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An Evaluation of the Interaction of Lysine and Methionine in Diets for Growing Broilers[1]

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Abstract: Levels of lysine (Lys) and methionine (Met) in excess of NRC recommendations may result in enhanced performance, especially in regard to breast meat yield (BMY). Some people have interpreted the “ideal Protein” concept to suggest that amino acids such as Met should be kept in an “Ideal” ratio with Lys even though Lys may be in excess of actual needs. The objectives of this study were twofold: 1) to evaluate the effects of levels of Lys and Met in excess of NRC recommendations in diets of male broilers grown for further processing; 2) to determine if any interaction exists between levels of Lys and Met when minimum levels are exceeded. Three studies of identical design were conducted. Corn, soybean meal and corn gluten meal of known composition were used to formulate basal diets for 0 to 3, 3 to 6, and 6 to 9 wk which provided a minimum of 110% of NRC (1994) amino acid recommendations other than Lys, Met and TSAA which were at 100% of recommended levels. From the base diets, experimental diets were derived by additions of lysine HCl and DL methionine to provide a factorial arrangement with three levels of Lys (NRC, NRC + 0.15%, NRC + 0.3%) and four levels of Met and TSAA (NRC, NRC + 0.05%, NRC + 0.1%, NRC + 0.15%). Each of the 12 diets was fed to two (trial 1) or four (trial 2 and 3) replicate pens of 50 male broilers (Cobb 500). Birds were weighed and feed consumption determined at 3, 6, 7, 8, and 9 week. Samples of birds were processed at 7, 8, 9 wk for parts yield. Although significant differences in performance were noted among trials due to environmental temperature there was no trial x treatment interaction so data were combined. There were no significant interactions between Lys and Met for any parameter when both were fed equal to or in excess of NRC recommendations. Increasing Lys above NRC recommendations significantly improved BW and FCR at 21 d but not at later ages; BMY was improved by increasing Lys only at 63 d. Increasing Met above NRC significantly improved FCR at 42 and 56d; there was no significant effect of Met levels on BMY at any age. Results of this study suggest that people formulating diet on “Ideal Protein” basis should not elevate the level of Met if lysine is in excess of its minimum needs.

Key words: Broilers, lysine, methionine, carcass yield, breast meat

Introduction

A number of studies have been conducted to determine requirements of methionine and lysine for broiler chicks because they are considered the first two limiting amino acids in practical corn-soybean meal based diets, and are often supplemented in crystalline forms. Recent research has suggested that levels of lysine and methionine in excess of NRC (1994) recommendations may result in enhanced performance, especially in regard to breast meat yield (Hickling *et al.*, 1990; Moran and Bilgili, 1990; Schutte and Pack, 1995). Since lysine is set as the reference amino acid in the “Ideal protein” concept (Agricultural Research Council, 1981; Baker and Han, 1994), some people erroneously extrapolate the requirement for other amino acids by simply keeping the “ideal” ratio with lysine even though Lys may be in excess of actual needs. This may result in higher levels of essential amino acids than is actually needed.

Though numerous studies have been conducted on Met and Lys requirements, few studies have considered these two simultaneously, and the presence of a specific interaction between those two amino acids is inconclusive. The objectives of this study were twofold: 1) to evaluate the effects of levels of Lys and Met in excess of NRC recommendations in diets of male broilers grown for further processing; 2) to determine if any interaction exists between levels of Lys and Met when minimum levels of either amino acid are exceeded.

Materials and Methods

Three experiments with identical design were conducted to examine the interaction between lysine and methionine. Trial 1 started on May 13th and ended on July 17th, trial 2 was initiated on September 17th and concluded on November 19th, and trial 3 started on June

[1]Published with approval of the Director, Arkansas Agricultural Experiment Station, Fayetteville AR 72701. Mention of a trade name, proprietary product, or specific equipment does not constitute a guarantee or warranty by the University of Arkansas and does not imply its approval to the exclusion of other products that may be suitable.

