ISSN 1682-8356
ansinet.org/ijps

INTERNATIONAL JOURNAL OF

POULTRY SCIENCE

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International Journal of Poultry Science 7 (8): 773-782, 2008
ISSN 1682-8356

Effect of Feed and Air Temperature on Optimum Egg Size and Profits During Phase 1 of Bovans White Hens

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Abstract: Two experiments were conducted to determine the most economical protein and lysine levels to feed laying hens during Phase I (weeks 21-36) of the laying cycle in order to optimize egg weight and profits when hens were exposed to warm (25.6°C Average in Exp. 1) and cool temperatures (20.0°C average in Exp. 2). In both experiments, nine hundred sixty 21-weeks old hens were randomly divided into six groups of 160 hens per group and fed one of six diets. Diets were formulated based on protein and lysine. Three diets formulated on protein contained 17.00, 18.70 and 20.80% protein and 0.90, 1.02 and 1.17% lysine, respectively. Three diets formulated based on lysine contained 0.75, 0.83 and 0.92% lysine and 14.98, 16.19 and 17.34% protein, respectively. Response criteria were egg production, feed consumption and egg weight. Neither diet nor method of formulation had an effect ($p>0.05$) on any response criteria other than egg weight in Exp. 1 and Exp. 2. In both experiments, egg weight increased ($p<0.05$) as the Lysine (or protein) content increased. Using an economic analysis with egg and feed prices at the time of the study, Bovans White hens required 1,076 mg lysine, 750 mg total sulphur amino acids (TSAA), 19.1 g protein and 264 kcal ME/hen/d for optimum profits during Phase I under warm conditions and 1,100 mg Lysine, 789 mg TSAA, 20.22 g protein and 310 kcal ME/hen/d during Phase I for maximum profits when kept under cool temperatures. Because feed and egg prices vary, there can be no fixed lysine (protein) requirement for optimal profit.

Key words: Feeding method, feed formulation, layer performance, lysine, profit

Introduction

Bovans White is the second largest Leghorn population after Hy-Line. In the United States, studies have been conducted to determine nutritional requirements of Leghorn strains like the Hy-Line, Delta and others, however, few studies have been conducted to determine nutritional requirements of Bovans Whites.

Nutritionists formulate diets based on Lys (Lys) or protein. The protein method is recommended by management guides. With this method the nutritionist chooses the protein level and the protein level controls the Lys level. When formulating based on Lys the Lys level is chosen and the protein level depends on the Lys level. Formulation based on amino acids (Lys) is recommended by the amino acid industry because it allows for more use of synthetic methionine. Feed formulation based on Lys has been widely used since the mid 1960's. Studies by Roland *et al*. (1995) and Sohail and Roland (1997) showed that hens fed diets formulated on protein produced heavier eggs than hens fed diets formulated on Lys. The method which produced greater profits was dependent on the spread in feed price due to energy and protein cost and spread in egg price due to size.

There was no information concerning the quantity of nutrients required to maximize egg size or how Bovans White hens respond to diets formulated based on protein vs. diets formulated based on Lys. These studies were conducted to determine the performance potential of Bovans White hens when fed dietary treatments formulated based on protein or Lys. Data obtained will be used to develop an Econometric Feeding and Management program for Bovans hens similar to what was developed for Hy-Line W-36 hens (Roland *et al*., 1998).

Materials and Methods

A randomized complete block design with a 2×3 factorial arrangement of treatments was used. Diets were formulated using two formulation methods, based on either Lys or protein. Each method consisted of three methionine (Met)/total sulfur amino acid (TSAA) levels corresponding to a set of three diets high, moderate, or low in Lys or protein level (Table 1). The first set of diets was formulated based on Lys, where Methionine + cystine (Cys) to Lys ratio was kept constant at 0.83 (a ratio used by many commercial egg producers and specified by NRC (1994)). The second set were formulated based on protein, where Met+Cys/Lys ratio ranged from 0.69 in the high protein diet to 0.73 in the low protein diet. Diets formulated based on protein had higher protein, Lys, energy and Met+Cys compared to diets formulated based on Lys. However, all respective diets had similar amounts of methionine (the high protein diet and the high Lys diet had similar amounts of synthetic methionine added and the low protein had similar amounts of synthetic methionine as the low Lys diet). Experiments were conducted in a computer-

Table 1: Ingredients and nutrient composition of experimental diets

	Diet					
	Lys			Protein		
Formulation	High	Medium	Low	High	Medium	Low
Ingredients						
Corn	61.20	65.24	68.84	49.31	56.02	61.46
SBOM, 48%	25.16	21.84	18.88	34.50	28.92	24.41
Limestone	5.07	5.08	5.09	5.05	5.06	5.07
Hardshell	4.00	4.00	4.00	4.00	4.00	4.00
Dicalcium phosphate	1.63	1.64	1.66	1.58	1.61	1.63
Poultry oil	1.83	1.13	0.50	4.50	3.34	2.41
Salt	0.43	0.43	0.43	0.43	0.43	0.43
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Mineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.19	0.14	0.11	0.15	0.12	0.09
Calculated analysis						
ME (kcal kg^{-1})	2834	2834	2834	2871	2871	2871
Protein (%)	17.34	16.09	14.98	20.80	18.70	17.00
Calcium (%)	4.00	4.00	4.00	4.00	4.00	4.00
Total Phosphorus (%)	0.61	0.60	0.59	0.64	0.62	0.61
Available Phosphorus (%)	0.40	0.40	0.40	0.40	0.40	0.40
Sodium (%)	0.19	0.19	0.19	0.19	0.19	0.19
Met+Cys (%)	0.76	0.69	0.62	0.81	0.73	0.66
Lys (%)	0.92	0.83	0.75	1.17	1.02	0.90

