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Estimating energy utilization in laying hens: what are the best response criteria?

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Primary Audience: Nutritionists, Researchers

SUMMARY

An experiment was conducted to evaluate the effects of varying dietary energy on the performance and energy storage in laying hens from 36 to 52 wk of age. A total of 252 Hy-Line W-36 laying hens were housed in cages with 3 birds per cage and 12 replicate cages per treatment. Birds were control fed 1 of 7 experimental diets ranging in dietary energy from 2,750 to 3,050 kcal/kg with a 50 kcal/kg difference among each of the diets. Egg production, energy intake, feed intake, egg weight, egg mass, and feed efficiency were calculated every 2 wk so that performance data could be analyzed every 2 wk using repeated measures analysis. Hens were weighed every 4 wk for repeated measures analysis and carcass total, lean, and fat mass were determined at 52 wk using dual X-ray absorptiometry. Correlations between dietary energy and energy intake with performance parameters, and body composition were generated. Dietary energy (kcal/kg) was significantly correlated with all performance parameters except hen housed egg production (**HHEP**; $P = 0.07$) and lean carcass mass ($P = 0.60$). For dietary energy, the highest correlations were total carcass mass ($r = 0.60$) and carcass fat mass ($r = 0.54$). Energy intake (kcal/d) was significantly correlated with all performance parameters except feed intake ($P = 0.18$). The highest correlations were between energy intake and total carcass mass ($r = 0.63$) or body weight ($r = 0.51$). These results suggest that dietary energy has a more pronounced effect on body mass and fatty tissue over the short run (16-wk period) before direct performance responses are observed. Therefore, hen body weight and composition can be used as a more sensitive measurement of shorter-term hen energy status than egg production or feed efficiency.

Key words: body composition, energy intake, fat mass, egg production, laying hen

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DESCRIPTION OF PROBLEM

In laying hens, energy is partitioned between maintenance, production, and storage (Murugesan and Persia, 2013). Energy recommendations vary based on strain, age, breed, among other factors (Classen, 2017). In previous research, feed intake (**FI**) and egg production parameters are the most common response criteria that researchers have used to measure energy utilization in poultry (Wu et al., 2005). Previous work has suggested that laying hens will adjust FI when consuming diets differing in dietary energy content in an attempt to maintain a constant intake of energy (Carew et al., 1980; Wu et

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al., 2005). These responses are dependent on amount (3,078 kcal/kg) and range (280 kcal/kg difference) of dietary energy as laying hens only reduced FI ($P \leq 0.05$) in diets that contained 3,078 kcal/kg but did not alter feed intake when 2,519 or 2,798 kcal/kg were offered (Harms et al., 2000). When smaller differences (90 kcal/kg) in dietary energy were provided there were no differences in FI ($P = 0.32$) or egg mass (**EM**; $P = 0.10$) across 4 strains of commercial laying hens fed 2,810 and 2,900 kcal/kg of ME (Jalal et al., 2007). The difficulty in quantifying egg production differences with smaller differences in dietary energy has been noted in more recent experiments (Murugesan and Persia, 2013; Bobeck et al., 2014). Egg production may not be the most sensitive or an adequate response criterion to validate small dietary energy differences, especially over a short period of time.

Other response criteria, such as body weight and composition, might provide a more sensitive response criteria in laying hens fed various dietary energy concentrations (Murugesan and Persia, 2013). Diets with 2,790 and 2,880 kcal/kg were fed to Hy-Line W-36 hens for a 12-wk period and reduced fat pad weight in hens fed the lower energy diet ($P = 0.03$; Murugesan and Persia, 2013). Therefore, the objective of the current experiment was to evaluate the effects of dietary energy concentration on hen housed egg production (**HHEP**), EM, egg weight (**EW**), FI, FE, energy intake (**EI**), BW, and body composition in caged first cycle laying hens from 36 to 52 wk and to correlate these responses with feed and energy intake to determine the most efficient response criteria for dietary energy.