Table 1: Composition (g.kg) and nutrient analysis of basal diets

Ingredient	Starter 0-21 d		Grower 21-42 d		Finisher 42-63 d	
Yellow corn	497.10		587.15		672.20	
Dehulled soybean meal	304.96		280.30		232.35	
Corn gluten meal	90.25		32.23		2.36	
Poultry oil	59.11		53.62		47.34	
Dicalcium phosphate	17.91		12.87		13.31	
Ground limestone	11.06		13.97		11.44	
Sodium chloride	4.57		4.57		4.57	
Vitamin premix[1]	2.00		2.00		2.00	
Trace mineral mix[2]	1.00		1.00		1.00	
DL-methionine (98%)	0.78		0.41		0.44	
Coban-60[3]	0.75		0.75		0.75	
L-Threonine	0.01		0.63		1.24	
L-Arginine	0.00		0.00		0.50	
BMD-50[4]	0.50		0.50		0.50	
Variable ingredients[5]	10.00		10.00		10.00	
Total	1000.00		1000.00		1000.00	
Nutrient	C[6]	A[7]	C	A	C	A
ME, kcal/kg	3200.00	---	3200.00	---	3200.00	----
CP, %	22.25	22.20	20.12	21.36	16.84	17.10
Met, %	0.50	0.52	0.38	0.38	0.32	0.33
Cys, %	0.40	0.41	0.34	0.37	0.28	0.35
Lys, %	1.10	1.13	1.00	0.98	0.85	0.87
Trp, %	0.25	---	0.25	---	0.25	---
Thr, %	0.88	0.98	0.81	0.81	0.75	0.82
Ile, %	0.95	1.03	0.84	0.79	0.68	0.74
His, %	0.57	0.56	0.53	0.46	0.45	0.45
Val, %	1.06	1.12	0.94	0.93	0.78	0.85
Leu, %	2.18	2.47	1.95	1.86	1.54	1.68
Arg, %	1.38	1.31	1.24	1.13	1.10	1.13
TSAA, %	0.90	0.92	0.72	0.75	0.60	0.68

[1]Provides per kg of diet: vitamin A 7714 IU; cholecalciferol 2204 IU; vitamin E 16.53 IU; vitamin B_{12} 0.013mg; riboflavin 6.6 mg; niacin 39 mg; pantothenic acid 10 mg; choline 465 mg; menadione 1.5 mg; folic acid 0.9 mg; thiamin 1.54 mg; pyridoxine 2.76 mg; d-biotin 0.066 mg; ethoxyquin 125 mg; Se 0.1 mg. [2]Provides per kg of diet: Mn (from $MnSO_4 \bullet H_2O$) 100 mg; Zn (from $ZnSO_4 \bullet 7H_2O$) 100 mg; Fe (from $FeSO_4 \bullet 7H_2O$) 50 mg; Cu (from $CuSO_4 \bullet 5H_2O$) 10 mg; I (from $Ca(IO_3)_2 \bullet H_2O$) 1 mg. [3]Elanco Animal Health division of Eli Lilly & Co., Indianapolis, IN 46285. [4]Alpharma, Fort Lee, NJ 07024. [5]Variable amounts of L-Lysine HCl, DL methionine and washed sand. [6]Calculated from NRC (1994) adjusted to CP and moisture content of intact ingredients. [7]Analyzed in duplicate within each trial by Degussa Corporation, Allendale NJ 07401.

8th and ended on August 10th. Birds in both trial 1 and 3 were subjected to hot weather when the trial was in session.

Diet formulation: Diets were formulated by linear programming for starter (0 to 21 days), grower (21 to 42 days), and finisher (42 to 63 days) periods. Corn, soybean meal, and corn gluten meal served as intact sources of crude protein. All these ingredients are considered to have good amino acid digestibility (NRC, 1994). The protein and moisture content of the feedstuffs used in this study were determined prior to formulation and their nutrient content adjusted accordingly. The same source of corn, soybean meal, and corn gluten meal were used in all three trials. A basal diet was formulated for each age period in which amino acids other than lysine, methionine, and TSAA were at a minimum of 110% of NRC (1994) recommended levels (Table 1). These three amino acids were calculated to be at 100% of their recommended levels. For each age period, a large batch of basal diet was prepared and aliquots used for mixing the diets. From this basal diet, twelve experimental diets were derived by additions of L-Lysine HCl and DL methionine to provide a factorial arrangement with three levels of lysine (NRC, +0.15%, +0.30%) and four levels of methionine and TSAA (NRC, +0.05%, +0.10%, +0.15%). The amount of DL methionine and lysine Hcl added to each test diet is

Table 2: Calculated and analyzed levels of supplemental lysine and methionine in test diets (mean of duplicate analyses from three trials)

