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Effect of Dietary Energy on Performance, Egg Components, Egg Solids, Egg Quality and Profits in Seven Commercial Leghorn Strains During Second Cycle Phase Two

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Abstract: This study was a 3 X 7 factorial arrangement with three dietary energy levels (low, medium and high) and seven commercial Leghorn strains. The objective of this experiment was to determine the effect of increasing dietary energy on performance, egg composition, egg solids, egg quality, and profits in seven commercial Leghorn strains during second cycle phase 2 (from 88 to 97 week of age). This experiment lasted 10 weeks. Seven strains of hens (n=245 of each strain) at 88 week of age were randomly divided into 21 treatments (6 replicates of 15 birds per treatment). Strain had a significant effect on feed intake, egg production, egg specific gravity, egg weight, percent whole egg solids, and haugh unit. There were no interactions between strain and dietary energy on any parameters during second cycle phase 2 (88 to 97 weeks of age). Dietary energy had no significant effect on any parameter. However as dietary energy increased, egg production, final body weight of hens, egg mass, egg yolk color and egg yolk weight numerically increased; moreover feed conversion numerically improved from 2.06 to 2.02, resulting in a 1.94% improvement of feed conversion. It is difficult to determine an ideal dietary energy level for the hens in second cycle phase 2 because increasing dietary energy had no significant effect on feed intake, egg mass and feed conversion. Because feed ingredient and egg price vary, there can be no fixed ideal dietary energy requirement for optimal profits.

Key words: Strains, nutrient density, dietary energy, lysine

INTRODUCTION

Protein and energy are the major nutrients of laying hens diets. As much as 85% of total costs of the diet come from protein and energy ingredients. Some studies showed that increasing dietary energy significantly decreased feed intake (Grobas *et al.*, 1999; Harms *et al.*, 2000; Bohnsack *et al.*, 2002; Wu *et al.*, 2005a,b) and improved feed conversion (Wu *et al.*, 2005b), but others have shown that there is no significant effect of dietary energy on feed intake (Summer and Leeson 1993; Jalal *et al.*, 2006).

Some earlier research indicated that increasing dietary energy significantly increased egg mass (Wu *et al.*, 2005b; Harms *et al.*, 2000) whereas other researchers indicated that there was no significant effect on egg mass (Wu *et al.*, 2005a; Summers and Leeson, 1993).

Many studies have shown that increasing dietary energy had no significant effect on egg weight (Jalal *et al.*, 2006; Summer *et al.*, 1993) or on egg production (Grobas *et al.*, 1999; Harms *et al.*, 2000). These results might be due to decreased nutrient (protein and amino acids) intake. As energy content increased in the diet, feed intake normally decreased, resulting in decreased nutrient (protein and amino acids) intake (Guangbing *et al.*, 2007). A better understanding of the effect of increasing dietary energy might help to maximize profits by optimizing egg weight and egg production.

Several commercial Leghorn strains are currently used by egg producers. However, each strain has different production characteristics, percent egg components, egg solids and quality (Wu *et al.*, 2005a,b), some strains may be beneficial for table egg production whereas others may be beneficial for liquid and dried egg processing. Few studies have been conducted to compare responses to dietary energy across strains.

There is little research on the effect of dietary energy on performance, egg components, egg solids, and egg quality in commercial leghorn strains. It is necessary to have a better understanding on how to optimize the use of dietary energy to get optimal performance and profits. Therefore the objective of this experiment was to determine the effect of dietary energy on performance, egg composition, egg solids, egg quality and profits in seven Leghorn strains during second cycle phase 2 (from 88 to 97 week of age).

MATERIALS AND METHODS

This study was a 3 X 7 factorial arrangement with three dietary energy levels (Low, medium and High) and seven commercial Leghorn strains. Ingredients and nutrient composition of experimental diets are shown in table 1.The dietary energy/lysine ratio (334 kcal/g) was maintained the same in three diets.