MATERIALS AND METHODS

Experimental Design

All animal procedures used in the experiment were approved by the Virginia Tech Animal Care and Use Committee. A total of 252 Hy-Line W-36 laying hens were housed in cages (465 cm^2/bird) with 12 replicate cages per treatment and 3 birds per cage. Two weeks before the start of the experiment, all hens were placed on a common peaking diet. When hens reached 36 wk of age, they were provided experimental dietary treatments and hens were allotted to have no difference in initial egg production or BW among treatment groups. The experiment was a randomized complete block design with the experimental unit being 1 cage of 3 birds. Hens were control-fed 97 g of feed daily from 36 to 52 wk to align with guide recommendations (Hy-Line Management Guide). Experimental diets were randomly assigned to cages within the established blocks. The lighting program was maintained at 16L:8D for the duration of the experiment. Each experimental unit received 1 of 7 dietary treatments varying in ME: 2,750 kcal/kg, 2,800 kcal/kg, 2,850 kcal/kg, 2,900 kcal/kg, 2,950 kcal/kg, 3,000 kcal/kg, or 3,050 kcal/kg of ME (Table 1). Dietary energy was adjusted using soybean oil as the primary energy source. Wheat middlings and acid insoluble ash were added to the diets to minimize differences in dietary fat content in an attempt to reduce differences in passage rate (Poorghasemi et al., 2013).

Performance and Production

Feed intake, EI, HHEP, EW, EM, and FE were calculated every 2 wk over the entire 16-wk experimental period to justify the repeated measures analysis. Feed intake was determined by weighing the remaining feed at the end of the 2-wk period and subtracting it from the weight of all feed added. Old feed was discarded and the new diet was then weighed and added to the respective cage. Energy intake was calculated on a pen basis and expressed on an individual bird basis by multiplying dietary energy × FI. Eggs were collected and weighed daily to determine HHEP and EW. Egg mass was calculated by multiplying HHEP × EW. Feed efficiency (**FE**) was determined by dividing EM by kg of feed consumed. Initial BW of the hens was measured at 36 wk and then every 4 wk (for repeated measures analysis) throughout the experimental period rather than every 2 wk which could increase stress on the birds.

Dual-Energy X-Ray Absorptiometry

At 52 wk, all hens were weighed and then transported to the processing facility at Virginia Tech. All hens were euthanized via cervical

Table 1. Composition of experimental diets fed to Hy-Line W-36 laying hens from 36 to 52 wk of age.

Ingredients	2,750 (kcal/kg)	2,800 (kcal/kg)	2,850 (kcal/kg)	2,900 (kcal/kg)	2,950 (kcal/kg)	3,000 (kcal/kg)	3,050 (kcal/kg)
	(%)						
Corn[1]	52.06	51.94	53.26	53.63	54.92	55.74	57.98
Soybean meal (48% CP)[2]	19.35	19.37	19.36	19.50	19.88	19.75	19.98
DDGS[3]	3.00	3.00	2.50	2.50	2.00	1.50	0.50
Poultry by-product meal[4]	3.00	3.00	3.50	3.50	3.50	4.00	4.50
Wheat middlings[5]	5.00	5.00	4.00	3.50	2.50	2.00	0.50
Soybean oil	2.87	3.49	3.74	4.23	4.54	4.91	4.98
Acid insoluble ash	3.00	2.50	2.00	1.50	1.00	0.50	0.00
Limestone, small particle	4.71	4.71	4.70	4.70	4.69	4.69	4.67
Limestone, large particle	4.71	4.71	4.70	4.70	4.69	4.69	4.67
Dicalcium phosphate	1.10	1.10	1.08	1.08	1.09	1.07	1.05
Sodium chloride	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Sodium bicarbonate	0.15	0.15	0.15	0.15	0.15	0.15	0.15
DL-methionine	0.16	0.17	0.16	0.16	0.16	0.16	0.16
L-lysine·HCl	0.02	0.02	0.01	0.01	0.00	0.00	0.00
Choline chloride (60%)	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Vitamin and mineral premix[6]	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Calculated nutrients							
Metabolizable energy (kcal/kg)	2,750	2,800	2,850	2,900	2,950	3,000	3,050
Crude protein (CP)	17.13	17.13	17.22	17.25	17.25	17.33	17.41
Crude fat (CF)	5.92	6.50	6.77	7.24	7.50	7.89	7.96
Calcium	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Nonphytate phosphorous	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Crude fiber	2.53	2.52	2.45	2.43	2.37	2.32	2.21
Digestible Met + Cys	0.66	0.66	0.66	0.66	0.66	0.66	0.66
Digestible Lys	0.79	0.79	0.79	0.79	0.79	0.79	0.81
Digestible Trp	0.17	0.17	0.17	0.17	0.17	0.17	0.17
Digestible Thr	0.58	0.58	0.59	0.59	0.59	0.59	0.60
Digestible Val	0.72	0.72	0.72	0.72	0.72	0.72	0.73
Analyzed nutrients							
Crude protein	17.00	15.60	17.90	17.50	16.90	17.10	18.00
Gross energy (kcal/kg)	3,040	3,080	3,181	3,282	3,247	3,262	3,334
Crude fat	3.72	3.86	5.00	5.47	5.34	5.97	6.51