Treatment	Lysine		Methionine	
	C[1]	A[2]	C	A
Starter diets (0-21 d)				
1	0.00	0.02	0.08	0.09
2	0.00	0.03	0.13	0.13
3	0.00	0.02	0.18	0.17
4	0.00	0.02	0.23	0.22
5	0.15	0.18	0.08	0.14
6	0.15	0.17	0.13	0.13
7	0.15	0.17	0.18	0.17
8	0.15	0.19	0.23	0.25
9	0.30	0.36	0.08	0.08
10	0.30	0.35	0.13	0.13
11	0.30	0.35	0.18	0.12
12	0.30	0.36	0.23	0.19
Grower diets (21-42 d)				
1	0.00	0.02	0.04	0.04
2	0.00	0.01	0.09	0.08
3	0.00	0.01	0.14	0.13
4	0.00	0.01	0.19	0.20
5	0.15	0.18	0.04	0.05
6	0.15	0.19	0.09	0.10
7	0.15	0.19	0.14	0.16
8	0.15	0.20	0.19	0.23
9	0.30	0.33	0.04	0.05
10	0.30	0.35	0.09	0.10
11	0.30	0.34	0.14	0.14
12	0.30	0.37	0.19	0.22
Finisher diets (42-63 d)				
1	0.00	0.00	0.04	0.04
2	0.00	0.00	0.09	0.11
3	0.00	0.02	0.14	0.14
4	0.00	0.00	0.19	0.18
5	0.15	0.16	0.04	0.04
6	0.15	0.17	0.09	0.09
7	0.15	0.17	0.14	0.16
8	0.15	0.16	0.19	0.18
9	0.30	0.31	0.04	0.05
10	0.30	0.28	0.09	0.08
11	0.30	0.33	0.14	0.15
12	0.30	0.31	0.19	0.17

[1]C = calculated value. [2]A = Analyzed in duplicate within each trial by Degussa Corporation, Allendale NJ 07401

shown in Table 2. The crude protein and metabolizable energy contributions of the amino acids (NRC, 1994) were considered in the formulation. Diets were adequately fortified with vitamins and trace minerals using supplements obtained from a commercial integrator. All diets were pelleted with steam; starter diets were fed as crumbles.

The basal diet for each period (starter, grower, and finisher) in each of the three trials was assayed for crude protein and total amino acids by a commercial[2] laboratory specializing in amino acid analyses. All twelve experimental diets within each age group in each of the three trials were assayed for supplemental amino acids by the same laboratory. The calculated and analyzed values for the test diets is presented in Table 1 with the calculated and analyzed values for supplemental levels

[2]Degussa Corporation, Allendale NJ 07401.

Table 3: Effect of levels of lysine and methionine on body weight of male broilers at different ages (combination of three trials with a total of ten pens of 50 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
21 d body weight (g)					
NRC	615	625	632	638	628[c]
NRC + 0.15%	691	701	668	670	683[a]
NRC + 0.30%	673	671	661	646	663[b]
Mean	660	666	654	651	
42d body weight (g)					
NRC	2,060	2,074	2,139	2,081	2,089
NRC + 0.15%	2,130	2,192	2,116	2,114	2,138
NRC + 0.30%	2,135	2,150	2,091	2,109	2,121
Mean	2,108	2,139	2,115	2,101	
49d body weight (g)					
NRC	2,595	2,563	2,633	2,596	2,579
NRC + 0.15%	2,584	2,674	2,629	2,573	2,615
NRC + 0.30%	2,649	2,674	2,601	2,592	2,629
Mean	2,609	2,637	2,621	2,587	
56d body weight (g)					
NRC	2,946	2,961	3,016	2,939	2,966
NRC + 0.15%	2,975	3,081	2,923	2,927	2,977
NRC + 0.30%	2,991	2,989	2,975	2,993	2,987
Mean	2,971	3,010	2,972	2,953	
63d body weight (g)					
NRC	3,344	3,304	3,402	3,294	3,336
NRC + 0.15%	3,344	3,440	3,275	3,243	3,326
NRC + 0.30%	3,375	3,383	3,372	3,360	3,373
Mean	3,354	3,376	3,350	3,299	
Probability >F					
Variable	21d	42d	49d	56d	
63d Lysine	0.0001	0.0695	0.5957	0.8393	0.5479
Methionine	0.4294	0.4607	0.5853	0.5669	0.5065
Lys x Met	0.2024	0.2376	0.5875	0.4619	0.5230
CV	5.05	5.40	6.71	5.69	5.65

[abc]Means in columns with common superscripts do not differ significantly ($P < 0.05$).

of Lys and Met presented in Table 2.

