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Optimal Methionine + Cysteine / Lysine Ratio for First Cycle Phase 1 Commercial Leghorns

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Abstract: A study was conducted to determine the optimal methionine plus cysteine to lysine (Met+Cys/Lys) ratio in corn-soy diets of Hy-Line W-36 hens (wk 21-34) during Phase 1. Hens (n = 1,920; 21-wk old) were randomly divided into 12 groups of 160 hens per group (20 hens x 8 replicates for each treatment). Three levels of lysine (0.79, 0.87 and 0.97%) with four Met+Cys/Lys ratios (0.71, 0.75, 0.79 and 0.83) were used. Response criteria were egg production, feed consumption and egg weight. An interaction ($P < 0.001$) was observed between lysine (Lys) level and Met+Cys/Lys ratio on egg production, feed consumption and egg weight. Lowering the Met+Cys/Lys ratio in the lowest Lys diet (0.79%) had an adverse effect on egg production, feed consumption and egg weight, however there was little or no effect on these parameters in diets containing two higher Lys levels (0.87 and 0.97%). An economic analysis indicated that the optimal Met+Cys/Lys ratios for diets containing 0.97, 0.87 and 0.79% lysine were 0.71, 0.75 and 0.83, respectively. Results indicated that the current National Research Council (NRC, 1994) recommendation of 0.83 for the Met+Cys/Lys ratio was too high for diets containing higher lysine or protein levels required for low consuming hens at peak production. Egg producers using a Met+Cys/Lys ratio of 0.83 may be overfeeding synthetic methionine by as much as one pound or more per ton of feed.

Key words: Commercial layers, egg production, egg weight, lysine, methionine

Introduction

In, 1951, synthetic methionine (Met) became available for poultry diets. This allowed poultry producers to formulate diets based on amino acids (such as lysine (Lys) rates maintained as feed intake changes with no minimum protein specification. For example, when the Met+Cys value is divided by the Lys value, a ratio of 0.83 is obtained for every diet. This method of formulation based on Met+Cys/Lys ratio has been in use for the past 30 years. Formulating diets based on amino acids allows nutritionists to formulate diets closer to the animal's requirement, thereby reducing waste as well as cost.

Some management guidelines (Hy-Line, 1998-99) recommend a minimum protein value and also specify minimum Met+Cys and Lys values to give a Met+Cys/Lys ratio of 0.83. When the minimum protein specification is met in a practical corn-soy diet, more lysine is supplied than specified, resulting in a Met+Cys/Lys ratio closer to 0.68 than 0.83 (Hy-Line, 1998-99). NRC (1994) also explains in detail how to keep the ratio constant as the feed intake changes.

Although the nutrient requirements for maximum profits are influenced directly by feed and egg prices (De Grote, 1972; Hurwitz and Bornstein, 1978; Cunningham, 1984; Fisher, 1991; Zhang and Coon, 1996), many producers simply select one of the two methods (lysine versus protein) and formulate diets based on feed intake. Feed and egg prices are two major factors influencing profits, but many producers do not alter the method of feed formulation or diets as feed and egg prices change. Roland *et al.* (1995) recognized that price spreads in diets due to changing energy and protein cost were not influencing diets fed and developed an econometrics feeding and management program, which allows producers to switch methods of formulation and diets as feed and egg prices change. Based on research (Roland *et al.*, 1998), it has been concluded that there can be no fixed amino acid requirements as specified by NRC (1994) or management guides (Hy-Line, 1998) for maximum profits, because energy intake along with feed and egg prices influence requirements for maximum profits.

To develop the program, one of the first things needed was to reconfirm that diets formulated based on amino acids were most economical. Hens fed diets formulated based on protein for every diet comparison produced more and heavier eggs than hens fed diets formulated based on lysine (Sohail and Roland, 1997; Schutte *et al.*, 1988). Adding methionine to a lower protein diet should have an improved response equal to a higher protein diet (Schutte *et al.*, 1988). More importantly it was discovered that even though hens fed diets based on protein laid more and bigger eggs, they made less money when protein cost was high, but more when protein cost was low.

To optimize profits, one must switch diets and method of formulation as feed and egg prices and environmental temperature dictate (Roland *et al.*, 2000). Although many researchers reported that adding synthetic methionine to low protein diets was economical (Johnson and Fisher, 1958, Combs, 1962; Harms *et al.*, 1988; Waldroup and Hellwig, 1995), no papers indicated that adding methionine to give an 0.83-0.85 ratio to a high protein diets was economical or improved performance. We began to suspect that the Met+Cys/Lys ratio suggested or recommended by NRC (1994) and management guides, used by many producers for over 25 years, maybe incorrect. We believe the ratio was never determined in high protein diets. It was simply calculated in the mid, 1970's because of the concept of feeding based on intake.