[1]Corn was formulated with 8.3% CP, 1.9% CF, and 3,350 kcal/kg metabolizable energy (ME).

[2]Soybean meal was formulated with 48.2% CP, 1.2% CF, and 2,550 kcal/kg ME.

[3]Dried distiller's grains with solubles were formulated with 27.0% CP, 9.0% CF, and 2,400 kcal/kg ME.

[4]Poultry by-product meal was formulated with 57.7% CP, 13.0% CF, and 2,950 kcal/kg ME.

[5]Wheat middlings was formulated with 15.7% CP, 4.0% CF, and 1,850 kcal/kg ME.

[6]Supplied the following per kg diet at a 0.50% inclusion rate: vitamin A, 4,403 IU; vitamin D3, 1,457 IU; vitamin E, 1.10 IU; menadione, 0.77 mg; vitamin B12, 4.40 μg; choline, 254.79 mg; niacin, 13.21 mg; pantothenic acid, 4.05 mg; riboflavin, 2.75 mg; Cu, 2.70 mg; Fe, 33.75 mg; I, 0.67 mg; Mn, 42.90 mg; Zn, 32.50 mg; Co, 0.17 mg.

dislocation, scalded for 50 s in 62°C water (Brower, Houghton, IA, model #AM48, serial # 0526) and plucked using rubber fingers for 60 s (Ashley Machine Company, Greenburg, IN) to remove feathers. Birds were defeathered to ensure accuracy of the dual-energy X-ray absorptiometry (**DXA**) scan. After the scalding and defeathering, DXA scans using a Lunar Prodigy machine were conducted to determine body composition (GE Lunar, GE Healthcare, Waukesha, WI). The Lunar Prodigy machine was calibrated with a quality assurance block before the instrument was used. The DXA analysis included total mass, fat mass, and lean mass of the hens, all of which are calculated based on 2 X-ray beams of different energy levels (Schallier et al., 2019). The total carcass mass is the sum of lean and fat mass and also includes bone mass.

Chemical Analyses

Experimental diets were analyzed for gross energy, crude protein, and crude fat (Table 1). The gross energy of the diet was determined using a Parr 6400 bomb calorimeter (Parr Instrument Company, Moline, IL). Crude protein analysis was determined using the Elementar Vario EL cube (Elementar Americas Inc., Ronkonkoma, NY). Crude fat was determined by ether extraction (Nancy J. Thiex, Shirley Anderson, and Bryan Gildemeister, 2006).