Birds and Housing: Day-old male chicks of a commercial broiler strain[3] were obtained from a local hatchery where they had been vaccinated in ovo for Marek's virus and had received vaccinations for Newcastle Disease and Infectious Bronchitis post hatch via a coarse spray. Fifty birds were randomly assigned to each of the 24 (Trial 1) or 48 (Trials 2 and 3) pens (56 ft^2) in a commercial-type poultry house with build up wood shaving litter over concrete floors. Each pen was equipped with two tube feeders and an automatic water fount. Incandescent lamps supplemented natural daylight to provide 23 hr light daily. The test feeds and tap water were provided for ad libitum consumption. Each dietary treatment was assigned to two pens (Trial 1) or four pens (Trial 2 and 3) of male broilers.

Measurements: Birds were group weighed by pen at 21, 42, 49, 56, and 63 d. Feed consumption was determined at the same intervals. Birds were checked twice daily for mortality; dead birds were weighed and the weight was used to adjust feed conversion ratio (FCR; total feed consumed divided by weight of live birds plus dead birds). At 49, 56, and 63 day of age, five birds from each pen that were within one-half standard deviation of the overall pen mean and free from visible defects were randomly chosen for processing. Feed but not water was withheld 12 hr prior to processing. At approximately 10 hr after feed withdrawal, birds were caught, placed in coops, and transported approximately 1 mile to the University pilot processing plant for slaughter and

[3]Cobb 500. Cobb-Vantress, Inc., Siloam Springs AR 72761.

Table 4: Effect of levels of lysine and methionine on feed conversion by male broilers at different ages (combination of three trials with a total of ten pens of 50 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
0 to 21 d feed conversion (g/g)					
NRC	1.414	1.395	1.366	1.374	1.387[a]
NRC + 0.15%	1.333	1.324	1.339	1.335	1.333[b]
NRC + 0.30%	1.372	1.360	1.362	1.390	1.371[a]
Mean	1.373	1.360	1.356	1.366	
0 to 42 d feed conversion (g/g)					
NRC	1.759	1.746	1.703	1.745	1.78
NRC + 0.15%	1.748	1.713	1.711	1.704	1.719
NRC + 0.30%	1.735	1.725	1.708	1.720	1.722
Mean	1.747[X]	1.728[XY]	1.707[Y]	1.723[XY]	
0 to 49 d feed conversion (g/g)					
NRC	1.879	1.876	1.840	1.857	1.863
NRC + 0.15%	1.920	1.848	1.819	1.850	1.859
NRC + 0.30%	1.857	1.843	1.822	1.865	1.847
Mean	1.885	1.856	1.827	1.857	
0 to 56 d feed conversion (g/g)					
NRC	2.030	2.028	1.995	2.012	2.016
NRC + 0.15%	2.039	1.998	1.997	2.003	2.009
NRC + 0.30%	2.031	2.017	1.970	1.994	2.003
Mean	2.033[X]	2.014[XY]	1.987[Y]	2.003[Y]	
0 to 63 d feed conversion (g/g)					
NRC	2.137	2.158	2.103	2.128	2.132[a]
NRC + 0.15%	2.144	2.096	2.086	2.112	2.110[ab]
NRC + 0.30%	2.102	2.105	2.073	2.094	2.094[b]
Mean	2.128	2.120	2.088	2.111	
Probability >F					
Variable	0-21 d	0-42 d	0-49 d	0-56 d	0-63 d
Lysine	0.0001	0.1590	0.6721	0.5859	0.0338
Methionine	0.4930	0.0207	0.0832	0.0225	0.1099
Lys x Met	0.2978	0.7188	0.7675	0.8875	0.8063
CV	3.41	2.74	4.51	2.74	2.92

[abc]Means in columns with common superscripts do not differ significantly ($P < 0.05$). [XY] Means in rows with common superscripts do not differ significantly ($P < 0.05$).

processing yield as described by Izat *et al.* (1991).