Harms (1981) realized that hens eat more feed as temperatures become cooler. What hens really needed was just more energy not more protein. As a result, the concept of feeding based on intake was developed, saving producers millions. To maintain a constant nutrient intake as feed intake changed, nutritionists used the Met+Cys/Lys ratio that was determined using low protein diets and calculated what the nutrient level should be to maintain the same nutrient intake as feed intake changed. Originally, the Met+Cys/Lys ratio has never been determined for high protein diets required to achieve maximum production or egg weight with diets formulated based on lysine, it was important to determine the correct ratio using birds fed diets more typical of what is fed. Objectives of this study were to determine the ideal Met+Cys/Lys ratio (optimal quantity of methionine needed in corn-soy diets) for Hy-Line W-36 Leghorns, and to determine the economics of using additional synthetic methionine in diets varying in dietary protein.

Materials and Methods

Hy-Line W-36 hens (n = 1,920, 21-wk old) were used. Hens were arranged in a randomized complete block design with each treatment having eight replicates of 20 hens per replicate, housed four hens per cage (40.6 x 45.7cm) 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. Three levels of lysine (0.97, 0.87 and 0.79%) with four Met+Cys/Lys ratios (0.71, 0.75, 0.79 and 0.83) per Lys level were used in a 3 x 4 factorial arrangement of treatments (Table 1).

This experiment was conducted in a computer-regulated, environmentally-controlled house under warm conditions with an average daily temperature of approximately 25.6^{o}C (21.1^{o}C during the night and 28.9^{o}C during the day). A standard lighting program (16h light: 8h dark) with a light intensity of one foot candle was followed. Feed and water were supplied *ad libitum*. Feed consumption was recorded weekly for the 14-wk experiment. Egg production was summarized weekly. Egg weights were determined bi-weekly using all eggs collected for 2 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 increments. Mortality was recorded daily. Data were analyzed using the General Linear Models procedure of SAS (SAS Institute, 1986). The effects of Lys level, Met+Cys/Lys ratio, and the appropriate interactions were included in the model. Means were separated using Duncan's multiple range test (Duncan, 1955).

Results and Discussion

Lys had an effect ($P < 0.001$) on egg production (Table 2). Overall, egg production increased from 86.0-91.0% as the Lys level increased. Results were in agreement with previous research (Nathanael and Sell, 1980; Schutte *et al.*, 1982; Sohail and Roland, 1997). The Met+Cys/Lys ratio had an effect ($P < 0.001$) on egg production. Egg production increased from 87.0-90.0% as the ratio increased from 0.71-0.83.

There was an interaction ($P < 0.001$) between Lys and Met+Cys/Lys ratio for egg production as early as the fourth wk (Table 2). Based on the 14-wk average, this interaction occurred in the diet containing the lowest Lys level (0.79%). Egg production was significantly decreased by decreasing the Met+Cys/Lys ratio from 0.83-0.71 in the diet containing the lowest lysine level (0.79%), but there was very little response in reducing the Met+Cys/Lys ratio in the two higher Lys diets. Egg production decreased from 88-81%, when the Met+Cys/Lys ratio was reduced from 0.83-0.71 in the lowest Lys diet, or one percent from 92-91%, when reducing the Met+Cys/Lys ratio from 0.83-0.71 in the highest Lys diet. A seven fold greater decrease in egg production was observed by lowering the Met+Cys/Lys ratio in the low Lys diet than in the higher Lys diets. This indicated that the optimal Met+Cys/Lys ratio was not the same in the lower Lys diet as it was in the higher Lys diet, and that the ratio of 0.83 recommended by the NRC (1994) was too high for the higher lysine diets. Results supported the previous research that the Met+Cys/Lys ratio of 0.83 suggested by the NRC (1994) may be correct for low protein diets, but a low protein (Lys) diet would never be fed to hens coming into production. Reducing the ratio in the diets containing the two higher Lys levels had no adverse influence on egg production. Results were in agreement with the findings of Yadalam and Roland (1999). Harms and Miles (1988) also reported that as the Met+Cys/Lys ratio was increased in a low Lys diet, egg production increased. There was no increase in egg production above a Met+Cys/Lys ratio of 0.75.

