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Performance Comparison and Lysine Requirements of Seven Commercial Brown Egg Layer Strains During Phase One

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Abstract: This study was a 3 × 7 factorial arrangement of 3 lysine levels (0.917, 0.828 and 0.747) and seven commercial brown egg layer strains. The objective of this experiment was to determine the effect of increasing dietary lysine on performance, egg composition, egg solids, egg quality and profits in seven commercial brown egg layer strains and to determine the lysine requirement during phase one (from 21-36wk of age). This experiment lasted 16 weeks. Seven strains of hens (n = 240 of each strain) at 21 week of age were randomly divided into 21 treatments (8 replicates of 10 birds/treatment). The results showed that there were no interactions between lysine and strain on any parameter. Lysine had significant effects on egg weight, egg mass, feed conversion, percent albumen solids, yolk color, shell color, albumen weight, egg shell and albumen components. There were significant strain effects on egg production, feed consumption, egg weight, egg mass, feed conversion, specific gravity, yolk weight, shell color, shell, albumen and yolk components, yolk, albumen and whole egg solids. Strain 1 had the best overall performance. All strains peaked in production over 94% and were laying 94-96% at 36 weeks of age. Average egg weight (21-36wk) was 60.3g, varying from 59.0-62.8g between strains. Average feed intake was 112.3g/hen/day varying from 109.6-116.7g/hen/day between strains. Average egg weight of hens fed diets containing the highest lysine level was 2.04g heavier than the hens fed the diets containing the lowest lysine level. Increasing dietary lysine from 0.747-0.917% significantly improved feed conversion from 2.20-2.06g feed/g egg and increased egg mass from 51.8-54.32g/hen/day. Average lysine intake of hens fed 0.917% level was 1023mg/hen/day varying from 1005-1070mg/hen/day between strains. Because egg prices and ingredient prices often change, there can be no fixed dietary lysine level for optimal profits.

Key words: Brown layer Strain, lysine requirement, shell color

Introduction

Brown-egg-laying hens predominate in many parts of the world, and their use is rapidly growing in the USA and other South American countries as well. Different brown strains have different production characteristics, egg components, egg solids, and egg quality (Wu *et al.*, 2008). Some strains may be beneficial for further procession such as dried and liquid egg production where as some strains may be beneficial for table egg production. Several commercial Brown-egg-layer strains are currently used by egg producers.

Protein (lysine) is the major nutrient representing a high percentage of total cost of the diets. Liu *et al.* (2005) and Wu *et al.* (2007a) reported that increasing Protein (lysine) level significantly improved egg production, egg weight; egg mass, feed consumption, feed conversion, egg specific gravity and body weight of hens. As hens age, the nutrient requirement decreases (Sell *et al.*, 1987 and Wu *et al.*, 2005). If the nutrient contents of diets fed to old hens are the same as that of diets fed to young hens, some of nutrients may be wasted and cost of production may increase. It is important for commercial leghorn industry to know the lysine requirement, variation in strain performance, and if there are any interaction between strain and lysine on performance. Hens are normally fed lysine ranging from 0.828-0.956% during phase one. Current high cost of protein (lysine), emphasize the need to know the lysine requirement for optimal performance and profits. However very few studies have been conducted to determine the lysine requirement across brown egg layer strains during phase one.

Egg quality has become an important aspect of egg marketing as retail outlets are now demanding high standards for conventional internal and external quality characteristics. Throughout the world, preference for shell color in table eggs differs and is based mainly on the visual appearance of the egg. Although shell color has little to do with the nutritional value of a table egg, uniformity of color of brown eggs, together with a certain minimum depth of color are important considerations for consumers. Pale-shelled eggs are often deemed unacceptable causing some highly productive strains to be rejected. Egg shell color between strains has received very limited or no research attention (Odabasi *et al.*, 2007).

Even though brown egg laying hens are not used for liquid and breaker egg industry, there may be a potential of using them in future. Increasing amino acids such as methionine and lysine significantly increase percent albumen in Hy-line W-36 hens during phase 1 (Shafer *et al.,* 1998 and Novak *et al.,* 2004). It might be beneficial for the egg processing industry to know how to manipulate dietary lysine to improve liquid egg and dried egg production. There are very few if any studies available on the effect of dietary lysine on egg composition and egg solids of brown egg layers.