Statistical Analysis

Performance data were analyzed by the MIXED procedure of SAS 9.4 using a repeated measures model (SAS Institute Inc., Cary, NC; Wen et al., 2019). Means were further separated using Tukey's HSD test when $P \leq 0.05$. Data from DXA analysis, including carcass fatty tissue and lean mass, were analyzed using the GLM procedure in SAS 9.4 (SAS Institute Inc., Cary, NC). Feed intake was used as a covariate for all DXA measurements as feed intake was not consistent over the feeding period. Body composition means were further separated using Fisher's LSD test when $P \leq 0.05$. Linear and quadratic contrasts were conducted on all performance and body composition data using JMP Pro 16.0 (SAS Institute Inc., Cary, NC). Correlations between energy intake and dietary energy for hen's performance and body composition were completed using JMP Pro 16.0 (SAS Institute Inc., Cary, NC; Schallier et al., 2019). Significance was accepted at $P \leq 0.05$.

RESULTS AND DISCUSSION

Performance and Production

No difference in egg production was observed among treatment groups the 2 wk prior to initiation of the experiment (P = 0.97; Pooled SEM = 2.94) and ranged from 88.2 to 92.4%. Initial BW of hens was not different among treatment groups and ranged from 1.530 to 1.573 kg/bird (P = 0.70; Pooled SEM = 0.019). Crude fat in the diets ranged from 5.92% in the low energy diet (2,750 kcal/kg of ME) to 7.96% in the high energy diet (3,050 kcal/kg of ME; Table 1). Gross energy of the diets was 3,040 kcal/kg in the low energy diet (2,750 kcal/kg of ME) and 3,334 kcal/kg in the high energy diet (3,050 kcal/kg of ME; Table 1).

Over the entire experimental period, there were no differences in HHEP (P = 0.09; 87.8 to 91.7%) or EM (P = 0.11; 52.9 to 55.1 g/d) among treatments when repeated measures were used (Table 2). However, there was a significant linear response for EM over the period and EM increased with increasing dietary energy. Previous research reported no differences in egg production when laying hens were fed diets varying in dietary energy (Carew et al., 1980; Scheideler et al., 2005; Jalal et al., 2007). Scheideler et al. (2005) fed Babcock B-300 and Hy-Line W-36 laying hens 2,805 or 2,890 kcal/kg of ME with no differences in egg production from 25 to 40 wk of age ($P > 0.05$), regardless of strain. There was no effect of dietary energy on egg production from 38 to 60 wk of age when Bovans White Leghorn laying hens consumed the breeder recommended dietary ME or a 3% ME reduction (Novak et al., 2008). Recent research from Granghelli et al. (2019) also reported no differences in egg production from 20 to 48 wk of age when Novogen White laying hens consumed diets ranging in energy from 2,600 to 3,000 kcal/kg of ME. It is important to note that few current experiments

Table 2. Effects of varying dietary energy levels on performance parameters of Hy-Line W-36 laying hens from 36 to 52 wk of age[1].

Dietary energy (kcal/kg)	HHEP[2] (%)	Egg weight (g)	Egg mass (g/d)	Feed intake (g/d)	Feed efficiency (g egg/kg)	Energy intake (kcal/d)
2,750	89.4	59.2[c]	52.9	96.8[ab]	546[b]	266.1[g]
2,800	87.8	60.4[a]	53.0	96.6[abc]	548[b]	270.5[f]
2,850	90.7	60.3[a]	54.6	96.8[a]	564[a]	275.9[e]
2,900	91.7	59.3[bc]	54.4	96.2[abc]	565[a]	279.0[d]
2,950	89.5	60.1[a]	53.8	96.2[abc]	559[ab]	283.7[c]
3,000	91.0	59.9[ab]	54.5	95.6[c]	568[a]	287.6[b]
3,050	91.6	60.1[ab]	55.1	96.0[bc]	573[a]	292.7[a]
Pooled SEM	1.05	0.18	0.63	0.21	6	0.61
				P value		
Treatment[3]	0.09	≤0.01	0.11	0.02	0.02	≤0.01
Linear[4]	0.07	0.46	0.02	0.02	0.02	≤0.01
Quadratic[4]	0.83	0.65	0.66	0.96	0.63	0.92

[1]Data are means of 12 groups of 3 Hy-Line W-36 laying hens from 36 to 52 wk of age. Initial body weight: 1,556 g ($P = 0.70$; SEM: 19) and initial egg production: 90.6% ($P = 0.97$; SEM: 2.94).