Lys had an effect ($P < 0.05$) on feed consumption in wk 6 and 7 of this study (Table 3). During these wks, feed consumption increased as the Lys level was increased from 0.79-0.97%. The Met+Cys/Lys ratio had an effect ($P > 0.05$) on feed consumption during the first three wk, with feed consumption increasing with decreasing Met+Cys/Lys ratio.

Table 1: Ingredient and nutrient composition of experimental diets

%Lysine	0.97				0.87				0.79			
TSAA/Lys ratio	0.71	0.75	0.79	0.83	0.71	0.75	0.79	0.83	0.71	0.75	0.79	0.83
Ingredients												
Corn	59.41	59.34	59.27	59.19	63.89	63.82	63.75	63.69	67.46	67.40	67.34	67.28
SBOM(48%)	26.96	26.98	26.98	26.99	23.28	23.28	23.29	23.30	20.32	20.33	20.33	20.34
Limestone	5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.07	5.08	5.08	5.08	5.08
Hardshell	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Dicalcium phosphate	1.61	1.61	1.61	1.61	1.63	1.63	1.64	1.64	1.65	1.65	1.65	1.65
Poultry oil	1.88	1.92	1.95	1.98	1.13	1.14	1.17	1.19	0.49	0.51	0.54	0.56
Salt	0.45	0.45	0.45	0.45	0.46	0.46	0.46	0.46	0.45	0.45	0.45	0.46
Vitamin premix[1]	0.25	0.25	0.25	0.25	0.25	0.25	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	0.25	0.25	0.25	0.25	0.25	0.25
DL-Methionine	0.09	0.13	0.17	0.17	0.06	0.09	0.13	0.17	0.03	0.06	0.09	0.13
Calculated analysis												
ME(kcal/kg)	2827	2827	2827	2827	2827	2827	2827	2827	2827	2827	2827	2827
Protein (%)	18.05	18.05	18.05	18.04	16.67	16.66	16.66	16.66	15.56	15.55	15.56	15.55
Calcium (%)	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Total phosphorus	0.62	0.62	0.62	0.62	0.61	0.61	0.61	0.61	0.60	0.60	0.60	0.60
Available phosphorus	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Sodium (%)	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20	0.20
Met + Cys (%)	0.69	0.73	0.77	0.81	0.62	0.65	0.69	0.72	0.56	0.59	0.62	0.66
Lysine (%)	0.97	0.97	0.97	0.97	0.87	0.87	0.87	0.87	0.79	0.79	0.79	0.79

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

There was an interaction of Lys level and Met+Cys/Lys ratio on feed consumption as early as the fourth wk (Table 3). Based on the 14-wk average, the lowest Lys level was responsible for the interaction. A decrease in feed consumption was observed by decreasing the Met+Cys/Lys ratio from 0.83-0.71 in the lowest Lys level, but little or no response in the diets containing the two higher Lys levels. Feed consumption decreased from 85-80g feed/hen/d as the Met+Cys/Lys ratio decreased from 0.83-0.71 in the lowest Lys diet. This indicated that the optimal Met+Cys/Lys ratio was not the same in the lower Lys and higher Lys diets, and the ratio of 0.83 recommended by the NRC (1994) is too high for higher Lys diets. Results supported the earlier research that the Met+Cys/Lys ratio of 0.83 recommended by the NRC (1994) may be correct for low protein diets, but no one would feed a low protein diet to hens coming into production.

Increasing lysine from 0.79-0.97% had an effect ($P < 0.001$) on egg weight within one wk (Table 4). Average egg weight increased from 52.15-53.64g as Lys increased from 0.79-0.97%. Results were in agreement with previous studies (Nathanael and Sell, 1980; Roland *et al.*, 1998; Yadalam *et al.*, 1999).

There was also a significant interaction between Lys and the Met+Cys/Lys ratio on egg weight as early as the second wk of this study (Table 4). Based on the 14-wk average, the lowest Lys diet was responsible for this interaction. There was a decrease in egg weight because of decreasing the Met+Cys/Lys ratio from 0.83-0.71 in the lowest Lys level, but little or no response in diets containing the two higher Lys levels. Egg weight decreased from 52.58-50.89g as a result of reducing the Met+Cys/Lys ratio from 0.83-0.71 in the hens fed the lowest Lys diet, but was relatively consistent in hens fed diets containing the higher Lys levels. This indicated that the optimal Met+Cys/Lys ratio was not the same in the lower and the higher Lys diets, and that ratio of 0.83 recommended by the NRC (1994) is too high for the higher Lys diets. Results supported the previous research that the Met+Cys/Lys ratio of 0.83 recommended by the NRC (1994) may be correct for low protein diets, but a low protein diet would never be fed to hens coming into production.