[1]Provided per kg of diet: retinol acetate, 8,000 IU; cholecalciferol, 2,200 ICU; dl, a-tocopherol acetate, 8 IU; vitamin B_{12}, 0.02 mg; riboflavin, 5.5 mg; dicalcium pantothenic acid, 13 mg; niacin, 36 mg; choline, 500 mg; folic acid, 0.5 mg; thiamin, 1mg; pyridoxine, 2.2 mg; biotin, 0.05 mg; menadione sodium bisulfate complex, 2 mg, [2]Provided per kg of diet: manganese, 65 mg; iodine, 1mg; iron, 55 mg; copper, 6 mg; zinc, 55 mg; selenium, 0.15 mg

regulated, environmentally-controlled house under conditions with an average daily temperature of approximately 25.6°C (21.1°C during the night and 28.9°C during the day) in Exp. 1 and 20.0°C (15.6°C during the night and 23.3°C during the day) in Exp. 2. A lighting program (16 h light:8 h dark in Exp. 1 and 13.5 h light: 10.5 h dark in Exp. 2) with a light intensity of 2.0 foot candles was followed. Hens (n = 960; 21 weeks of age) were arranged randomly with each treatment having eight replicates of 20 birds per replicate, housed four birds per cage (40.6×45.7 cm) in five adjacent cages. Hens in each replicate shared a feed trough and had access to drinking cups. Replicates were equally distributed into upper and lower cage levels to minimize cage level effect. Feed and water were supplied *ad libitum*. Feed consumption was recorded weekly for the 16 weeks experiment. Egg production was summarized weekly. Egg weights were determined bi-weekly using all eggs collected for two consecutive days (or weekly after week 10 in Experiment 2). Egg specific gravity was determined monthly using all eggs collected for two consecutive days by the method of Strong (1989), which involved placing eggs in a series of saline solutions ranging from 1.060-1.100 in 0.005 unit increments. Mortality was recorded daily. Data were analyzed using the General Linear Models procedure of SAS (SAS Institute, 2000). The effects of method of feed formulation (protein vs. Lys), dietary density and the appropriate interactions were included in the model. Means were separated using Tukey's *W* Procedure.

Results and Discussion

Experiment 1: Method of formulation (diets formulated on protein vs. diets formulated on Lys) had no effect ($p>0.05$) on egg production (Table 2). Hens peaked during weeks 12 (32 weeks of age) laying over 95%. Production average for 1-16 weeks (21-36 weeks of age) was 88.0 and 89.0%, when fed the diets based on Lys and protein, respectively.

Diet (high, moderate and low densities) had no influence ($p>0.05$) on average egg production. Birds fed the high and low density diets averaged 88%, whereas birds fed the moderate protein diet averaged 89%. No interactions were observed between the diet and method of formulation, except during weeks 10. All diets had similar egg production, except for the low density diet formulated based on protein.

Method of feed formulation had no influence on feed consumption (Table 3). Birds fed diets formulated based on protein consumed an average of 93.4 g feed/hen/d. Hens fed the diets formulated based on Lys consumed 93.8 g feed/hen/d. Hens fed the diets formulated based on protein containing the higher energy level were expected to consume slightly less than hens fed diets formulated based on Lys. However, no difference in feed consumption was observed, probably due to an increase in egg weight of hens fed diets formulated based on protein.

Diet density had no effect on feed consumption, except during weeks 13 and 15, with the birds fed the diet with

Table 2: Effect of method of formulation and diet on egg production in Experiment 1 (warm environment)

		Egg production (%)							
		Week							
Formulation	Diet	1	2	3	4	5	6	7	8
		NS	NS	NS	NS	NS	NS	NS	NS
Lysine		53.0	70.0	80.0	89.0	92.0	93.0	94.0	95.0
Protein		52.0	52.0	69.0	80.0	89.0	91.0	93.0	94.0
SEM		2.00	1.82	1.40	1.10	0.78	0.79	0.81	0.72
		NS	NS	NS	NS	NS	NS	*Q	NS
	High	53.0	69.0	79.0	88.0	91.0	92.0	94.0	95.0
	Moderate	50.0	66.0	80.0	88.0	92.0	94.0	96.0	94.0
	Low	55.0	72.0	82.0	90.0	91.0	92.0	92.0	93.0
	SEM	2.44	2.21	1.72	1.35	0.96	0.97	0.98	0.88
		NS	NS	NS	NS	NS	NS	NS	NS
	High	54.0	67.0	78.0	87.0	91.0	94.0	94.0	97.0
Lysine	Moderate	49.0	65.0	79.0	87.0	92.0	94.0	95.0	94.0
	Low	58.0	77.0	85.0	92.0	93.0	92.0	93.0	94.0
	High	53.0	70.0	79.0	89.0	91.0	91.0	93.0	94.0
Protein	Moderate	50.0	68.0	82.0	90.0	92.0	95.0	96.0	94.0
	Low	52.0	68.0	80.0	87.0	90.0	92.0	92.0	92.0
	SEM	3.46	3.12	2.43	1.91	1.37	1.38	1.39	1.24