Statistical Analysis: Pen means served as the experimental unit. Data were first subjected to the analysis of variance (SAS Institute, 1991) as a factorial arrangement of trials and dietary treatments. No significant interactions between trials and dietary treatments were noted, so the data were pooled for final analysis as a factorial arrangement with the main effects of lysine, methionine, and the interactions of the two main effects. Mortality data were transformed to $\sqrt{n+1}$ prior to analysis; data are presented as natural numbers. Where significant differences were observed, treatment means were separated by repeated t tests using the lsmeans option of the GLM. Statements of significant differences among or between treatment means is based on a value of $P < 0.05$.

Results and Discussion

Analyzed values for total crude protein and amino acids of the basal diets were in close agreement with calculated ones (Table 1). Analyzed results of added levels of lysine and methionine also closely matched the calculated values (Table 2).

The effect of levels of lysine and methionine on bodyweight at different ages is shown in Table 3. No significant interactions were observed between Lys and Met for any parameter when both Lys and Met were fed equal or in excess of NRC (1994) recommendations. Increasing Lys above NRC (1994) recommendations significantly increased BW at 21 d but not at latter ages. Adding 0.15% of lysine to NRC recommended level resulted in significantly higher 21 d BW than either NRC recommendations or NRC + 0.30% lysine levels. Further adding 0.30% lysine to NRC level had no benefit, and

Table 5: Effect of levels of lysine and methionine on mortality by male broilers at different ages (combination of three trials with a total of ten pens of 50 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
0 to 21 d mortality (%)					
NRC	0.60	1.66	2.44	0.93	1.40
NRC + 0.15%	2.73	2.65	2.76	2.54	2.67
NRC + 0.30%	3.51	0.33	1.45	1.16	1.61
Mean	2.28	1.55	2.21	1.54	
0 to 42 d mortality (%)					
NRC	2.86	3.16	5.54	2.75	3.58^{b}
NRC + 0.15%	4.66	6.53	7.69	5.08	5.99^{a}
NRC + 0.30%	6.61	6.44	6.63	6.00	6.42^{a}
Mean	4.71	5.38	6.62	4.61	
0 to 49 d mortality (%)					
NRC	9.80	8.33	12.14	8.56	9.71
NRC + 0.15%	10.70	11.56	13.14	11.16	11.64
NRC + 0.30%	13.27	14.27	12.84	11.83	13.05
Mean	11.25	11.39	12.71	10.52	
0 to 56 d mortality (%)					
NRC	13.63	13.55	18.25	14.54	14.99
NRC + 0.15%	15.03	17.59	20.71	19.59	18.23
NRC + 0.30%	22.44	23.20	19.02	16.66	20.33
Mean	17.03	18.11	19.33	16.93	
0 to 63 d mortality (%)					
NRC	25.33	21.70	25.88	20.09	23.25
NRC + 0.15%	23.16	24.07	27.86	25.98	25.27
NRC + 0.30%	30.84	31.42	24.01	23.75	27.51
Mean	26.44	25.73	25.92	23.27	
Probability >F					
Variable	0-21 d	0-42 d	0-49 d	0-56 d	0-63 d
Lysine	0.1443	0.0233	0.4475	0.1206	0.2149
Methionine	0.6625	0.3660	0.9116	0.8399	0.6722
Lys x Met	0.3734	0.9592	0.9964	0.7143	0.4112
CV[1]	1.43	2.38	5.85	7.02	3.96

[1]CV of transformed means. [ab]Means in columns with common superscripts do not differ significantly ($P < 0.05$).

actually reduced BW significantly compared to the + 0.15% level but was still significantly greater than that of birds fed the NRC level. There was no significant effect of Met and TSAA levels on BW at any age.

The effect of levels of lysine and methionine on feed conversion at different ages is shown in Table 4. No significant interactions were observed between Lys and Met for any parameter when both Lys and Met were fed equal or in excess of NRC (1994) recommendations. The dietary lysine content significantly influenced FCR at 21 and 63 d but not at other ages. At 21 d, birds fed NRC + 0.15% Lys had a significantly improved FCR compared to the birds fed diets containing either NRC or NRC + 0.30% Lys. At 63 d there was a slight but nonsignificant improvement in FCR as a result of feeding NRC + 0.15% with a significant improvement over the NRC treatment as a result of feeding NRC + 0.30%. Increasing methionine above NRC significantly improved FCR at 42 and 56 d, but not at other periods. The addition of 0.10% Met significantly improved FCR at 42 and 56 d as compared to those fed NRC and was numerically improved at other ages. Birds fed diets with 0.05 or 0.15% greater levels of Met and TSAA were intermediate in FCR between those fed + 0.10% and NRC levels.