Lys had no effect on average egg specific gravity (Table 5). However, the Met+Cys/Lys ratio had a significant effect on 14-wk average egg specific gravity and egg specific gravity decreased as the Met+Cys/Lys ratio increased from 0.71-0.83. There was no interaction between Lys and Met+Cys/Lys ratio on egg specific gravity.

Feed conversion (g feed/g egg) improved ($P < 0.01$) with increasing Lys level (Table 6). Met+Cys/Lys ratio had an effect ($P < 0.05$) on feed conversion during the fourth wk, with feed conversion improving as the Met+Cys/Lys ratio increased from 0.71-0.83. There was no interaction between lysine level and Met+Cys/Lys ratio on feed conversion.

An effect ($P < 0.01$) of Lys level on feed conversion (lbs. feed/doz/ eggs) was observed (Table 7). The Met+Cys/Lys ratio had a significant effect ($P < 0.05$) on feed conversion. Overall, feed conversion improved as Met+Cys/Lys ratio increased from 0.71-0.83. There was no interaction between Lys and Met+Cys/Lys ratio on feed conversion.

In summary, lowering the Met+Cys/Lys ratio in the lowest Lys diet (0.79%) had adverse effects on egg production, egg weight, and feed consumption, whereas lowering

Table 2: Effect of lysine level and total sulfur amino acid (TSAA)/lysine ratio on egg production (%)

		Week							
Treatment		1	2	3	4	5	6	7	8
Lysine(%)		*	***	***	***	***	***	***	***
0.97		84^{a}	92^{a}	94^{a}	93^{a}	93^{a}	93^{a}	91^{a}	91^{a}
0.87		82^{ab}	91^{a}	93^{a}	92^{a}	92^{a}	92^{b}	90^{a}	90^{a}
0.79		81^{b}	89^{b}	89^{b}	88^{b}	89^{b}	87^{c}	84^{b}	84^{b}
SEM		2.0	1.4	1.2	1.3	1.0	1.1	1.3	1.3
TSAA/Lys		NS	**	NS	***	**	***	***	***
0.71		82	89^{b}	91	90^{b}	90^{c}	89^{b}	85^{c}	85^{c}
0.75		82	90^{b}	91	90^{b}	91^{bc}	90^{b}	88^{b}	88^{b}
0.79		84	92^{a}	92	92^{a}	92^{ab}	92^{a}	90^{a}	91^{a}
0.83		84	92^{a}	93	93^{a}	92^{a}	92^{a}	90^{a}	90^{ab}
SEM		2.3	1.6	1.4	1.1	1.1	1.3	1.5	1.5
Lysine(%)	TSAA/Lys	NS	NS	NS	***	**	***	NS	NS
0.97	0.71	84	92	94	93	91	92	90	90
	0.75	83	90	93	92	92	92	90	90
	0.79	96	94	92	92	93	94	93	93
	0.83	85	94	95	95	94	95	91	91
0.87	0.71	83	90	93	92	92	92	86	86
	0.75	82	90	92	92	91	90	89	89
	0.79	82	91	92	94	92	91	92	93
	0.83	82	93	92	92	92	93	92	92
0.79	0.71	79	86	87	83	85	83	80	80
	0.75	79	90	89	86	89	87	85	85
	0.79	84	90	90	91	91	90	86	86
	0.83	84	90	91	91	91	90	86	86
SEM		3.9	2.8	2.4	2.5	2.0	2.3	2.6	2.6

Table 2: Continue

		Week						
Treatment		9	10	11	12	13	14	Mean
Lysine(%)		***	***	***	***	***	***	***
0.97		92^{a}	92^{a}	91^{a}	91^{a}	90^{a}	88^{a}	91^{a}
0.87		91^{a}	90^{a}	89^{a}	90^{a}	88^{a}	87^{a}	90^{b}
0.79		87^{b}	85^{b}	85^{b}	85^{b}	86^{b}	83^{b}	86^{c}
SEM		1.4	1.5	1.4	1.3	1.4	1.4	0.7
TSAA/Lys		***	***	***	***	***	***	***
0.71		88^{b}	87^{b}	84^{b}	86^{b}	86^{b}	83^{c}	87^{c}
0.75		90^{a}	89^{a}	88^{a}	89^{a}	87^{b}	86^{b}	88^{b}
0.79		91^{a}	91^{a}	90^{a}	90^{a}	89^{a}	88^{a}	90^{a}
0.83		92^{a}	90^{a}	89^{a}	90^{a}	90^{a}	87^{ab}	90^{a}
SEM		1.6	1.7	1.7	1.5	1.6	1.6	1.5
Lysine(%)	TSAA/Lys	***	***	***	**	***	***	***
0.97	0.71	93	93	91	90	92	90	91
	0.75	91	91	90	89	87	86	90
	0.79	92	92	92	92	90	89	92
	0.83	93	92	91	93	90	88	92
0.87	0.71	90	90	86	88	85	85	88
	0.75	91	91	89	90	88	88	89
	0.79	92	91	92	92	89	89	91
	0.83	93	90	89	90	90	87	91
0.79	0.71	80	77	76	79	81	75	81
	0.75	88	86	86	87	85	83	86
	0.79	88	89	88	87	88	86	88
	0.83	90	89	88	88	89	87	88
SEM		2.8	3.0	2.9	2.6	2.7	2.8	1.5