Table 2: Continued

		Egg production (%)								
		Week								
Formulation	Diet	9	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Lysine		94.0	95.0	95.0	96.0	96.0	95.0	94.0	90.0	89.0
Protein		93.0	93.0	94.0	95.0	95.0	95.0	94.0	92.0	88.0
SEM		0.69	0.84	0.86	0.70	0.75	0.70	0.66	0.94	0.52
		*L	NS	NS	NS	NS	NS	NS	NS	NS
	High	95.0	95.0	95.0	96.0	94.0	95.0	94.0	92.0	88.0
	Moderate	95.0	95.0	97.0	95.0	97.0	96.0	94.0	90.0	89.0
	Low	92.0	95.0	94.0	95.0	95.0	94.0	94.0	91.0	88.0
	SEM	0.84	94.0	1.04	0.86	0.91	0.85	0.81	1.15	0.65
		NS	*	NS	NS	NS	NS	NS	NS	NS
	High	96.0	96.0	95.0	96.0	95.0	96.0	94.0	90.0	89.0
Lysine	Moderate	95.0	94.0	97.0	96.0	97.0	96.0	94.0	88.0	88.0
	Low	93.0	96.0	93.0	96.0	96.0	94.0	95.0	91.0	90.0
	High	94.0	94.0	94.0	95.0	93.0	95.0	94.0	94.0	88.0
Protein	Moderate	94.0	96.0	96.0	95.0	97.0	95.0	94.0	92.0	89.0
	Low	90.0	92.0	94.0	95.0	94.0	94.0	93.0	90.0	87.0
	SEM	1.19	1.45	1.48	1.23	1.29	1.21	1.15	1.62	0.91

*(p<0.05), *L (p<0.05, linear), *Q (p<0.05, quadratic), NS (p<0.05, not significant)

the highest density having a lower average feed consumption. There were no interactions between the method of feed formulation and diet density based on feed consumption.

Birds fed diets formulated based on protein had higher egg weight (p<0.01) than birds fed diets based on Lys (Table 4). At 36 weeks of age, the average egg weight of birds fed diets formulated based on protein was 59.0 g, which was 0.8 g heavier than the 58.2 g average of the birds fed diets based on Lys. For the 16 weeks average, birds fed diets formulated based on protein had an average egg weight of 55.8 g, which was 0.7 g heavier than the 55.1 g for the birds fed diets formulated based on Lys.

An effect (p<0.05) of dietary density on egg weights was also observed. This effect was observed as early as weeks 8. Hens fed the densest diets produced 55.7 g eggs, which were 0.1 g heavier than eggs from birds fed the moderate density diets and 0.7 g heavier than the eggs from birds fed the least dense diets. Studies done with the Hy-Line birds yielded similar results (Roland *et al*., 1995; Sohail and Roland, 1997).

No interactions between the method of formulation and diet were observed based on egg weight, except during weeks 12. The interaction (weeks 12) indicated that hens fed the high protein diet laid heavier eggs than hens fed the low Lys diet and none of the other diets being different from either of these diets or each other.

Table 3: Effect of method of formulation and diet on feed consumption in Experiment 1 (warm environment).

		Feed consumption (g/h/d)							
		Week							
Formulation	Diet	1	2	3	4	5	6	7	8
		NS	NS	NS	NS	NS	NS	NS	NS
Lysine		78.9	85.6	87.0	88.7	94.9	93.7	93.9	95.2
Protein		77.8	86.0	87.5	88.0	93.4	92.3	92.1	93.6
SEM		0.96	0.99	1.01	1.18	0.96	0.89	0.94	0.96
		NS	NS	NS	NS	NS	NS	NS	NS
	High	77.8	84.9	85.9	86.7	92.8	91.8	92.6	94.3
	Moderate	77.7	85.8	86.9	88.8	94.7	93.5	93.2	94.2
	Low	79.6	86.6	89.0	89.6	94.8	93.7	93.2	94.8
	SEM	1.17	1.22	1.17	1.41	1.19	1.10	1.21	1.23
		NS	NS	NS	NS	NS	NS	NS	NS
	High	78.0	84.3	85.2	87.6	93.6	93.1	94.2	95.6
Lysine	Moderate	78.6	85.6	86.7	89.1	95.7	94.2	93.1	93.9
	Low	80.0	86.9	89.1	89.4	95.3	93.8	94.4	96.0
	High	77.5	85.5	86.6	85.7	92.0	90.6	91.1	93.0
Protein	Moderate	76.8	86.1	87.0	88.6	93.8	92.8	93.2	94.4
	Low	79.1	86.3	88.9	89.7	94.3	93.5	92.1	93.5
	SEM	1.76	1.84	1.77	2.13	1.76	1.60	1.74	1.77

Table 3: Continued

		Feed consumption (g/h/d)								
		Week								
Formulation	Diet	9	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Lysine		98.5	100.6	97.4	99.4	97.9	98.8	93.4	97.7	93.8
Protein		98.5	99.9	95.8	99.5	98.7	98.2	93.7	98.8	93.4
SEM		1.13	0.97	0.86	1.07	1.05	1.06	0.96	0.76	0.74
		NS	NS	NS	NS	*Q	NS	*L	NS	NS
	High	97.6	99.2	95.0	97.6	95.6	96.4	91.0	97.9	92.3
	Moderate	97.7	100.0	98.1	100.2	100.2	100.1	94.9	98.8	94.1
	Low	100.2	101.7	96.8	100.5	99.0	99.0	94.7	98.0	94.4
	SEM	1.33	1.16	1.00	1.24	1.11	1.20	0.99	0.97	0.87
		NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	98.0	99.2	95.5	98.1	96.0	96.9	89.7	97.1	92.6
Lysine	Moderate	96.0	99.3	98.5	101.0	100.7	101.9	96.1	99.4	94.4
	Low	101.5	103.4	98.3	99.0	96.8	97.7	94.5	96.6	94.5
	High	97.3	99.1	94.5	97.1	95.3	96.0	92.3	98.7	92.0
Protein	Moderate	99.3	100.7	97.8	99.4	99.7	98.2	93.8	98.3	93.8
	Low	99.0	100.0	95.2	102.0	101.1	100.3	94.9	99.4	94.3
	SEM	1.91	1.66	1.43	1.80	1.53	1.67	1.39	1.37	1.32

*L ($p<0.05$,linear), *Q ($p<0.05$, quadratic), NS ($p<0.05$, not significant)

Even though the methionine level of each diet (high, moderate and low) in both methods of formulation was essentially the same, hens fed diets formulated based on protein produced heavier eggs. There was no difference in energy intake (266 versus 268 kcal ME/hen/d) for the hens fed diets based on Lys versus protein.