Technological advances in genetics, management, animal health and behavior have allowed laying hens to have better feed efficiency, larger egg size and longer persistence of production. Thus it is necessary to conduct research in nutritional requirement determination and in optimization of the use of nutrients, so that laying hens can have the maximum genetic potential expression (William *et al.,* 2005). Therefore the objective of this experiment was to determine the effect of increasing dietary lysine on performance, egg composition, egg solids, egg quality, in seven commercial brown egg layer strains and to determine the nutrient (lysine) requirements that allow for the best performance in phase one (from 21-36wk of age).

Materials and Methods

This study was a 3 x 7 factorial arrangement with three dietary lysine levels (0.917, 0.828 and 0.747) and seven commercial brown egg layer strains. The seven brown commercial or experimental egg laying strains (obtained from Centurion poultry Inc.[1]) were identified as strain 1-7. Strain 5 was the Bovans Brown classic. Ingredients and nutrient composition of experimental diets are shown in Table 1. Feed and feed ingredient samples were analyzed for amino acids[2]. Dietary energy (2840MEkcal/kg) was maintained the same in all diets. Energy and lysine levels of experimental diets were determined to meet the minimum nutrients requirements specified by (NRC, 1994). In this experiment, seven brown egg laying strains (total n = 1680) at 21 week of age were randomly assigned into 21 treatments (8 replicates of 10 hens per treatment). The trial lasted 16 weeks. Hens were housed two per cage in a 40.6 x 45.7cm cage. Each replicate consisted of five adjoining cages. 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 as close to 26^{0}C as possible. Pullets were housed at 18 week of age. Light was increased by 15 minutes per week from 12 hours per day to 16 hours per day. The house had controlled ventilation and lighting (16h/d). All 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 and calculated 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. Feed consumption was determined by subtracting the ending feed weight of each trough (each replicate) from beginning feed weight weekly. Egg specific gravity was determined using 9 gradient saline solutions varying in specific gravity from 1.060-1.100 in 0.005 unit increments (Holder and Bradford, 1979). Mortality was determined daily and feed consumption was adjusted accordingly. Body weight was obtained by weighing 3 hens 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 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.

Table 1: Ingredients and nutrient content of the experimental diets

Ingredient (%)	Diet 1	Diet 2	Diet 3
Corn	68.39	64.80	60.82
Soy bean meal	19.42	22.40	25.69
Hard shell[1]	4.0	4.0	4.0
Limestone	5.0	5.0	5.0
Dicalcium phosphate	1.73	1.73	1.74
Poultry oil	0.51	1.12	1.79
NaCl	0.39	0.39	0.39
Vitamin Premix[2]	0.25	0.25	0.25
Mineral Premix[3]	0.25	0.25	0.25
DL-Methionine	0.034	0.07	0.10
Total	100	100	100
Calculated Analysis			
ME (Kcal/kg)	2840	2840	2840
Crude protein	14.81	15.97	17.26
Ca	4.0	4.0	4.0
Available phosphorus	0.42	0.42	0.42
Na	0.18	0.18	0.18
Methionine+Cystine	0.560	0.621	0.688
Lysine	0.747	0.828	0.917

[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-alpha-tocopheryl acetate), 8IU; vitamin B_{12}, 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.

Three eggs from each treatment replicate were randomly collected at the middle and at the end of the experiment for measuring solids. The yolk and albumen were mixed and 5-6g of homogenate was pipetted into an 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 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 units 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 units were calculated from the records of albumen height and egg weight using the formula:

$$HU = 100 \log_{10} (H-1.7 W^{0.37}+7.56)$$

where HU = Haugh unit, H = height of the albumen (mm) and W = egg weight (g). Shell color was measured (3 eggs of each treatment replicate) at the middle and at the end of the experiment using CHROMA METER CR-300 (Minolta co, Ltd. Osaka, Japan). The egg shell color reported as L*, a* and b*. The L* value represents lightness and ranges from 0-100, with 0 corresponding to black and 100 to white. Redness-greenness and yellowness-blueness, were measured by a* and b*, respectively.