^{abc} = Means with no shared superscripts in a column are significantly different, P<0.05. *(P<0.05), **(P<0.01), ***(P<0.001).

Table 3: Effect of lysine level and total sulfur amino acid (TSAA)/lysine ratio on feed consumption (g/hen/d)

		Week						
Treatment		1	2	3	4	5	6	7
Lysine(%)		NS	NS	NS	NS	NS	*	*
0.97		75.1	80.3	84.4	83.4	85.9	85.7	85.0
0.87		74.3	79.6	84.7	83.6	85.9	86.1	85.1
0.79		74.5	79.1	83.6	83.1	86.2	84.1	83.2
SEM		0.45	0.48	0.44	0.43	0.63	0.55	0.51
TSAA/Lys		*	*	*	NS	NS	NS	NS
0.71		75.8	80.2	84.8	83.6	87.1	85.3	84.5
0.75		75.1	80.7	85.1	84.0	86.1	86.5	84.9
0.79		74.0	78.9	83.5	82.8	85.5	84.3	83.7
0.83		73.7	78.8	83.5	83.0	85.3	85.0	84.5
SEM		0.52	0.55	0.50	0.49	0.73	0.64	0.58
Lysine(%)	TSAA/Lys	NS	NS	NS	*	NS	**	***
0.97	0.71	76.2	81.7	85.4	84.6	87.8	88.1	88.3
	0.75	75.2	80.5	84.7	83.9	86.2	86.4	84.1
	0.79	74.8	80.3	84.2	82.8	85.4	84.3	84.4
	0.83	74.2	78.8	83.2	82.3	84.3	84.0	83.3
0.87	0.71	76.3	81.3	86.6	85.1	87.6	86.8	85.4
	0.75	75.0	80.7	85.3	83.9	85.0	85.9	84.6
	0.79	73.0	77.5	83.1	82.3	84.6	84.7	84.3
	0.83	73.1	79.0	83.7	83.0	86.5	86.8	85.9
0.79	0.71	74.8	77.8	82.4	81.0	85.8	81.0	79.9
	0.75	75.1	80.9	85.2	84.2	87.2	87.1	86.1
	0.79	74.3	78.9	83.2	83.4	86.6	83.9	82.6
	0.83	73.7	78.6	83.4	83.8	85.2	84.3	84.2
SEM		0.90	0.95	0.87	0.86	1.26	1.11	1.01

Table 3: Continue

		Week							
Treatment		8	9	10	11	12	13	14	Mean
Lysine(%)		NS	NS	NS	NS	NS	NS	NS	NS
0.97		89.3	86.5	87.4	85.4	87.0	85.4	85.7	84.8
0.87		90.4	86.6	87.2	84.9	86.3	85.0	85.7	84.7
0.79		88.5	85.4	85.7	85.1	85.3	84.0	84.7	83.7
SEM		0.60	0.61	0.67	0.64	0.65	0.55	0.61	0.39
TSAA/Lys		NS	NS	NS	NS	NS	NS	NS	NS
0.71		88.1	85.4	85.7	84.8	84.7	83.5	84.0	84.1
0.75		90.6	86.7	87.4	86.3	86.3	84.9	85.8	84.9
0.79		89.4	86.4	87.3	86.9	86.9	85.4	85.2	84.2
0.83		89.4	86.2	86.7	87.0	87.0	85.4	86.3	84.3
SEM		0.70	0.70	0.78	0.75	0.75	0.63	0.71	0.45
Lysine(%)	TSAA/Lys	**	**	***	*	***	***	***	***
0.97	0.71	91.6	89.6	90.8	88.5	89.7	88.5	88.9	87.1
	0.75	89.8	86.2	86.6	84.2	85.3	84.2	85.4	84.5
	0.79	88.0	85.4	86.8	84.7	87.2	84.7	84.6	84.1
	0.83	88.0	84.9	85.4	84.1	85.9	84.1	83.8	83.3
0.87	0.71	88.8	85.5	86.4	83.9	84.8	83.9	83.9	84.7
	0.75	90.4	86.5	87.6	84.9	86.3	84.9	85.9	84.8
	0.79	91.3	87.7	87.6	85.8	87.5	86.3	85.4	84.4
	0.83	90.8	86.8	87.1	85.0	86.7	85.0	87.4	84.8
0.79	0.71	83.8	81.1	79.8	82.1	79.6	77.9	79.3	80.4
	0.75	91.7	87.4	88.0	85.6	87.2	85.6	86.0	85.5
	0.79	89.0	86.1	87.3	85.3	86.1	85.3	85.6	84.1
	0.83	89.3	87.0	87.8	87.2	88.4	87.2	87.8	84.8
SEM		1.21	1.22	1.34	1.29	1.30	1.09	1.22	0.78

