake as dietary energy level increased so that the similar quantities of dietary energy (0.022 to 0.023 MJ/kg) was consumed to produce 1 g egg. Increasing dietary energy by the addition of poultry oil significantly improved nutrient (protein, lysine, or TSAA) utilization. As added dietary energy increased from 0.00 to 0.67 MJ/kg, feed intake linearly decreased and feed conversion linearly improved. However, a further increase of added dietary energy from 0.67 to 1.00 MJ/kg had no additional effect on feed intake and feed conversion. Based on feed intake and feed conversion, increasing 0.67 MJ/kg dietary energy by the addition of 33.5 g poultry oil/kg gave optimal performance in Hy-line W-36 hens from 40 to 51 wk of age. Because feed ingredient prices and egg price vary, there can be no fixed ideal dietary energy level for optimal profits during phase 2 (wk 40 to 51).

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