Data were analyzed by ANOVA using proc mixed of Statistical Analysis System (SAS Institute, 2000) for a randomized complete block with a factorial arrangement of treatments. Dietary lysine and strains were fixed, whereas blocks were random. The factorial treatment arrangement consisted of three dietary lysine levels and seven strains. The following model was used to analyze the data:

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

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

[1]Centurion poultry, Inc. Lexington, GA 30648.

[2]Degussa Corporation, Allendale, NJ 07401.

Results and Discussion

Feed consumption: There was no significant interaction between strain and dietary lysine on feed consumption (Table 2). There was a significant strain effect on feed consumption. Feed consumption of Strain 5 was significantly higher than those of strain 1, 4 and 7 but was similar to strain 2, 3 and 6. There was no significant effect of dietary lysine on feed consumption. This result was in agreement with Wu *et al.*, 2007b, who reported that there was no significant effect of dietary protein (lysine) on feed consumption with Hy-line W-36 hens.

Egg production: There was a significant strain effect on egg production (Table 2). Strain 1 had the highest egg production whereas strain 2 had the lowest. Dietary lysine did not significantly affect egg production and there was no significant interaction between strain and dietary lysine on egg production. This result was in agreement with Bateman *et al.*, 2002a, 2002b and 2003 who reported that there was no significant interaction between strain and lysine on egg production with white leghorns. Wu *et al.*, 2007b also reported that there was no effect of dietary lysine on egg production.

Egg mass: Significant strain and dietary lysine effects were observed on egg mass (Table 2). Strain 1 had the highest egg mass among seven strains. Increasing dietary lysine linearly increased egg mass from 51.79-54.32g resulting in a 4.88% increase in egg mass. There was no significant interaction between strain and dietary lysine on egg mass.

Egg weight: Both dietary lysine and strain had a significant effect on egg weight (Table 2). Strain 4 had the lowest egg weight. Dietary lysine linearly increased egg weight by 3.44% from 59.37-61.41g. There was no significant interaction between strain and dietary lysine on egg weight. This result was consistent with the previous reports that there was no significant interaction between strain and lysine on egg weight with white leghorns (Bateman *et al.*, 2002a, 2002b, 2003).

Feed conversion: Dietary lysine and strain significantly effected feed conversion. However there was no interaction between strain and lysine on feed conversion (Table 2). Strain 1 had the best feed conversion whereas strain 2 had the worst. Hens fed high lysine diets had better feed conversion than hens fed low lysine levels. This result was in agreement with that of Liu *et al.* (2005) and Wu *et al.* (2007b) who reported increasing dietary lysine improved feed conversion with Hy-line W-36 hens.

Egg specific gravity, final body weight and mortality: There was a significant effect of strain on egg specific gravity. However dietary lysine or interaction between lysine and strain had no significant effect on egg specific gravity (Table 4). Egg specific gravity of strain 1 was significantly greater than that of the other six strains. There was no significant effect of dietary lysine, strain or interaction between strain and lysine on body weight and mortality.

Table 2: Effect of lysine on feed intake, egg production, egg mass, feed conversion and egg weight of seven brown egg layer strains during first cycle phase 1 (21wk to 36 wk of age)