*(P<0.05), **(P<0.01), ***(P<0.001), NS (P<0.05).

he Met+Cys/Lys ratio in the higher Lys diets (0.87 and 0.97%) had no effect on egg production, egg weight or feed consumption. This indicated that the correct Met+Cys/Lys ratio was correct for a low protein diet, which would never be fed to today's laying hens, but was not correct for the higher protein diets. There are

Table 4: Effect of lysine and TSAA/lysine ratio on egg weight (g)

Treatment		Week 1	2	3	4	6	8	10	12	14	Mean
Lysine (%)		*	***	***	**	***	***	***	***	***	***
0.97		49.0	50.8	52.1	52.9	54.0	55.0	55.9	56.7	56.2	53.6
0.87		48.7	50.4	51.5	52.2	53.4	54.5	55.5	56.3	55.6	53.1
0.79		48.2	49.7	50.6	51.1	52.7	53.6	54.0	54.6	54.8	52.2
SEM		0.22	0.14	0.16	0.41	0.17	0.14	0.32	0.34	0.17	0.12
TSAA/Lys		NS	NS	NS	*	NS	**	NS	**	**	*
0.71		48.9	50.3	51.5	51.1	53.0	53.8	54.6	55.0	55.0	52.6
0.7		48.4	50.2	51.4	52.1	53.4	54.3	55.1	56.9	55.6	53.0
0.79		48.7	50.4	51.4	51.8	53.5	54.7	55.8	55.8	55.7	53.1
0.83		48.6	50.4	51.3	53.3	53.5	54.7	55.2	55.7	55.9	53.2
SEM		0.25	0.17	0.18	0.48	0.20	0.16	0.37	0.39	0.19	0.14
Lysine (%)	TSAA/Lys	NS	**	**	NS	*	**	NS	NS	***	***
0.97	0.71	49.6	51.5	52.9	52.4	54.5	55.1	56.3	57.0	57.0	54.0
	0.75	48.7	50.7	51.5	51.5	53.9	54.6	55.4	57.0	55.9	53.2
	0.79	48.9	50.7	52.2	52.1	54.1	55.4	56.6	56.6	56.0	53.6
	0.83	48.8	50.5	51.9	55.7	53.6	55.0	55.4	56.4	55.9	53.6
0.87	0.71	48.9	50.5	51.7	51.5	52.9	54.2	55.5	55.1	55.2	52.8
	0.75	48.4	50.3	51.6	52.8	53.3	54.4	55.3	58.3	55.5	53.3
	0.79	48.6	50.2	51.1	52.1	53.5	54.7	56.1	55.7	55.9	53.1
	0.83	49.0	50.6	51.5	52.4	53.8	54.7	55.2	56.0	55.9	53.2
0.79	0.71	48.3	48.9	49.8	49.5	51.6	52.2	52.0	52.8	52.9	50.9
	0.75	48.0	49.7	51.2	52.0	53.0	54.0	54.6	55.4	55.3	52.6
	0.79	48.7	50.3	50.8	51.2	52.8	53.9	54.6	55.2	55.3	52.5
	0.83	47.9	50.1	50.6	51.7	53.2	54.3	54.8	54.8	55.9	52.6
SEM		0.43	0.29	0.31	0.82	0.34	0.28	0.64	0.68	0.34	0.24

*(P<0.05), **(P<0.01), ***(P<0.001), NS(P<0.05)