In this experiment, seven strains of hens (total n=1890)

Table 1: Ingredients and nutrient content of Experimental diets

Ingredient (%)	Diet 1	Diet 2	Diet 3
Corn (8.6%)	65.65	63.66	61.65
Soy bean meal (48%)	22.42	23.02	23.62
Hard shell[1]	4.00	4.00	4.00
Limestone	5.51	5.66	5.82
Dicalcium phosphate	1.50	1.54	1.58
Poultry oil	0.00	1.17	2.36
NaCl	0.36	0.37	0.38
Vitamin Premix[2]	0.25	0.25	0.25
Mineral Premix[3]	0.25	0.25	0.25
DL-Methionine	0.06	0.07	0.08
Total	100	100	100
Calculated analysis			
ME (Kcal/kg)	2,776	2820	2864
Crude protein	16.05	16.18	16.32
Ca	4.15	4.22	4.29
Available Phosphorus	0.39	0.39	0.39
Sodium	0.17	0.17	0.18
Methionine	0.33	0.34	0.35
Methionine + Cystine	0.62	0.63	0.64
Lysine	0.83	0.84	0.86
Dietary energy/Lysine ratio (ME/g)	334	334	334

[1]Hard shell = large particle limestone (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, 2,200ICU, vitamin E (as DL – α - tocopheryl acetate), 8 IU; vitamin B12, 0.02mg; riboflavin, 5.5mg; D-calcium pentothenic acid, 13mg; niacin, 36mg; choline, 500mg; folic acid, 0.5mg; vitamin B1(thiamin mononitrate), 1mg; pyridoxine, 2.2mg; biotin, 0.05mg; vitamin K (menadione sodium bisulfate complex), 2mg.

[3]Provided per kilogram of diet: manganese, 65mg; iodine,1mg; iron, 55mg;copper, 6mg;zinc, 55mg; selenium, 0.3mg.

at 88 weeks of age were randomly assigned into 21 treatments (6 replicates of 15 birds per treatment). Hy-line W-36, Dekalb, and several experimental Bovans strains were used in this trial. The trial lasted 10 weeks. Three hens were housed in a 40.6 X 45.7 cm cage, and 5 adjoining cages consisted of a replicate. Replicates were equally distributed into upper and lower cage levels to minimize cage level effect. All hens were housed in an environmentally controlled house with temperature maintained at approximately 26°C as possible.

The house had controlled ventilation and lighting (16L:8D). Hens were supplied with feed and water *ad libitum.* Animal housing and handling procedures during experimentation were in accordance with guidelines of Auburn University's Institutional Animal Care and Use Committee (IACUC). Feed consumption was recorded weekly for calculation of average daily feed consumption. Egg production was recorded daily, and egg weight and specific gravity were recorded once every two weeks. Egg weight and egg specific gravity were measured using all eggs produced during 2 consecutive days. Egg specific gravity was determined using 9 gradient saline solutions varying in specific gravity from 1.060 to 1.100 in 0.005 unit increments (Holder and Bradford, 1979). Mortality was determined daily, and feed consumption was adjusted accordingly. Body weight was obtained by randomly weighing three hens (1 of 5 cages) per replicate at the end of the experiment. Egg mass (g of egg/hen per day) and feed conversion (g of feed/g of egg) were calculated from egg production, egg weight, and feed consumption.

Egg components were measured using 3 randomly selected eggs from each treatment replicate at the middle and end of the experiment. Eggs were weighed and broken. The yolks were separated from the albumen. Before the yolk weight was determined, the chalaza was removed by forceps. Each yolk was rolled on a blotting paper towel to remove adhering albumen. The shells were cleaned of any adhering albumen and dried for 5 days. Albumen weight was calculated by subtracting the weight of yolk and shell from the whole egg weight.