Lysine (%)	Strain	Feed intake (g/hen per day)	Egg Production (%)	Egg mass (g of egg/h per day)	Feed conversion (g of feed/g of egg)	Egg Weight (g)
0.747		113.61	87.21	51.79[b]	2.20[a]	59.37[c]
0.828		111.64	87.45	52.47[b]	2.13[b]	60.09[b]
0.917		111.58	88.45	54.32[c]	2.06[c]	61.41[a]
	Strain 1	109.63[b]	90.59[a]	54.81[a]	2.00[c]	60.49[a]
	Strain 2	111.93[ab]	82.50[c]	49.46[c]	2.27[a]	60.20[a]
	Strain 3	112.52[ab]	88.12[ab]	53.68[ab]	2.10[b]	60.87[a]
	Strain 4	111.09[b]	88.43[ab]	52.14[b]	2.13[b]	58.97[b]
	Strain 5	116.65[a]	89.16[ab]	53.84[ab]	2.17[b]	60.38[a]
	Strain 6	114.01[ab]	89.26[ab]	53.76[ab]	2.12[b]	60.22[a]
	Strain 7	110.18[b]	86.05[ab]	52.02[b]	2.12[b]	60.44[a]
0.747 × Strain	Strain 1	111.83	89.54	53.22	2.10	59.43
	Strain 2	112.70	81.66	48.10	2.35	58.87
	Strain 3	111.90	84.85	50.72	2.22	59.73
	Strain 4	113.44	88.30	51.92	2.19	58.78
	Strain 5	117.56	89.32	53.17	2.21	59.52
	Strain 6	116.05	90.50	54.33	2.14	60.04
	Strain 7	111.81	86.26	51.08	2.19	59.22
0.828 × Strain	Strain 1	109.22	91.71	55.95	1.95	61.01
	Strain 2	111.95	82.37	49.13	2.29	60.44
	Strain 3	112.13	89.62	54.67	2.05	60.97
	Strain 4	111.61	89.97	52.52	2.13	58.37
	Strain 5	116.46	88.68	53.34	2.19	60.12
	Strain 6	111.92	87.04	51.74	2.16	59.45
	Strain 7	108.20	82.80	49.92	2.18	60.28
0.917 × Strain	Strain 1	107.85	90.53	55.25	1.95	61.03
	Strain 2	111.14	83.46	51.16	2.17	61.29
	Strain 3	113.52	89.89	55.64	2.04	61.91
	Strain 4	108.20	87.01	51.98	2.08	59.75
	Strain 5	115.92	89.46	55.01	2.11	61.49
	Strain 6	114.06	90.23	55.21	2.06	61.16
	Strain 7	110.52	89.08	55.06	2.01	61.82
Pooled SEM		1.85	1.73	1.2	0.032	0.48
	-----------	-----------	-----------	Probability	-----------	-----------
Lysine		NS	NS	0.0008	< 0.0001	< 0.0001
Strain		0.045	< 0.0001	< 0.0001	< 0.0001	< 0.0001
Lysine×Strain		NS	NS	NS	NA	NA

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

Increasing dietary lysine significantly increased percent albumen, percent albumen solids and albumen weights (Table 3). However, increasing dietary lysine decreased percent shell. There was no significant interaction between lysine and strain on percent components, percent solids or albumen, yolk and shell weight (Table 3). Strain had a significant effect on percent egg components, percent egg solids and yolk weight (Table 3). Strain 5 and strain 1 and 7 had the highest and lowest percent yolk respectively. Strain 1, 2, 6 and 7 had highest percent albumen and strain 1, had the highest percent shell. Strain 4 had the highest yolk and whole egg solids whereas strain 1, 2, 4 and 5 had the highest albumen solids.

Both dietary lysine and strain had a significant effect on shell color (Table 4). Strain 4 and 5 had the darkest and lightest shell color respectively (Table 4). Increasing dietary lysine significantly decreased yolk color due to a reduction in corn use, as the level of protein increased. This result was in agreement with that of Karunajeewa. (1972), who reported that increasing dietary lysine from 0.747-0.825%, significantly decreased yolk color from 6.58-6.45 with white leghorn hens.

Strain 1 had the best overall performance (Table 2). Compared to brown egg laying hens of other six strains, Strain 1 hens had the best efficiency in utilizing nutrients to produce one gram egg (Table 5). The best performance of all seven strains was obtained with hens fed diets containing 0.0917% lysine. Strain 5 (Bovans brown classic) hens consumed 20.0g protein, 1063mg lysine, 798mg TSAA and 329kcal ME per hen daily or 0.36g protein, 19.32mg lysine, 14.51mg TSAA and 5.98kcal ME per g egg for the best performance (Table 5). Strain 5 required 15% more protein, 17% more TSAA, and 33% more lysine than the values recommended by NRC (1994).