Table 5: Effect of lysine and TSAA/lysine ratio on egg specific gravity

Treatment		Week 3	4	8	12	Mean
Lysine (%)		NS	NS	NS	NS	NS
0.97		1.0869	1.0852	1.0849	1.0831	1.0850
0.87		1.0872	1.0856	1.0853	1.0823	1.0851
0.79		1.0869	1.0855	1.0853	1.0824	1.0850
SEM		0.0002	0.0002	0.0002	0.0010	0.0003
TSAA/Lys (%)		NS	*	NS	NS	*
0.71		1.0871	1.0858	1.0856	1.0847	1.0858
0.75		1.0872	1.0857	1.0851	1.0828	1.0852
0.79		1.0870	1.0854	1.0849	1.0816	1.0847
0.83		1.0868	1.0848	1.0850	1.0814	1.0845
SEM		0.0002	0.0003	0.0002	0.0012	0.0003
Lysine (%)	TSAA/Lys (%)	NS	NS	NS	NS	NS
0.97	0.71	1.0872	1.0855	1.0856	1.0837	1.0855
	0.75	1.0877	1.0852	1.0849	1.0825	1.0851
	0.79	1.0863	1.0852	1.0847	1.0833	1.0849
	0.83	1.0865	1.0848	1.0846	1.0828	1.0847
0.87	0.71	1.0872	1.0857	1.0850	1.0844	1.0856
	0.75	1.0870	1.0858	1.0850	1.0831	1.0852
	0.79	1.0875	1.0854	1.0853	1.0835	1.0854
	0.83	1.0871	1.0853	1.0858	1.0783	1.0841
0.79	0.71	1.0870	1.0862	1.0862	1.0860	1.0864
	0.75	1.0868	1.0861	1.0854	1.0826	1.0852
	0.79	1.0871	1.0856	1.0848	1.0780	1.0840
	0.83	1.0867	1.0842	1.0848	1.0830	1.0847
SEM		0.0004	0.0005	0.0004	0.0020	0.0006

*(P<0.05), NS(P<0.05).

controversies regarding the Met+Cys requirement of laying hens. Estimated requirements are 0.53% (275 mg/hen/d; NRC (1994) or 0.45% (286 mg/hen/d; Moran *et al.*, 1967). Results of Roland *et al.* (1998) concluded that there can be no fixed Met+Cys requirement for maximum profits.

An economic analysis (Roland *et al.*, 1998) was conducted using the feed and egg prices at the time of this study. Results indicated that the optimal Met+Cys/Lys ratio was 0.71% for diets containing the 0.97% Lys, 0.75 for diets containing 0.87% Lys and 0.83 for diets containing the 0.79% Lys. This would lower the

Table 6: Effect of lysine and TSAA/lysine ratio on feed conversion (g feed/g egg)

		Week									
Treatment		1	2	3	4	6	8	10	12	14	Mean
Lysine (%)		*	**	*	***	NS	NS	**	**	**	**
0.97		1.82	1.90	1.85	1.83	1.79	1.87	1.72	1.70	1.74	1.80
0.87		1.87	1.94	1.90	1.89	1.85	1.91	1.76	1.76	1.79	1.85
0.79		1.93	2.03	1.97	1.99	1.83	1.89	1.87	1.87	1.88	1.91
SEM		0.028	0.030	0.030	0.026	0.032	0.039	0.031	0.031	0.028	0.025
TSAA/Lys		NS	NS	NS	*	NS	NS	NS	NS	NS	NS
0.71		1.89	1.96	1.88	1.97	1.85	1.84	1.81	1.80	1.83	1.87
0.75		1.92	1.95	1.93	1.91	1.83	1.92	1.79	1.73	1.81	1.87
0.79		1.85	1.97	1.93	1.88	1.83	1.91	1.78	1.77	1.78	1.86
0.83		1.83	1.94	1.88	1.85	1.78	1.89	1.75	1.76	1.79	1.83
SEM		0.032	0.034	0.034	0.030	0.036	0.045	0.036	0.033	0.032	0.029
Lysine (%)	TSAA/Lys	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
0.97	0.71	1.87	1.97	1.85	1.83	1.83	1.92	1.77	1.78	1.77	1.84
	0.75	1.86	1.90	1.90	1.90	1.86	1.91	1.74	1.69	1.78	1.84
	0.79	1.79	1.90	1.83	1.79	1.73	1.80	1.69	1.69	1.71	1.77
	0.83	1.78	1.84	1.80	1.79	1.73	1.87	1.68	1.65	1.71	1.76
0.87	0.71	1.82	1.89	1.86	1.91	1.81	1.83	1.70	1.74	1.76	1.81
	0.75	1.89	1.92	1.86	1.82	1.80	1.87	1.74	1.66	1.75	1.81
	0.79	1.95	2.05	2.05	1.98	2.01	2.11	1.86	1.84	1.85	1.97
	0.83	1.83	1.90	1.84	1.84	1.79	1.84	1.74	1.72	1.79	1.81
0.79	0.71	1.99	2.03	1.93	2.16	1.90	1.78	1.96	1.87	1.95	1.95
	0.75	2.01	2.05	2.02	2.00	1.83	1.99	1.90	1.84	1.92	1.95
	0.79	1.83	1.96	1.92	1.88	1.75	1.83	1.80	1.79	1.79	1.84
	0.83	1.89	2.08	1.99	1.92	1.82	1.95	1.84	1.90	1.86	1.92
SEM		0.056	0.059	0.060	0.052	0.063	0.078	0.062	0.057	0.056	0.051