Three eggs from each treatment replicate were randomly collected at the middle and at the end of the experiment for measuring solid. The yolk and albumen were mixed and 5 to 6g of homogenate was pipetted into aluminum dish with weight recorded to 0.001g. The sample was dried in an oven for 24h at 40.5°C (AOAC, 1990) and then weighed. Three eggs which randomly selected from each treatment replicate were used to analyze yolk and albumen solid. After yolk was separated from albumen, three yolks and albumen per treatment replicate were mixed separately. The procedure for analyzing albumen and yolk solid was the same as the procedure for whole egg solid content. Yolk color and haugh unit were measured (3 eggs from each treatment replicate) at the middle and at the end of the experiment using an egg multitester EMT-5200 (Robotmation, co, Ltd. Tokyo, Japan). Haugh unit was calculated from the records of albumen height and egg weight using formula: $HU=100\log_{10}(H-1.7W^{0.37}+7.56)$, where HU=Haugh unit, H=height of the albumen (mm) and W = egg weight (g).

Data were analyzed by ANOVA using proc mixed of statistical analysis system (SAS institute, 2000) for a randomized complete block with factorial arrangement of treatments. The factorial treatment arrangement consisted of three dietary energy levels and seven leghorn strains. Dietary energy and strains were fixed; whereas blocks were random, the following model was used to analyze the data:

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

Where Y_{ijk} = individual observation, μ = overall mean, α_i = dietary energy effect, β_j = strain effect, $(\alpha\beta)_{ij}$ = interaction between dietary energy and strain, P_k = effect of block, e_{ijk} = error component. 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= 0.05 was used for analysis.

Table 2: Effect of strain and dietary energy on performance of seven commercial white leghorns during second cycle phase 2 (88wk to 97wk of age)

Dietary energy	Strain	Feed intake (g/hen per day)	Egg production (%)	Egg specific gravity (Unit)	Body Weight (Kg)	Mortality (%)	Egg mass (g of egg/h per day)	Feed conversion (g of feed/ g of egg)	Egg weight (g)
Low		103.1	74.6	1.076	1.80	0.18	49.81	2.06	66.71
Medium		103.5	75.0	1.076	1.87	0.33	50.72	2.04	67.63
High		103.8	75.8	1.076	1.89	0.17	51.16	2.02	67.55
	Strain A	106.6^{a}	73.3^{bc}	1.077^{ab}	1.88	0.30	50.67	2.11	69.18^{a}
	Strain B	105.2^{ab}	77.6^{ab}	1.077^{a}	1.91	0.09	52.11	2.05	67.02^{b}
	Strain C	100.7^{c}	73.4^{bc}	1.076^{abc}	1.84	0.22	48.33	2.06	66.49^{b}
	Strain D	104.3^{ab}	79.0^{a}	1.075^{c}	1.89	0.13	52.44	1.99	66.36^{b}
	Strain E	102.4^{bc}	76.9^{ab}	1.077^{ab}	1.87	0.35	51.28	2.00	66.68^{b}
	Strain F	102.6^{bc}	70.4^{c}	1.075^{bc}	1.87	0.30	48.55	2.12	68.99^{a}
	Strain G	102.4^{bc}	75.4^{ab}	1.075^{c}	1.73	0.19	50.06	2.05	66.37^{b}
Pooled SEM		1.38	2.94	0.0091	0.048	0.17	2.13	0.07	0.86
		----------	----------	----------	----------	Probability	----------	----------	----------
Strain		0.0123	0.0083	0.0064	NS	NS	NS	NS	<0.0001
Dietary Energy		NS	NS	NS	NS	NS	NS	0.09	0.0935
Strain×Energy		0.0838	NS	NS	NS	NS	NS	NS	NS
Contrasts									
Energy Linear		NS	NS	NS	NS	NS	NS	NS	NS
Energy quadratic		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).

RESULTS AND DISCUSSION

There were no interactions between strain and dietary energy on all parameters during second cycle phase 2 (88 to 97 weeks of age). Strain had a significant effect on feed intake. There was no significant effect of dietary energy on feed intake, (Table 2). This result is inconsistent with that of Grobas *et al.* (1999), Keshavarz K. & Nakajima *et al.* (1995), Zou *et al.* (2005) and Wu *et al.* (2005a); this might be due to the smaller gap between dietary energy levels (approximately 44 kcal ME/kg) in this experiment, compared to that (approximately over 80 kcal ME/kg) of other experiments. Strain A had the highest feed consumption (106.6g/hen per day) whereas strain C was the lowest feed consuming strain (100.7g/hen per day).