[2]Hen housed egg production and hen-day egg production were equal as there was no mortality.

[3]Repeated measures *P* value for Week: ≤0.01; Trt × Week: 0.99.

[4]Linear and quadratic contrasts were conducted to further evaluate treatment effects.

[a−g]Means within a column that do not share a common superscript differ ($P \leq 0.05$).

examine the longer-term effects of dietary energy on egg production. In the current short-term experiment, it does appear that egg-laying hens continue to lay eggs when consuming diets with various dietary energy concentrations over the short term, suggesting that egg production may not be a sensitive response criterion when measuring the effects of dietary energy from 36 to 52 wk of age.

Egg weights in the current experiment (36−52 wk of age) ranged from 59.2 to 60.6 g and hens fed diets with 2,750 and 2,900 kcal/kg had the lowest EW in comparison to other treatments ($P \leq 0.01$; Table 2). Although the 2,750 kcal/kg fed hens resulted in the lowest EW, these eggs were not different than those produced from hens fed 2,900 kcal/kg. Egg weights in previous experiments with laying hens fed varying dietary energy levels ranged from 58.7 to 59.2 g and 56.8 to 57.0 g with no differences (Scheideler et al., 2005; Murugesan and Persia, 2013). The lack of clear pattern over the increasing dietary energy concentrations and the lack of support in previous literature suggest that EWs are not a sensitive measurement of dietary energy at least over short-term responses to dietary energy.

Hens were control fed 97 g of feed daily, but increasing dietary energy resulted in a linear decrease in FI. This observation is supported by previous work which found that birds reduced FI when fed diets with a 419 or 585 kcal/kg increase in energy over a 48- or 52-wk period, respectively (Hill et al., 1956; Carew et al., 1980). However, when Hy-Line W-36 laying hens were fed diets with a 280 kcal/kg energy difference over an 8-wk period, no differences in FI were observed (Harms et al., 2000). Similarly, no difference in FI was observed when Hy-Line W-36 hens were fed 2,790 or 2,880 kcal/kg of ME over a 12-wk period ($P > 0.05$; Murugesan and Persia, 2013). The current experiment utilized repeated measures analysis which can measure smaller differences in feed intake over time and a 1.2 g difference in daily feed intake was significant. Larger differences in dietary energy seem to have a greater effect on feed intake in laying hens over a 16-wk period compared to smaller dietary energy differences. Energy intake increased linearly with increasing dietary energy with values ranging from 266.1 to 292.7 kcal/d of ME ($P \leq 0.01$). Hens fed the highest energy diet demonstrated a 9.1% increase in EI compared to those consuming the lowest energy diet. These results are supported by previous research which reported a higher hen EI with 3,078 kcal/kg diets compared to 2,519 or 2,798 kcal/kg (Harms et al., 2000). There was a significant linear increase in FE as dietary energy increased over the experimental period (Table 2). Hens fed 3,050 kcal/kg resulted in a 5% increase in FE in comparison to hens fed 2,750 kcal/kg. It is important to note that although hens were control fed 97 g of feed daily, hens consuming the higher energy diets did demonstrate a reduction in FI, resulting in the improved FE. Data from past research and the current experiment suggest that a 300 kcal/kg reduction in dietary energy does not affect short-term egg production of Hy-Line W-36 laying hens. However, performance parameters such as BW, FI, and FE can be influenced by changes in dietary energy from 36 to 52 wk of age.