Neither diet nor method of formulation had an effect on egg specific gravity and there were no interactions between the formulation method and diets (Table 5). Since egg weight of hens fed diets formulated based on Lys was lower than hens fed diets formulated based on protein, a better egg specific gravity was expected in hens fed diets based on Lys.

The econometric feeding and management program developed by Roland *et al.* (1998) was used to calculate the economics of using diets formulated based on protein or Lys and profits were determined in cents per dozen eggs (Table 6). Feed prices at time of the study were used to determine profits for each diet. Price spreads used between medium and large eggs were 3, 21 and 30 dents/doz. Within diets formulated based on Lys, the diet that gave most profits at the two higher price spreads was the moderate Lys diet. The low Lys diet lost the least money at the lowest price spread. However, the diets formulated based on protein had more profits, or lost the least money, than the diets formulated based on Lys, except at the lowest price

Table 4: Effect of method of formulation and diet on egg weight in Experiment 1 (warm environment)

		Egg weights (g)								
		Week								
Formulation	Diet	2	4	6	8	10	12	14	16	Mean
		NS	*	**	**	**	*	*	**	**
Lys		49.6	52.0	53.6	54.4	56.3	57.9	58.5	58.2	55.1
Protein		50.2	52.6	54.4	55.3	57.1	58.5	59.1	59.0	55.8
SEM		0.25	0.20	0.20	0.23	0.22	0.22	0.25	0.26	0.20
		NS	NS	NS	*L	*L	*L	*L	NS	*L
	High	50.2	52.3	54.2	55.1	57.1	58.5	59.1	58.9	55.7
	Medium	49.9	52.6	54.1	55.1	56.9	58.4	59.0	58.8	55.6
	Low	49.6	52.0	53.6	54.4	56.2	57.7	58.3	58.1	55.0
	SEM	0.31	0.26	0.26	0.29	0.27	0.27	0.30	0.33	0.25
		NS	NS	NS	NS	NS	*	NS	NS	NS
	High	49.7	51.6	53.6	54.6	56.5	57.9[ab]	58.5	58.3	55.1
Lys	Medium	49.7	52.5	54.0	54.9	56.9	58.5[ab]	59.2	58.7	55.5
	Low	49.6	51.9	53.2	53.8	55.6	57.3[b]	57.7	57.7	54.6
	High	51.7	53.0	54.8	55.6	57.7	59.1[a]	59.7	59.6	56.3
Protein	Medium	50.0	52.7	54.2	55.3	56.9	58.3[ab]	58.9	58.8	55.6
	Low	49.7	52.2	54.0	55.0	56.7	58.1[ab]	58.8	58.6	55.4
SEM		0.43	0.34	0.35	0.39	0.36	0.36	0.41	0.45	0.33

[ab] = Means with no superscripts in common are significantly different, (p<0.05). *(p<0.05), **(p<0.01), *L (p<0.05, Linear), NS(p<0.05)

Table 5: Effect of method of formulation and diet on egg specific gravity in experiment 2 (cool environment)

		Egg specific gravity				
		Week				
Formulation	Diet	4	8	12	16	Mean
		NS	NS	NS	NS	NS
Lys		1.0902	1.0880	1.0894	1.0878	1.0888
Protein		1.0899	1.0879	1.0851	1.0882	1.0878
SEM		0.0002	0.0002	0.0020	0.0016	0.0007
		NS	NS	NS	NS	NS
	High	1.0898	1.0875	1.0857	1.0867	1.0874
	Moderate	1.0901	1.0883	1.0874	1.0884	1.0886
	Low	1.0902	1.0880	1.0886	1.0888	1.0889
	SEM	0.0003	0.0002	0.0025	0.0019	0.0009
		NS	NS	NS	NS	NS
	High	1.0902	1.0879	1.0859	1.0868	1.0877
Lys	Moderate	1.0904	1.0879	1.0896	1.0902	1.0895
	Low	1.0899	1.0880	1.0928	1.0862	1.0892
	High	1.0894	1.0872	1.0856	1.0866	1.0872
Protein	Moderate	1.0898	1.0886	1.0853	1.0866	1.0876
	Low	1.0905	1.0879	1.0845	1.0912	1.0885
SEM		0.0004	0.0003	0.0034	0.0028	0.0013

NS (p<0.05)

spread (3 cents/doz.). The high protein diet had the most profits (14.19 cents per doz. When there was a high price spread between medium and large eggs (30 or 21 cents per doz.).

At the 30 cents per doz. Price spread, hens fed the most profitable diet based on protein made 0.93 cents per dozen more than hens fed the most profitable diet formulated based on Lys (14.19 vs. 13.26) cents per doz.). Although, neither made a profit (-4.22 versus -4.86 cents per dozen) at the lowest price spread (3 cents per doz.), the most profitable.

Lys diet lost 0.64 cents per doz. less than the most profitable protein diet.

Hens fed the high protein diet made the most profits at the 30 cents/doz. price spread between medium and large eggs. The Lys, TSAA and protein consumed in the high protein diet was calculated to compare with NRC (1994) recommendations. For optimal profits, Bovans White hens required 1,076 mg Lys, 750 mg TSAA and 19.1 g protein/hen/d during Phase I in warm temperatures. The Lys value was 56% higher than the 670 mg Lys/hen/d recommended by the NRC (1994), the TSAA was 29% higher than the 580 mg TSAA/hen/d recommended by the NRS (1994) and the protein value was 27% higher than the 15 g protein/hen/d recommended by the NRS (1994).