Table 3: Effect of lysine on egg components, egg solids, and albumen, yolk and shell weights of seven brown egg layer strains during first cycle phase 1 (21wk to 36 wk of age)

		% Egg components			% of solids			Albumen, Yolk, Shell weight (g)		
Lysine (%)	Strain	Yolk	Albumen	Shell	Whole egg	Albumen	Yolk	Albumen	Yolk	Shell
0.747		24.87	65.55^{b}	9.59^{a}	24.16	12.94^{b}	54.37	39.15^{c}	14.84	5.71
0.828		24.40	65.97^{ab}	9.40^{ab}	24.17	13.24^{a}	54.29	40.57^{b}	14.97	5.77
0.917		24.32	66.46^{a}	9.32^{b}	23.96	13.21^{a}	54.11	41.57^{a}	15.22	5.83
	Strain 1	23.93^{c}	66.18^{a}	9.79^{a}	24.08^{bcd}	13.23^{a}	54.37^{ab}	40.22	14.52^{b}	5.94
	Strain 2	24.24^{bc}	66.49^{a}	9.29^{b}	24.22^{abc}	13.31^{a}	54.49^{ab}	40.06	14.57^{b}	5.59
	Strain 3	24.30^{bc}	66.17^{ab}	9.46^{ab}	23.91^{cde}	13.02^{ab}	54.05^{b}	40.82	14.99^{ab}	5.83
	Strain 4	25.18^{ab}	65.45^{ab}	9.24^{b}	24.55^{a}	13.31^{a}	54.86^{a}	40.66	15.62^{a}	5.73
	Strain 5	25.46^{a}	65.00^{b}	9.53^{ab}	24.37^{ab}	13.20^{a}	54.00^{b}	40.12	15.71^{a}	5.87
	Strain 6	24.72^{abc}	66.44^{a}	9.30^{b}	24.03^{bcd}	12.98^{ab}	53.89^{b}	40.69	15.14^{ab}	5.69
	Strain 7	23.81^{c}	66.38^{a}	9.40^{ab}	23.58^{e}	13.02^{ab}	54.28^{ab}	40.46	14.47^{b}	5.72
Pooled SEM		0.44	0.55	0.18	0.23	0.16	0.34	0.83	0.32	0.13
					Probability					
Lysine		0.08	0.02	0.04	NS	0.001	NS	< 0.0001	NS	NS
Strain		0.0006	0.05	0.05	< 0.0001	0.02	0.04	NS	< 0.0001	NS
Lysine x Strain		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: Effect of lysine on specific gravity, body weight, mortality, shell color [lightness (L*), redness (a*), yellowness (b*)][1] and egg quality of seven brown egg layer strains during first cycle phase 1 (21wk to 36 wk of age).

		Egg Specific Gravity	Body Weight	Mortality	Egg shell color			Egg quality	
Lysine (%)	Strain	(Unit)	(Kg)	(%)	L*	a*	b*	Haugh Unit	Yolk color
0.747		1.0906	2.05	0.11	60.55^{a}	17.91^{b}	30.34^{b}	78.37	5.45^{a}
0.828		1.0907	2.00	0.10	59.96^{b}	18.35^{a}	30.63^{a}	78.15	5.26^{b}
0.917		1.0906	2.03	0.07	60.28^{ab}	18.15^{ab}	30.59^{a}	79.45	5.17^{b}
	Strain 1	1.0919^{a}	1.92	0.08	59.61^{cd}	18.57^{bc}	30.40^{b}	77.69	5.19
	Strain 2	1.0900^{b}	2.06	0.16	58.86^{d}	19.03^{b}	31.13^{a}	81.21	5.41
	Strain 3	1.0905^{b}	2.03	0.03	61.02^{b}	17.74^{d}	30.49^{b}	80.69	5.30
	Strain 4	1.0900^{b}	1.96	0.18	58.04^{e}	19.58^{a}	31.26^{a}	80.41	5.33
	Strain 5	1.0906^{b}	2.09	0.08	62.10^{a}	16.98^{e}	30.17^{bc}	77.22	5.31
	Strain 6	1.0905^{b}	2.09	0.05	60.78^{b}	17.65^{d}	30.30^{b}	76.37	5.25
	Strain 7	1.0909^{b}	2.02	0.08	61.53^{ab}	17.28^{de}	29.89^{c}	77.75	5.23
Pooled SEM		0.00051	0.07	0.084	0.85	0.53	0.37	2.47	0.13
					Probability				
Lysine		NS	NS	NS	0.04	0.007	0.005	NS	0.0002
Strain		0.0003	NS	NS	< 0.0001	< 0.0001	< 0.0001	NS	NS
Lysine x Strain		NA	NS	NS	NS	NS	NS	NS	NS