Body Weight and Composition

At 52 wk of age, there was a significant linear increase in BW with hens fed the highest energy diet having a 112 g increase in BW compared to the lowest energy diet (Table 3). Murugesan and Persia (2013) fed 2 diets with 90 kcal/kg difference in dietary ME and reported no differences in the BW of Hy-Line W-36 laying hens over a 12-wk period. As with feed intake, these data suggest that larger differences in dietary ME may be needed to alter laying hen body weight over a shorter time period. A positive linear response was observed in BWG ($P \leq 0.01$; Table 3) and the hens fed the lowest energy diet gained 41.0 g/bird over the experimental period whereas birds fed the highest energy diet gained 156.7 g/bird. All other treatments were intermediate in BWG. Previous work with Hy-Line Brown laying hens over a 35-wk period demonstrated a positive linear response in BWG when birds were fed diets ranging in dietary AME_n from 2,650 to 2,950 kcal/kg (Perez-Bonilla et al., 2012). Body weight and weight gain appear to be a more sensitive measurement for laying hen energy status rather than egg production when measured over the short term. Laying hens fed low energy diets will continue to produce eggs at the expense of body energy reserves over a 16-wk period while hens fed high energy diets will continue to produce eggs and store the excess energy in the body.

As expected, there was a significant linear increase in total carcass mass of laying hens fed increasing concentrations of dietary energy, similar to hen BW (Table 3). There was no difference among treatments in carcass lean mass of the birds ($P = 0.40$). However, even with the decreased FI observed in hens fed the higher energy diets, there was a positive linear response in carcass fat mass as dietary energy increased ($P \leq 0.01$). When comparing the hens fed 2,750 kcal/kg to those fed 3,050 kcal/kg,

Table 3. Effects of varying dietary energy levels on body weight, body weight gain, total mass, fat mass, and lean mass of Hy-Line W-36 laying hens from 36 to 52 wk of age[1].

Dietary energy (kcal/kg)	BW[2] (g/bird)[4]	BWG (g/bird)	Total mass[3] (g/bird)	Fat mass (g/bird)	Lean mass (g/bird)
2,750	1,560[e]	41[c]	1,449[d]	292[d]	1,164
2,800	1,591[de]	90[bc]	1,499[c]	339[cd]	1,165
2,850	1,627[bc]	108[ab]	1,550[b]	409[ab]	1,150
2,900	1,630[bc]	115[ab]	1,555[b]	375[bc]	1,177
2,950	1,612[cd]	137[ab]	1,534[bc]	379[bc]	1,149
3,000	1,656[ab]	132[ab]	1,580[ab]	420[ab]	1,150
3,050	1,672[a]	157[a]	1,624[a]	429[a]	1,188
Pooled SEM	8	18	17	18	15
			P value		
Treatment	≤0.01	≤0.01	≤0.01	≤0.01	0.40
Linear[5]	≤0.01	≤0.01	≤0.01	≤0.01	0.60
Quadratic[5]	0.40	0.22	0.49	0.12	0.25

[1]Means presented in the table are the average of 12 replicates per treatment.

[2]BW measurement was based on a repeated measures every 4 wk throughout the experimental period.

[3]Total mass is the weight of the bird without feathers.

[4]Repeated measures BW *P* value for Week: ≤0.01; Trt × Week: 0.98.

[5]Linear and quadratic contrasts were conducted to further evaluate treatment effects.

[a–e]Means within a column that do not share a common superscript differ ($P \leq 0.05$).

hens consuming the high energy diet demonstrated a 33% increase in fat mass. In agreement with these data, Hy-Line W-36 laying hens fed diets containing 2,880 kcal/kg of ME resulted in hens that had an increased abdominal fat pad weight, in comparison to hens fed 2,790 kcal/kg of ME ($P = 0.03$; Murugesan and Persia, 2013). Similarly, a 9% reduction in carcass fat was reported when Hy-Line W-36 laying hens consumed a diet with 2,746 kcal/kg of ME compared to 2,900 kcal/kg of ME ($P \leq 0.01$) with no differences in egg production (Bobeck et al., 2014). Body composition plays an important role in laying hens because excess body fat may lead to a drop in egg production (Sun and Coon, 2005). A negative correlation was reported between body weight and hen day egg production when measured from onset of production to 53 wk of age (McDaniel and Brake, 1981). However, the current data and previous experiments suggest that over the short term, laying hens continue to produce eggs at the expense of their energy body reserves (Murugesan and Persia, 2013; Bobeck et al., 2014). Over the long term, it would be expected that the loss of body fat reserves and body weight would reduce egg production. Although additional laying hen data on body composition are sparse, this observation was also shown in commercial broiler breeders by Sun and Coon (2005). These authors reported increased carcass fat in breeders fed 2,970 kcal/kg compared to those fed 2,816 kcal/kg of ME, again no differences in egg production ($P > 0.05$) over a 42-wk experiment. Hubbard breeder pullets fed a high energy diet (3,080 kcal/kg of ME) resulted in a higher body fat content relative to those fed 2,550 kcal/kg of ME (Bennet and Leeson, 1990). The current experiment and past research suggest that carcass fat tissue may be more sensitive to changes in dietary energy over a 16-wk period than egg production.