Strain had a significant effect on egg production whereas dietary energy had no significant effect on egg production (Table 2). However, increasing dietary energy increased egg production numerically from 74.6 to 75.8% resulting in a 1.6% increase. This result was consistent with that of Wu *et al.* (2007), who reported that there was no significant effect of dietary energy on egg production. Strain D had the highest egg production (79.0%) and Strain F had the lowest egg production (70.4%).

Dietary energy had no significant effect on egg weight. However, dietary energy numerically increased egg weight from 66.71 to 67.55g, resulting in a 1.3% increase. Strain had a significant affect on egg weight (Table 2). Strain A had the highest egg weight (69.18g) whereas strain D had the lowest egg weight (66.36g). Result of dietary energy on egg weight of this study was inconsistent with that of Wu *et al.* (2007), who reported that there was a significant effect of dietary energy on egg weight. This may be due to the comparatively larger gap between dietary energy levels (2747, 2874, and 3002 kcal/kg ME). However, percent egg yolk did not increase with the increasing dietary energy (Table 3). This suggested that older hens as in this experiment may have the ability to synthesize sufficient lipoprotein. Thus, increasing dietary fat may not help to increase egg yolk weight in older hens.

Neither strain nor dietary energy had a significant effect on egg mass (Table 2). However, egg mass was numerically increased from 49.8 to 51.16 g of egg/hen per day. Similarly both strain and dietary energy had no significant effect on feed conversion (Table 2). However, as dietary energy increased, feed conversion numerically improved from 2.06 to 2.02, resulting in a 1.94% improvement of feed conversion. It is difficult to determine an ideal dietary energy for the hens in second cycle phase 2, because increasing nutrient density had no significant effect on feed intake, egg mass and feed conversion.

Strain significantly affected egg specific gravity (Table 2). Egg specific gravity ranged from 1.075 to 1.077. Dietary energy had no significant effect on egg specific gravity probably because egg weight did not significantly increase with increasing dietary energy.

Dietary energy had no significant effect on haugh unit (Table 3). However, As dietary energy increased, haugh unit numerically decreased from 73.72 to 73.16 units, this may be due to increased egg weight with increased dietary energy. Strain had a significant effect on haugh unit. Strain B had the highest quality eggs whereas strain E and F had the lowest. Increasing dietary energy had no effect on egg components, egg solids, egg quality and albumen, yolk, and shell weights in second cycle phase 2 (88 to 97 week of age). Wu *et al.* (2007) also reported that there was no significant effect of

Table 3: Effect of strain and dietary energy on egg components, egg solids, egg quality and albumen, yolk, shell weight of seven commercial white leghorns during second cycle phase 2 (88wk to 97wk of age)

Dietary energy	Strain	Egg components (%)			Egg solids (%)			Egg quality		Albumen, yolk, shell wt.(g)		
		Yolk	Albumen	Shell	Whole egg	Albumen	Yolk	Haugh Unit	Yolk color	Albumen	Yolk	Shell
Low		26.51	65.22	8.26	24.48	11.95	52.72	73.72	5.31	42.99	17.42	5.44
Medium		26.72	65.03	8.25	24.04	11.49	52.28	73.40	5.32	42.89	17.59	5.44
High		26.65	65.30	8.05	24.34	11.47	51.56	73.16	5.42	43.42	17.69	5.34
Strain												
	Strain A	26.90	64.76	8.33	23.49 [c]	12.04	52.46	73.06 [abc]	5.33	43.70	18.15	5.62
	Strain B	27.03	64.57	8.39	24.27 [abc]	11.46	52.20	77.22 [a]	5.19	42.00	17.59	5.46
	Strain C	27.32	64.60	8.08	24.89 [a]	11.57	53.02	72.64 [bc]	5.31	42.61	17.99	5.33
	Strain D	26.88	65.04	8.08	24.69 [ab]	11.58	51.36	73.06 [abc]	5.28	42.60	17.53	5.26
	Strain E	26.41	65.53	8.06	24.58 [ab]	11.47	52.19	69.57 [c]	5.42	42.55	17.06	5.21
	Strain F	25.44	66.46	8.10	24.06 [bc]	11.81	51.78	71.77 [c]	5.44	44.74	17.08	5.45
	Strain G	26.40	65.32	8.27	24.04 [bc]	11.55	52.30	76.69 [ab]	5.47	43.51	17.56	5.50
Pooled SEM		0.63	0.71	0.24	0.49	0.30	0.75	2.73	0.20	0.37	0.48	0.18
							Probability					
Strain		NS	NS	NS	0.0153	NS	NS	0.0112	NS	NS	NS	NS
Dietary Energy		NS	NS	NS	NS	0.06	NS	NS	NS	NS	0.06	NS
Strain×Energy		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Contrasts												
Energy Linear		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Energy quadratic		NS	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 (p = 0.05).