Values may appear high, but new strains produce more and larger eggs on average than older strains, so it would stand to reason that they would have higher dietary requirements. Nutrient requirements were also calculated on a per gram of egg laid basis and were 21.6 mg Lys, 15.0 mg TSAA, 0.38 g protein and 5.31 kcal ME per g of egg.

Experiment 2: Method of feed formulation had no effect on egg production, except during the third week (Table 7). Diets formulated based on protein had higher egg production during weeks three of this study compared to the diets formulated on Lys (94.0 vs. 92%). Overall, hens fed the diets formulated based on protein had 87.0% vs. 84.0% egg production for hens fed the diets formulated based on Lys.

Diet had no effect on egg production: There was no interaction between method of feed formulation and diet density on egg production. All hens peaked at over 95% during the fifth week and averaged more than 91% for the 16 weeks of this study, which corresponded to Phase 1.

The method of feed formulation had an effect ($p<0.05$) on feed consumption during week 6, 7 and 8 (Table 8). Birds fed diets formulated based on protein consumed more feed than birds fed diets formulated based on Lys during these weeks. Feed consumption was reduced during the 11th week because of heat stress. Outside temperatures exceeded our ability to keep the hens cool. Feed consumption was higher than in Exp 1, but this was expected due to lower ambient temperatures.

Diet density had an effect on feed consumption during weeks 1, 2 and 15, with birds fed the high and moderate density diets consuming less feed than birds fed low density diet during weeks 1 and 2. Birds fed the high density diet had a lower feed consumption than birds fed the moderate density diet during weeks 15.

Birds fed diets formulated based on protein, had a higher egg weight ($p<0.05$) than the birds fed diets formulated on Lys during weeks 11 through 16 (Table 9). Average egg weight reached a large egg size in the highest protein group during the 14th weeks of production.

Table 6: Influence of method of formulation and diet on profits (¢ per doz.)[a] in Experiment 1 (warm environment)

		Price spread		
		(¢ per doz.)		
Formulation	Diet	3[b]	21[c]	30[d]
	High	-4.77	-3.52	11.39
Lys	Moderate	-4.26	-2.08	13.26
	Low	-4.22	-3.79	10.72
	High	-5.09	-1.70	14.19
Protein	Moderate	-4.87	-2.50	12.94
	Low	-4.86	-3.07	12.09

[a] = based on a feed price of $106.44 per ton for the high Lys diet, $102.65 per ton for the moderate Lys diet and $99.28 per ton for the low Lys diet and $114.40 per ton for the high protein diet, $ 109.11 per ton for the moderate protein diet and $104.70 for the low protein diet. [b] = based on an Urner Barry egg price of 12¢/doz. for check and peewee, 43¢/doz. for small, 56¢/doz. for medium, 59¢/doz. for large, 62¢/doz. for extra large and 65¢/doz. for jumbo eggs. [c] = based on an Urner Barry egg price of 18¢/doz. for check and peewee, 31¢/doz. for small, 47¢/doz. for medium, 68¢/doz. for large, 75¢/doz. for extra large and 103¢/doz. for jumbo eggs. [d] = based on an Urner Barry egg price of 31¢/doz. for check and peewee, 40¢/doz. for small, 57¢/doz. for medium, 87¢/doz. for large, 91¢/doz. for extra large and 110¢/doz. for jumbo eggs

Table 7: Effect of method of formulation and diet on egg production in Experiment 2 (cool environment).

		Egg production (%)							
		Week							
Formulation	Diet	1	2	3	4	5	6	7	8
		NS	NS	*	NS	NS	NS	NS	NS
Lysine		59.0	84.0	92.0	96.0	96.0	95.0	96.0	95.0
Protein		62.0	87.0	94.0	94.0	96.0	96.0	96.0	96.0
SEM		1.50	1.02	0.80	0.63	0.63	0.60	0.55	0.65
		NS	NS	NS	NS	NS	NS	NS	NS
	High	61.0	86.0	94.0	95.0	96.0	96.0	96.0	96.0
	Moderate	62.0	86.0	93.0	94.0	97.0	96.0	97.0	95.0
	Low	58.0	84.0	92.0	96.0	96.0	95.0	96.0	96.0
	SEM	1.83	1.26	0.98	0.77	0.77	0.73	0.67	0.80
		NS	NS	NS	NS	NS	NS	NS	NS
	High	58.0	85.0	92.0	95.0	96.0	96.0	96.0	97.0
Lysine	Moderate	62.0	85.0	92.0	95.0	97.0	96.0	97.0	95.0
	Low	56.0	82.0	91.0	96.0	95.0	94.0	95.0	95.0
	High	64.0	87.0	95.0	95.0	97.0	96.0	96.0	96.0
Protein	Moderate	63.0	88.0	94.0	93.0	96.0	96.0	97.0	95.0
	Low	60.0	86.0	92.0	96.0	96.0	96.0	96.0	97.0
	SEM	2.59	1.77	1.38	1.09	1.09	1.03	0.95	1.13

Table 7: Continued

		Egg production (%)								
		Week								
Formulation	Diet	9	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Lysine		95.0	95.0	93.0	92.0	93.0	93.0	93.0	94.0	91.0
Protein		96.0	95.0	94.0	93.0	93.0	94.0	94.0	95.0	92.0
SEM		0.66	0.69	0.77	0.87	0.94	0.93	0.97	0.93	0.46
		NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	95.0	96.0	94.0	93.0	93.0	94.0	94.0	94.0	92.0
	Moderate	95.0	96.0	95.0	94.0	95.0	95.0	94.0	94.0	92.0
	Low	95.0	94.0	92.0	91.0	91.0	92.0	93.0	95.0	91.0
	SEM	0.81	0.84	0.93	1.05	1.14	1.13	1.19	1.14	0.56
		NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	95.0	96.0	94.0	93.0	94.0	94.0	93.0	93.0	92.0
Lysine	Moderate	95.0	95.0	94.0	93.0	94.0	93.0	93.0	93.0	92.0
	Low	95.0	94.0	91.0	92.0	91.0	92.0	94.30	94.0	90.0
	High	96.0	96.0	94.0	93.0	93.0	94.0	95.0	96.0	93.0
Protein	Moderate	95.0	96.0	97.0	94.0	95.0	96.0	95.0	95.0	93.0
	Low	96.0	94.0	93.0	91.0	92.0	91.0	93.0	95.0	92.0
	SEM	1.15	1.19	1.31	1.50	1.61	1.60	1.69	1.62	0.79