*(P<0.05), **(P<0.01), ***(P<0.001), NS(P<0.05)

Table 7: Effect of lysine and TSAA/lysine ratio on feed conversion (lbs. feed/doz. eggs)

		Week									
Treatment		1	2	3	4	6	8	10	12	14	Mean
Lysine (%)		*	***	**	***	NS	NS	***	***	***	***
0.97		2.35	2.53	2.52	2.51	2.53	2.71	2.52	2.53	2.57	2.53
0.87		2.39	2.54	2.55	2.54	2.58	2.70	2.54	2.54	2.58	2.55
0.79		2.47	2.68	2.64	2.71	2.55	2.70	2.70	2.68	2.74	2.65
SEM		0.030	0.025	0.025	0.023	0.035	0.023	0.023	0.025	0.023	0.018
TSAA/Lys		NS	NS	NS	***	NS	NS	NS	NS	*	*
0.71		2.45	2.61	2.56	2.68	2.59	2.63	2.62	2.61	2.66	2.60
0.75		2.46	2.59	2.62	2.62	2.58	2.76	2.61	2.59	2.67	2.61
0.79		2.34	2.55	2.55	2.51	2.52	2.69	2.55	2.55	2.56	2.54
0.83		2.36	2.58	2.55	2.54	2.52	2.73	2.56	2.58	2.64	2.56
SEM		0.034	0.029	0.029	0.027	0.040	0.047	0.027	0.029	0.027	0.021
Lysine (%)	TSAA/Lys	NS	NS	NS	*	NS	NS	NS	NS	NS	NS
0.97	0.71	2.41	2.64	2.56	2.53	2.59	2.77	2.59	2.64	2.62	2.59
	0.75	2.38	2.53	2.56	2.60	2.62	2.73	2.52	2.53	2.62	2.56
	0.79	2.31	2.51	2.49	2.45	2.45	2.62	2.51	2.51	2.51	2.48
	0.83	2.31	2.45	2.47	2.48	2.46	2.72	2.46	2.45	2.52	2.48
0.87	0.71	2.470	2.55	2.56	2.62	2.55	2.63	2.53	2.55	2.58	2.55
	0.75	2.41	2.54	2.54	2.51	2.55	2.69	2.55	2.54	2.57	2.54
	0.79	2.36	2.52	2.58	2.51	2.66	2.82	2.55	2.52	2.54	2.56
	0.83	2.37	2.55	2.50	2.53	2.55	2.66	2.54	2.55	2.64	2.54
0.79	0.71	2.54	2.64	2.56	2.90	2.61	2.49	2.75	2.64	2.79	2.66
	0.75	2.59	2.72	2.76	2.75	2.58	2.86	2.77	2.72	2.81	2.73
	0.79	2.35	2.61	2.58	2.58	2.45	2.64	2.60	2.61	2.63	2.56
	0.83	2.40	2.75	2.66	2.62	2.55	2.81	2.67	2.75	2.75	2.66
SEM		0.059	0.050	0.046	0.046	0.069	0.081	0.047	0.050	0.047	0.037

*(P<0.05), **(P<0.01), ***(P<0.001), NS(P<0.05)

amount of synthetic Met added by 2.4lb./ton in the corn-soy diet containing 0.97% Lys, 1.6lb/ton in the 0.87% Lys diet, while remaining the same for the 0.79% diet based on the current NRC (1994) recommended ratio of 0.83. The current NRC (1994) suggestion of 0.83 for the Met+Cys/Lys ratio is too high for hens fed protein levels required by modern Phase I commercial laying hens. As a result many egg producers may be over-feeding synthetic Met by as much as one pound or more per ton of feed.

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