The effect of levels of lysine and methionine on mortality at different ages is shown in Table 5. No significant interactions were observed between Lys and Met for any parameter when both Lys and Met were fed equal or in excess of NRC (1994) recommendations. With one exception, levels of methionine and/or lysine did not affect incidence of mortality. At 42 d, increasing the Lys content of the diet resulted in increased mortality as compared to those fed the NRC level. This may have been due to the numerically higher weight of birds in these treatments, since it has been shown that heavier birds are more susceptible to heat stress (Dale and

Table 6: Effect of levels of lysine and methionine on processing parameters of male broilers at 49 d of age (combination of three trials with a total of ten pens of 5 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
Dressing percentage (%)					
NRC	68.62	67.96	68.80	69.04	68.61
NRC + 0.15%	69.48	69.05	68.51	69.98	69.25
NRC + 0.30%	69.08	68.92	69.09	68.77	68.96
Mean	69.06	68.64	68.80	69.27	
Breast yield (%)					
NRC	22.55	23.08	23.47	23.62	23.18
NRC + 0.15%	22.77	23.61	23.11	23.77	23.31
NRC + 0.30%	22.77	23.31	23.37	22.90	23.09
Mean	22.70	23.33	23.32	23.43	
Leg quarter yield (%)					
NRC	35.07	34.86	34.77	35.11	34.95
NRC + 0.15%	35.52	34.84	35.00	34.39	34.94
NRC + 0.30%	34.83	34.60	34.94	35.02	34.85
Mean	35.14	34.77	34.90	34.84	
Wing yield (%)					
NRC	11.68	11.69	11.65	11.66	11.67
NRC + 0.15%	11.81	11.49	11.71	11.41	11.60
NRC + 0.30%	11.85	11.43	11.78	11.62	11.67
Mean	11.78	11.54	11.71	11.56	
Abdominal fat (%)					
NRC	2.32	2.02	2.32	2.17	2.21
NRC + 0.15%	2.39	2.33	2.36	2.24	2.33
NRC + 0.30%	2.71	2.35	2.32	2.37	2.44
Mean	2.47	2.23	2.34	2.26	
Probability >F					
Variable	Dressing percentage	Breast yield	Leg quarter yield	Wing yield	Abdominal fat
Lysine	0.3425	0.7827	0.9368	0.8011	0.2379
Methionine	0.6230	0.2068	0.7439	0.1955	0.4208
Lys x Met	0.7941	0.8416	0.7876	0.7396	0.9167
CV	3.15	5.08	2.99	2.84	17.60

Fuller, 1979). The relatively high overall incidence of mortality at 56 and 63 d was due to the high ambient temperature coupled with the stress of weighing and handling birds in the first and third trials.

The effects of dietary treatments on processing characteristics at 49, 56, and 63 d are shown in Tables 6, 7, and 8, respectively. There were no significant interactions between lysine and methionine for any parameter when both were fed equal to or in excess of NRC recommendations. Increasing lysine above NRC recommendations significantly increased breast meat yield at 63 d, but not at 49 or 56 d. At 63 d, birds fed the highest level of lysine (NRC + 0.30%) had significantly higher breast meat yield than birds fed either NRC or NRC + 0.15% lysine; there was no significant difference in breast meat yield between those fed diets with NRC or NRC + 0.15% Lys. There was no significant effect of Met or TSAA levels ranging from NRC to NRC + 0.30% on breast meat yield, abdominal fat content, dressing percentage, wing yield, or leg quarter yield.