*(p<0.05), NS(p<0.05)

Table 8: Effect of method of formulation and diet on feed consumption in Experiment 2 (cool environment)

		Feed consumption (g/h/d)							
		Week							
Formulation	Diet	1	2	3	4	5	6	7	8
		NS	NS	NS	NS	NS	*	*	*
Lysine		94.7	102.5	103.8	105.5	107.7	106.4	106.1	107.4
Protein		95.2	102.3	103.1	105.1	108.6	108.7	108.7	110.2
SEM		0.52	0.46	0.61	0.69	0.61	0.57	0.65	0.71
		**L	**L	NS	NS	NS	NS	NS	NS
	High	95.5	102.8	103.3	105.0	107.5	105.7	105.4	106.6
	Moderate	95.8	103.3	104.6	105.8	107.2	106.5	106.1	107.1
	Low	93.5	101.1	103.5	106.8	108.3	106.9	106.9	108.5
	SEM	0.53	0.45	0.75	0.86	0.78	0.83	0.94	1.03
		NS	NS	NS	NS	NS	NS	NS	NS
	High	94.4	102.5	103.3	105.0	107.5	105.7	105.4	106.6
Lysine	Moderate	96.0	103.3	104.6	105.8	107.2	106.5	106.1	107.1
	Low	93.9	101.7	103.5	105.8	108.3	106.9	106.9	108.5
	High	96.7	103.1	103.7	105.1	108.9	108.4	108.7	110.3
Protein	Moderate	95.7	103.4	103.8	105.5	109.2	109.4	109.4	111.1
	Low	93.2	100.4	101.8	104.7	107.7	108.2	108.1	109.2
	SEM	0.71	0.64	1.09	1.31	1.12	1.05	1.20	1.28

Table 8: Continued

		Feed consumption (g/h/d)								
		Week								
Formulation	Diet	9	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS
Lysine		110.5	107.4	103.0	106.3	110.6	108.9	109.9	108.9	106.2
Protein		110.8	107.0	102.8	107.2	109.1	109.4	109.3	109.6	106.7
SEM		0.58	0.60	0.60	0.64	1.02	0.84	0.74	0.81	0.50
		NS	NS	NS	NS	NS	NS	*Q	NS	NS
	High	112.1	107.4	103.4	105.9	109.8	107.7	109.1	107.9	105.9
	Moderate	109.3	107.4	102.5	106.6	110.1	109.8	110.7	108.9	106.4
	Low	110.1	107.2	103.0	106.3	111.9	109.4	110.0	109.8	106.4
	SEM	0.69	0.68	0.73	0.75	1.25	0.92	0.80	0.97	0.60

Table 8: Continued

		Feed consumption (g/h/d)								
		Week								
Formulation	Diet	9	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	112.1	107.4	103.4	105.9	109.8	107.7	109.1	107.9	105.9
Lysine	Moderate	109.3	107.4	102.5	106.6	110.1	109.8	110.7	108.9	106.4
	Low	110.1	107.2	103.0	106.3	111.9	109.4	110.0	109.8	106.4
	High	110.7	106.4	103.1	106.5	107.2	108.0	107.7	108.3	106.4
Protein	Moderate	112.1	109.2	104.0	109.5	112.1	112.4	112.1	111.3	108.1
	Low	109.6	105.5	101.4	105.6	108.1	107.8	108.1	109.3	105.5
	SEM	0.92	0.94	1.06	1.01	1.71	1.32	1.13	1.42	0.84

*(p<0.05), **L (p<0.01, linear), *Q (p<0.05, quadratic), NS (p<0.05, not significant)

Table 9: Effect of method of formulation and diet on egg weights in Experiment 2 (cool environment)

		Egg weights (g)											
		Week											
Formulation	Diet	2	4	6	8	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	*	*	**	***	**	**	*
Lys		51.1	53.9	56.1	57.4	57.9	58.1	58.6	58.8	59.2	59.9	59.9	57.4
Protein		51.1	54.5	56.5	57.8	58.3	58.8	59.3	59.6	60.4	60.8	60.9	58.0
SEM		0.24	0.20	0.23	0.20	0.23	0.23	0.24	0.21	0.20	0.23	0.21	0.18
		NS	NS	*L	*L	*L	*L	**L	*L	**L	**L	NS	*L
	High	51.1	54.3	56.7	57.8	58.6	58.8	59.4	59.4	60.2	60.6	60.7	58.0
	Moderate	51.4	54.4	56.5	57.9	58.2	58.7	59.3	59.6	60.1	60.8	60.7	58.0
	Low	50.9	54.0	55.6	57.1	57.5	57.8	58.2	58.6	59.2	59.6	59.9	57.1
	SEM	0.29	0.26	0.26	0.24	0.26	0.28	0.28	0.26	0.28	0.28	0.28	0.22
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	51.0	54.0	56.6	57.8	58.5	58.4	59.2	59.2	29.4	60.0	60.3	57.7
Lys	Moderate	51.4	54.1	56.1	57.5	57.9	58.3	58.8	59.0	59.7	60.6	60.1	57.6
	Low	51.0	53.7	55.4	57.0	57.2	57.7	57.8	58.1	58.5	59.0	59.3	56.8
	High	51.2	54.6	56.7	57.9	58.6	59.1	59.6	59.6	60.9	61.1	61.0	58.2
Protein	Moderate	51.4	54.6	56.8	58.3	58.5	59.2	59.8	60.2	60.5	60.9	61.2	58.3
	Low	50.8	54.4	55.8	57.2	57.8	58.0	58.6	59.0	59.9	60.2	60.5	57.5
	SEM	0.42	0.36	0.37	0.34	0.37	0.38	0.39	0.34	0.33	0.37	0.36	0.30