Table 4: Influence of dietary energy and poultry oil price on profits[1] from 88 to 97wk of age

		Nutrient density		
		Low	Medium	High
		Returns[4] ($/dozen)		
High poultry oil price ($ 0.40/kg)	High egg price[2]	0.368	0.362	0.355
	Low egg price[3]	0.220	0.214	0.208
Low poultry oil price ($ 0.22/kg)	High egg price	0.368	0.365	0.362
	Low egg price	0.220	0.218	0.215

[1]Corn price = \$0.12/kg, soy price = \$0.39/kg, $Caco_3$ = \$0.03/kg, hard shell = \$0.03/kg, Dicalcium phosphate = \$0.027/kg, salt = \$0.06/kg, vitamin premix = \$2.67/kg, mineral premix = \$0.59/kg, DL-methionine = \$2.59/kg.

[2]High Urner Berry egg price: jumbo size = 120 cents, extra large size = 117cents, large size = 112 cents, medium size = 75 cents and small size = 54 cents.

[3] Low Urner Berry egg price: jumbo size = 105 cents, extra large size = 101cents, large size = 97 cents, medium size = 75 cents and small size = 54 cents.

[4] Returns (R) were calculated using the equation R = UBEP – NR – PC – FdC, where UBEP = Urner Berry Egg Price, NR = nest run into package product delivered, PC = production cost and FdC = feed cost as described by Roland *et al.* (1998, 2000).

dietary energy on egg composition, shell weight, yolk and whole egg solids and yolk color during second cycle phase 1. Strain significantly affected whole egg solids. Strain C had the highest whole egg solids and strain A had the lowest whole egg solids.

The Econometric Feeding and Management Program developed by Roland *et al.* (1998, 2000) was used to calculate profits of different dietary energy levels at different poultry oil prices and egg prices (Table 4). When egg price was high, at both high and low poultry oil prices, maximum profit per dozen eggs was obtained in the hens fed low energy diets. Similarly, both at high and low poultry oil prices, equal profits (0.220 $/dozen) obtained in the hens fed low energy diets at low egg prices. Since feed ingredient prices and egg price vary, there can be no fixed ideal energy or a constant energy/lysine ratio for optimal profits during phase 2 (wk 88 to 97).

In conclusion, Strain had a significant effect on feed intake, egg production, egg specific gravity, egg weight, percent whole egg solids, and haugh unit. There were no interactions between strain and dietary energy on any parameters during second cycle phase 2 (88 to 97 weeks of age). Dietary energy had no significant effect on any parameter. However as dietary energy increased, egg production, final body weight of hens, egg mass, egg yolk color and egg yolk weight numerically increased; moreover feed conversion numerically improved from 2.06 to 2.02, resulting in a 1.94% improvement of feed conversion. It is difficult to determine an ideal dietary energy level for the hens in second cycle phase 2 because increasing dietary energy had no significant effect on feed intake, egg mass and feed conversion. Because feed ingredient and egg price vary, there can be no fixed ideal dietary energy requirement for optimal profits.

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