One of the first reports suggesting that amino acid levels in excess of NRC recommendations improved breast meat yield was that of Hickling *et al.* (1990), who fed broilers a combination of two Met levels (100 or 116% of 1984 NRC) with four levels of Lys (100, 106, 112, or 118 of 1984 NRC). Increasing Met, but not Lys, significantly improved BW and FCR at 6 wk but not at 3 wk. It is interesting that increasing Lys levels did not improve FCR, as some have suggested that the requirement of Lys or Met for maximum breast yield is equal or greater than that for maximum FCR (Han and Baker, 1994; Schutte and Pack, 1995). Hickling *et al.* (1990) noted "the effects of Lys on breast meat yield were inconclusive". Increasing Lys in diets containing the NRC level of Met

Table 7: Effect of levels of lysine and methionine on processing parameters of male broilers at 56 d of age (combination of three trials with a total of ten pens of 5 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
Dressing percentage (%)					
NRC	71.04	71.12	70.69	70.98	70.96
NRC + 0.15%	71.39	70.82	71.76	71.84	71.45
NRC + 0.30%	71.34	71.49	71.96	71.49	71.57
Mean	71.25	71.14	71.47	71.44	
Breast yield (%)					
NRC	23.07	23.06	23.34	23.09	23.14
NRC + 0.15%	22.81	23.66	23.36	23.53	23.34
NRC + 0.30%	22.82	23.46	23.74	23.84	23.46
Mean	22.90	23.39	23.48	23.49	
Leg quarter yield (%)					
NRC	34.70	34.81	34.21	34.32	34.51
NRC + 0.15%	34.63	34.31	34.53	34.42	34.47
NRC + 0.30%	34.59	34.03	34.99	34.67	34.57
Mean	34.64	34.38	34.58	34.47	
Wing yield (%)					
NRC	11.49	11.49	11.61	11.44	11.50
NRC + 0.15%	11.40	11.27	11.36	11.31	11.33
NRC + 0.30%	11.52	11.40	11.31	11.26	11.37
Mean	11.47	11.39	11.43	11.33	
Abdominal fat (%)					
NRC	2.39	2.34	2.20	2.37	2.33
NRC + 0.15%	2.52	2.28	2.39	2.38	2.39
NRC + 0.30%	2.50	2.31	2.39	2.51	2.43
Mean	2.47	2.31	2.33	2.42	
Probability >F					
Variable	Dressing percentage	Breast yield	Leg quarter yield	Wing yield	Abdominal fat
Lysine	0.2210	0.5704	0.9615	0.1845	0.6997
Methionine	0.8466	0.2988	0.9252	0.6528	0.6320
Lys x Met	0.8328	0.9045	0.8375	0.9202	0.9887
CV	3.55	6.85	3.09	2.71	17.79

did not influence breast meat yield; increasing Lys in diets with 116% NRC Met first increased and then decreased breast yield. Data from the present study does not indicate any interaction between Lys and Met and TSAA, and suggests that NRC recommended levels of Lys, Met, and TSAA are adequate for maximum breast meat yield of broilers grown to 56 d.

Although it has been demonstrated that the level of Lys needed to optimize feed conversion and breast yield is greater than that required for growth, there is little indication that NRC (1994) recommended levels are inadequate. Moran and Bilgili (1990) fed male and female birds of a commercial strain cross (not identified) from 28 to 42 d on a low-Lys (0.85%) diet based on sesame meal, or fortified with Lys to provide diets with 0.95 or 1.05% Lys compared to the NRC (1994) recommendation of 1.0% for this period. Both sexes responded similarly to Lys fortification. Body weight gain between 28 and 42 d was not influenced by Lys level; however FCR was reduced in a linear manner as Lys increased. As there was no quadratic response it is difficult to ascertain as to whether levels in excess of 1.05% Lys were required to minimize FCR. Breast meat as percent of either chilled or cooked carcass was increased linearly as Lys increased; again one is not able to determine if Lys in excess of 1.05% would result in further increases. This paper demonstrates that breast meat yield is influenced by Lys level, but does not necessarily provide evidence that levels in excess of NRC are necessary to maximize yield as there was no intermediate level between 0.95 and 1.05%.