Correlations

There were significant correlations between EI and all other parameters except FI (Table 4). The highest correlations were observed between EI and total mass ($r = 0.63$), BW ($r = 0.51$), and fat mass ($r = 0.47$). Although the correlations between EI and HHEP ($r = 0.38$), EM ($r = 0.41$), FE ($r = 0.38$), and lean mass ($r = 0.21$) were significant, these were lower than the correlations between EI and total mass, BW or fat mass. The correlations between dietary energy concentration and all other response criteria were significant, except for HHEP and lean mass (Table 4). The highest correlations were observed between dietary energy and total mass ($r = 0.60$), fat mass ($r = 0.54$), and BW ($r = 0.47$). The correlations between dietary energy and FE ($r = 0.33$), feed intake ($r = -0.25$), and EM ($r = 0.25$) were lower. In carcass fat mass, a stronger correlation is observed with dietary energy ($r = 0.54$) compared to EI ($r = 0.47$). This reduction in the relationship with carcass fat mass between dietary energy and EI is most likely a result of EI correcting for reduced FI in the higher energy diets. This response was also noted with EM, FE, and BW. As expected, there was a negative correlation between dietary energy and FI

Table 4. Correlation coefficients (r) between energy intake, dietary energy, performance parameters, and body composition.[1]

Parameter	HHEP[2] (%)	Egg mass (g/d)	Feed intake (g/bird)	Feed efficiency (g egg/kg)	BW[3] (g/bird)	Total mass (g/bird)	Fat mass (g/bird)	Lean mass (g/bird)
Dietary energy (kcal/kg)	0.20[4]	0.25	−0.25	0.33	0.47	0.60	0.54	0.06
	(0.07)[5]	(0.02)	(0.02)	(≤0.01)	(≤0.01)	(≤0.01)	(≤0.01)	(0.60)
Energy intake (kcal/d)	0.38	0.41	0.15	0.38	0.51	0.63	0.47	0.21
	(≤0.01)	(≤0.01)	(0.18)	(≤0.01)	(≤0.01)	(≤0.01)	(≤0.01)	(0.05)

[1]Correlations were conducted based on 12 replicates per treatment.

[2]Hen housed egg production and hen-day egg production were equal as there was no mortality.

[3]BW measurement was based on repeated measures every 4 wk throughout the experimental period.

[4]Correlation coefficient (r) for each parameter is the top number.

[5]P value ($P =$) for each correlation.

($r = -0.25$), which was reflected in the reduced FI for birds fed the higher energy diets despite being control fed. The strongest correlations were observed between body weight, total mass, and fat mass compared to all other response criteria, indicating that these criteria are the most reliable response criteria when considering short-term laying hen energy status. Although these responses produced the strongest correlations, energy status is a complex response and dietary energy or energy intake only predict about 50 to 60% of the body weight, total mass, or fat mass in laying hens over short-term production periods.

CONCLUSIONS AND APPLICATIONS

1. A 300 kcal/kg difference in dietary energy (2,750−3,050 kcal/kg) does not affect short-term (36−52 wk of age) egg production in Hy-Line W-36 laying hens.
2. Although egg production was unaffected, total mass, body weight, and fat mass were significantly decreased with decreasing dietary energy and were directly correlated with dietary energy, indicating that hens will continue to produce eggs at the expense of energy body reserves over short-term production.

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DISCLOSURES

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