a-c Means within a column and under each main effect with no common superscripts differ significantly ($p \leq 0.05$).
[1]A higher L* value means lighter color; a higher a* value means a redder color; a higher b* value means a more yellow color.

Table 5: Nutrient requirement of seven brown egg layer strains fed diets containing 0.917% lysine during first cycle phase 1 (21wk to 36 wk of age)

	Strain 1	Strain 2	Strain 3	Strain 4	Strain 5	Strain 6	Strain 7
Nutrients required per hen daily							
Protein (g)	18.6	19.2	19.6	18.7	20.0	19.7	19.1
Lysine (mg)	989	1019	1041	992	1063	1046	1013
TSAA (mg)	742	765	781	744	798	785	760
Dietary energy (kcal)	306	316	322	307	329	324	314
Nutrients required to produce one gram egg							
Protein (g)	0.34	0.38	0.35	0.36	0.36	0.36	0.35
Lysine (mg)	17.90	19.92	18.71	19.08	19.32	18.95	18.40
TSAA (mg)	13.43	14.95	14.04	14.31	14.51	14.22	13.80
Dietary energy (kcal)	5.54	6.18	5.79	5.91	5.98	5.87	5.70

Hy-line brown and Bovans brown strains are the most popular brown egg laying strains in the world. Comparing the nutrient requirements of Hy-line brown with the nutrient requirements of strain 5 (Bovans brown classic), the Bovans brown classic (strain 5) required 13.9% more protein, 8.7% more TSAA, and 17.6% more lysine than the values recommended by Hy-line brown management guide (2006-2008) and 2.6% more protein, 10.1% more TSAA and 18.4% more lysine than the values recommended by Bovans brown management guide (2008), respectively.

The Econometric Feeding and Management Program developed by Roland *et al.* (1998, 2000) was used to calculate profits at different dietary lysine levels and egg

Table 6: Nutrient requirement of seven brown egg layer strains fed diets containing 0.828% lysine during first cycle phase 1 (21wk to 36 wk of age)

	Strain 1	Strain 2	Strain 3	Strain 4	Strain 5	Strain 6	Strain 7
Nutrients required per hen daily							
Protein (g)	17.4	17.9	17.9	17.8	18.6	17.9	17.3
Lysine (mg)	904	927	928	924	964	927	896
TSAA (mg)	678	695	696	693	723	695	672
Dietary energy (kcal)	310	318	318	317	331	318	307
Nutrients required to produce one gram egg							
Protein (g)	0.31	0.36	0.33	0.34	0.35	0.35	0.35
Lysine (mg)	16.16	18.87	16.98	17.60	18.08	17.91	17.95
TSAA (mg)	12.12	14.15	12.74	13.20	13.56	13.43	13.46
Dietary energy (kcal)	5.54	6.47	5.82	6.04	6.20	6.14	6.16

Table 7: Nutrient requirement of seven brown egg layer strains fed diets containing 0.747% lysine during first cycle phase 1 (21wk to 36 wk of age)

	Strain 1	Strain 2	Strain 3	Strain 4	Strain 5	Strain 6	Strain 7
Nutrients required per hen daily							
Protein (g)	16.6	16.7	16.6	16.8	17.4	17.2	16.6
Lysine (mg)	836	842	836	847	878	867	835
TSAA (mg)	627	631	627	635	658	650	626
Dietary energy (kcal)	318	320	318	322	334	330	318
Nutrients required to produce one gram egg							
Protein (g)	0.31	0.35	0.33	0.32	0.33	0.32	0.32
Lysine (mg)	15.71	17.50	16.48	16.32	16.52	15.96	16.35
TSAA (mg)	11.78	13.12	12.35	12.24	12.38	11.96	12.26
Dietary energy (kcal)	5.97	6.65	6.27	6.21	6.28	6.07	6.22