Han and Baker (1994) examined the digestible Lys requirement of male and female broilers from 22 to 43 d post hatch. Their estimates of digestible amino acid

Table 8: Effect of levels of lysine and methionine on processing parameters of male broilers at 63 d of age (combination of three trials with a total of ten pens of 5 male broilers per treatment)

Lysine	Methionine/TSAA				
	NRC	NRC + 0.05%	NRC + 0.10%	NRC + 0.15%	Mean
Dressing percentage (%)					
NRC	72.23	71.53	73.63	73.05	72.61
NRC + 0.15%	71.57	70.52	73.86	71.38	71.83
NRC + 0.30%	72.41	72.69	72.68	72.52	72.58
Mean	72.07	71.58	73.39	72.32	
Breast yield (%)					
NRC	23.89	23.31	23.40	23.42	23.51[b]
NRC + 0.15%	23.85	23.46	23.45	23.38	23.54[b]
NRC + 0.30%	23.90	24.74	23.37	24.78	24.20[a]
Mean	23.88	23.84	23.41	23.86	
Leg quarter yield (%)					
NRC	35.12	35.73	35.15	34.50	35.12
NRC + 0.15%	34.71	34.87	34.75	35.65	34.99
NRC + 0.30%	34.78	34.17	34.64	34.35	34.48
Mean	34.87	34.92	34.85	34.83	
Wing yield (%)					
NRC	11.22	11.46	11.32	11.54	11.38
NRC + 0.15%	11.32	11.16	11.62	11.08	11.30
NRC + 0.30%	11.38	11.02	11.36	11.17	11.23
Mean	11.31	11.21	11.43	11.26	
Abdominal fat (%)					
NRC	2.34	2.42	2.39	2.32	2.37
NRC + 0.15%	2.44	2.47	2.42	2.34	2.42
NRC + 0.30%	2.57	2.58	2.78	2.28	2.55
Mean	2.45	2.49	2.53	2.32	
Probability >F					
Variable	Dressing percentage	Breast yield	Leg quarter yield	Wing yield	Abdominal fat
Lysine	0.4417	0.0298	0.1428	0.3182	0.3860
Methionine	0.1435	0.3948	0.9962	0.2627	0.5651
Lys x Met	0.6966	0.2595	0.3793	0.0854	0.9367
CV	3.27	6.64	3.17	3.57	18.91

[ab]Means in columns within a variable with common superscripts do not differ significantly (P < 0.05)

needs were 0.85 and 0.78% for BW gain and 0.89 and 0.85% for optimum FCR for males and females, respectively. They concluded that the Lys requirement for maximal breast meat yield was not greatly different from that predicted for FCR. They translated the digestible requirement for optimal FCR and breast yield on a corn-soybean meal type diet to a total Lys requirement of 1.01 % for males, 0.97% for females, or 0.99% for mixed sexes, in close agreement with the NRC (1994) recommendation of 1.0% total Lys.

Fewer reports have examined the role of methionine in breast meat yield. The study by Hickling *et al.* (1990) indicated that Lys above NRC levels did not improve breast meat yield unless Met was also greater than suggested by NRC. However, only two Met levels were compared (NRC, and 116%). Moran (1994) fed two strains of broilers (Ross x Ross; Steggles x Arbor Acres) diets either “deficient” or “adequate” in methionine from 0 to 8 wk with processing at both 6 and 8 wk. The low methionine diets reduced BW and breast yield and increased abdominal fat at 6 wk but not at 8 wk of age. The “deficient” diets fed from 6 to 8 wk were very near to the NRC (1994) requirement. Wallis (1999) demonstrated a response in breast meat yield to Met supplementation of a deficient diet but did not make any estimates about requirements for maximum yield.

One of the few reports that attempt to titrate a Met requirement to optimize breast yield was that of Schutte and Pack (1995). Feeding a range of Met or TSAA levels from 14 to 38 d, they estimated a TSAA requirement of 0.84% for BW gain, 0.88% for FCR, and 0.89% for breast yield. This again points out that feeding for optimum

FCR should optimize breast yield, in agreement with Han and Baker (1994). It is difficult to compare the recommendations of Schutte and Pack (1995) to NRC (1994) as different time periods are involved. As birds grown in the U. S. for further processing are typically grown to ages beyond 38 d, the application of these results to commercial U. S. Broiler production is minimal.

There is no question that breast meat yield, representing a major portion of the protein synthesis in the body, is sensitive to amino acid status of the diet. Broiler strains that emphasize breast meat yield should be expected to require higher levels of Lys than strains bred primarily for gain. Amino acid levels that optimize feed conversion appear to be similar to those needed to optimize breast meat yield. Results of the present study suggest no significant interactions between lysine and methionine when they were equal or in excess of NRC (1994) recommendations. The results imply that people formulating diets on the "Ideal Protein" basis should not elevate the level of Met if Lys is in excess of its minimum needs.

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