*(p<0.05), **(p<0.01), ***(p<.001), L=Linear effect

Table 10: Effect of method of formulation and diet on egg specific gravity in Experiment 2 (cool environment)

		Egg specific gravity				
		Week				
Formulation	Diet	4	8	12	16	Mean
		NS	NS	**	***	**
Lys		1.0914	1.0902	1.0876	1.0862	1.0888
Protein		1.0910	1.0902	1.0869	1.0852	1.0883
SEM		0.0002	0.0002	0.0002	0.0002	0.0001
		NS	*Q	NS	NS	NS
	High	1.0916	1.0905	1.0875	1.0859	1.0889
	Moderate	1.0911	1.0898	1.0870	1.0854	1.0883
	Low	1.0909	1.0901	1.0873	1.0857	1.0885
	SEM	0.0002	0.0002	0.0002	0.0003	0.0002
		NS	NS	NS	NS	NS
	High	1.0919	1.0905	1.0880	1.0867	1.0893
Lys	Moderate	1.0916	1.0900	1.0874	1.0860	1.0888
	Low	1.0919	1.0900	1.0873	1.0858	1.0885
	High	1.0914	1.0905	1.0869	1.0851	1.0885
Protein	Moderate	1.0906	1.0898	1.0866	1.0847	1.0879
	Low	1.0919	1.0901	1.0873	1.0856	1.0885
SEM		0.0004	0.0002	0.0003	0.0003	0.0002

NS(p<0.05), **(p<0.01), ***(p<0.001), *Q (p<0.05, quadratic effect)

Table 11: Effect of method of formulation and diet on feed conversion (g feed/g egg) in Experiment 2 (cool environment)

		Feed conversion (g feed/g egg)											
		Week											
Formulation	Diet	2	4	6	8	10	11	12	13	14	15	16	Mean
		*	NS	NS	NS	NS	*	NS	*	*	NS	NS	NS
Lys		2.07	2.06	2.00	1.97	1.95	1.90	1.96	2.03	1.98	1.98	1.95	1.99
Protein		1.99	2.06	2.02	2.00	1.93	1.86	1.95	1.97	1.93	1.92	1.90	1.96
SEM		0.026	0.021	0.015	0.016	0.014	0.014	0.017	0.020	0.019	0.021	0.019	0.013
		NS	NS	NS	NS	*L	*Q	NS	**L	*L	NS	NS	*L
	High	2.02	2.05	1.98	1.95	1.90	1.87	1.93	1.96	1.91	1.92	1.90	1.94
	Moderate	2.02	2.08	2.01	2.00	1.96	1.85	1.95	1.98	1.96	1.95	1.93	1.97
	Low	2.06	2.05	2.03	1.99	1.96	1.92	1.99	2.06	2.01	1.98	1.94	2.00
	SEM	0.036	0.026	0.018	0.019	0.015	0.016	0.019	0.024	0.021	0.028	0.025	0.015
		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
	High	2.06	2.05	1.95	1.91	1.91	1.88	1.93	1.98	1.93	1.97	1.92	1.95
Lys	Moderate	2.06	2.05	2.00	1.97	1.96	1.89	1.95	1.99	1.98	1.96	1.94	1.98
	Low	2.11	2.07	2.04	2.02	1.98	1.95	2.01	2.12	2.04	2.02	1.99	2.03
	High	1.99	2.05	2.01	1.99	1.90	1.87	1.92	1.94	1.89	1.88	1.87	1.94
Protein	Moderate	1.98	2.10	2.03	2.03	1.96	1.82	1.95	1.97	1.93	1.95	1.92	1.97
	Low	2.00	2.03	2.02	1.97	1.94	1.89	1.98	2.00	1.97	1.94	1.90	1.97
	SEM	0.049	0.038	0.025	0.022	0.022	0.020	0.028	0.028	0.029	0.037	0.034	0.020

*(p<0.05), **(p<0.01), ***(p<.001), L=Linear effect, Q=quadratic effect

Table 12: Effect of method of formulation and diet on feed conversion (lbs feed/doz. eggs) in Experiment 2 (cool environment)

		Feed conversion (lbs feed/doz. eggs)											
		Week											
Formulation	Diet	2	4	6	8	10	11	12	13	14	15	16	Mean
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Lys		2.77	2.93	2.95	2.98	2.97	2.92	3.04	3.15	3.10	3.13	3.09	3.00
Protein		2.67	2.94	3.00	3.04	2.97	2.88	3.05	3.10	3.08	3.08	3.05	2.99
SEM		0.037	0.029	0.022	0.024	0.020	0.019	0.023	0.029	0.029	0.030	0.030	0.018
		NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
	High	2.71	2.92	2.95	2.98	2.94	2.91	3.02	3.07	3.03	3.07	3.04	2.97
	Moderate	2.72	2.97	2.99	3.04	3.00	2.87	3.05	3.12	3.11	3.14	3.09	3.01
	Low	2.73	2.91	2.98	3.00	2.97	2.93	3.07	3.18	3.13	3.10	3.08	3.01
	SEM	0.050	0.035	0.029	0.031	0.023	0.023	0.028	0.034	0.033	0.037	0.037	0.022
		NS	NS	NS	*	NS	NS	NS	NS	NS	NS	NS	NS
	High	2.73	2.92	2.91	2.91	2.94	2.90	3.01	3.10	3.03	3.12	3.07	2.97
Lys	Moderate	2.77	2.93	2.95	2.99	2.99	2.90	3.03	3.11	3.12	3.14	3.08	3.00
	Low	2.80	2.93	2.98	3.02	2.99	2.96	3.07	3.24	3.15	3.13	3.11	3.04
	High	2.69	2.93	2.98	3.04	2.93	2.92	3.03	3.05	3.04	3.02	3.02	2.97
Protein	Moderate	2.67	3.01	3.02	3.10	3.00	2.84	3.07	3.13	3.10	3.13	3.10	3.01
	Low	2.65	2.89	2.99	2.97	2.96	2.89	3.06	3.12	3.12	3.08	3.04	2.98
	SEM	0.070	0.052	0.040	0.037	0.035	0.031	0.042	0.047	0.050	0.053	0.055	0.032