Table 8: Influence of dietary lysine on profits [1]of Bovans brown classic (Strain 5) hens during first cycle phase 1 (21wk to 36 wk of age)

	Price spread			
Diet	10 cents[2]	15 cents[3]	30 cents[4]	37 cents[5]
(Lysine %)	Returns [5]($/dozen)			
0.917	0.168	0.139	0.212	0.449
0.828	0.164	0.137	0.200	0.437
0.747	0.200	0.140	0.199	0.435

[1]Based on a feed price of $106.44 per to for the 0.917 lysine diet, $ 102.65 per ton for the 0.828 lysine diet, and $99.28 per ton for the 0.747 lysine diet. [2]Based on an Urner Barry egg price of 31 cents/doz. for check and peewee, 40 cents/doz. for small, 57 cents/doz. for medium, 67 cents/doz. for large, 68 cents/doz. for extra large and 69 cents/doz. for jumbo eggs. [3]Based on an Urner Barry egg price of 31 cents/doz. for check and peewee, 40 cents/doz. for small, 65 cents/doz. for medium, 80 cents/doz. for large, 81 cents/doz. for extra large and 84 cents/doz. for jumbo eggs. [4]Based on an Urner Barry egg price of 31 cents/doz. for check and peewee, 40 cents/doz. for small, 57 cents/doz. for medium, 87 cents/doz. for large, 91 cents/doz. for extra large and 110 cents/doz. for jumbo eggs. [5]Returns (R) were calculated using the equation R = UBEP-R-C-dC, 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).

prices (Table 8). Current feed prices were used. Price spreads, between medium and large eggs were 10, 15, 30 and 37 cents/dozen. Maximum profits per dozen of eggs were obtained in Bovans brown classic hens (Strain 5) fed the lowest lysine diet (0.747%) at small (10 and 15 cents/dozen) price spreads (0.200 and 0.140 $/dozen) whereas, highest profits were obtained by feeding the high lysine diet (0.917%) at larger (30 and 37 cents/dozen) price spreads (0.212 and 0.449 $/dozen). Since feed prices and egg price vary, there can be no fixed dietary lysine level for optimal profits during phase 1 (21 wk to 36 week of age).

In this study, nutrient requirement of Bovans brown classic hens' (strain 5) for optimal performance was obtained with the highest dietary lysine level (0.917). However, nutrient requirement for optimal profits vary according to the current ingredient and egg prices. According to the profit analysis (Table 8) highest profits with larger price spreads were obtained with the highest dietary lysine diet (0.917%) whereas with smaller price spread, highest profits were obtained with the lowest lysine diet (0.747%). In addition to the lysine requirement for optimal profits varying with ingredients and egg prices, the lysine requirement for optimal performance and profits also varies with energy intake (Table 5, 6 and 7); this complicates efforts to determine requirements for optimal performance and profits.

In conclusion, the results showed that there were no interactions between lysine and strain on any parameter. Lysine had significant effects on egg weight, egg mass, feed conversion, percent albumen solids, yolk color, shell color, albumen weight, egg shell and albumen components. There were significant strain effects on egg production, feed consumption, egg weight, egg mass, feed conversion, specific gravity, yolk weight, shell color, shell, albumen and yolk components, yolk albumen and whole egg solids. All strains peaked in production over 94% and were laying 94-96% at 36 weeks of age. Average egg weight (21-36wk) was 60.3g, varying from 59.0-62.8g between strains. Average feed intake was 112.3g/hen/day varying from 109.6-116.7g/hen/day between strains. Average egg weight of hens fed diets containing the highest lysine level was 2.04g heavier than the hens fed the diets containing the lowest lysine level. Increasing dietary lysine from 0.747-0.917% significantly improved feed conversion from 2.20- 2.06g feed/g egg and increased egg mass from 51.8-54.32g/hen/day. Average lysine intake of hens fed 0.917% level was 1023mg/hen/day varying from 1005- 1070mg/hen/day between strains. Because egg and ingredient prices and energy intake often change, there can be no fixed dietary lysine level for optimal profits.

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