*(p<0.05), NS(p<0.05)

An effect (p<0.05) of diet on egg weight was also observed. This effect was observed as early as week 6. Hens fed the denser diet produced heavier eggs. There was no interaction between method of feed formulation and diet based on egg weight.

Method of formulation had an effect (p<0.01) on the egg specific gravity, except during weeks 4 and 8 (Table 10). Hens fed the diets formulated based on Lys had a higher egg specific gravity than hens fed the diets formulated on protein. This was not observed in Exp 1. Diet had an effect on egg specific gravity during weeks 8. Birds fed high density diet had higher egg specific gravity than birds fed moderate diet. There was no interaction between method of feed formulation and diet based on egg specific gravity.

Method of feed formulation had an effect (P<0.05) on feed conversion based on g feed/g egg laid during weeks 1, 11, 13 and 14, with birds fed the diets formulated based on protein having lower feed conversion (Table 11). Even though birds fed diets formulated based on protein ate more feed than birds fed diets formulated based on Lys, the former laid more and larger eggs, offsetting the difference.

Diet also had an effect (p<0.05) on feed conversion based on g feed/g egg laid during weeks 10, 11, 13 and 14 as well as the 16-weeks mean. Birds fed the high density diets had better feed conversions than birds fed the low density diets. There was an interaction between

Table 13: Influence of method of formulation and diet on profits (¢ per doz.)[a] in Experiment 2 (cool environment)

		Price spread		
		(¢ per doz.)		
Formulation	Diet	3[b]	21[c]	30[d]
Lys	High	-4.88	-0.73	17.58
	Moderate	-4.38	1.08	17.87
	Low	-4.50	-0.27	16.01
Protein	High	-5.81	0.57	17.59
	Moderate	-5.13	1.32	18.44
	Low	-4.69	0.64	17.37

[a] = based on a feed price of $106.44 per ton for the high Lys diet, $102.65 per ton for the moderate Lys diet and $99.28 per ton for the low Lys diet and $114.40 per ton for the high protein diet, $ 109.11 per ton for the moderate protein diet and $104.70 for the low protein diet. [b]= based on an Urner Barry egg price of 12¢/doz. for check and peewee, 43¢/doz. for small, 56¢/doz. for medium, 59¢/doz. for large, 62¢/doz. for extra large and 65¢/doz. for jumbo eggs. [c] = based on an Urner Barry egg price of 18¢/doz. for check and peewee, 31¢/doz. for small, 47¢/doz. for medium, 68¢/doz. for large, 75¢/doz. for extra large and 103¢/doz. for jumbo eggs. [d] = based on an Urner Barry egg price of 31¢/doz. for check and peewee, 40¢/doz. for small, 57¢/doz. for medium, 87¢/doz. for large, 91¢/doz. for extra large and 110¢/doz. for jumbo eggs

method of feed formulation and diet based on feed conversion (g feed/g egg laid) during weeks 8. The high Lys diet had better feed conversion than the low Lys and the moderate protein diets.

Method of feed formulation had no significant effect on feed conversion based on lbs. of feed per doz. Eggs (Table 12). Diet also had no effect on feed conversion based on lbs. of feed per doz. Eggs. There was an interaction between method of feed formulation and diet on feed conversion (lbs. feed/doz. Eggs) during weeks 8. The high Lys diet had the best feed conversion and the moderate protein diet had the worst conversion.

Econometric feeding and management program developed by Roland *et al.* (1998) was used to calculate the most economical diet (Table 13). Current feed prices were used to determine profits. Price spreads between the medium and large eggs were 3, 21 and 30 cents/doz. The protein, Lys and Methionine consumed in the most economical diet were calculated to compare to the NRC (1994) recommendation.

The diet formulated based on Lys that gave most profits at all price spreads was the moderate Lys diet. However, diets formulated based on protein gave more profits than the diets formulated based on Lys. The moderate diet formulated based on protein gave the most profits when there was a 30 or 21 cents spread between the medium and large eggs. At the lowest price spread of 3 cents per doz., the low protein diet had more profit. Hens fed the moderate diet formulated based on protein consumed 1,100 mg/hen/d Lys, 789 mg/hen/d TSAA and 20.22 g/hen/d protein. The Lys value was 64% higher than the 670 mg Lys/hen/d recommended by the NRC (1994) and the protein value was 35% higher than the 15 g protein/hen/d recommended by the NRC (1994). Nutrient requirements were also calculated on a per gram of egg laid basis and were 20.1 mg Lys, 14.4 mg TSAA, 0.37 g protein and 5.66 kcal ME per g of egg.

Results clearly indicated that Bovans White hens can optimize production on a wide range of protein (Lys) and wide price spreads can occur due to differences in egg size, the nutrient levels required for optimal profits in Phase I varies with egg price. Therefore, because egg and feed prices continually vary, no fixed requirement for protein, Lys, TSAA or ME can be stated for optimal profits.

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