Utilizing L-Threonine in Practical Corn/Soy Broiler Diets

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ABSTRACT

L-Threonine is now commercially available in the United States in sufficient quantities and at a price that makes it feasible and cost effective to use in broiler feeds. Since threonine is next limiting after methionine and lysine in US type diets, L-threonine allows nutritionists to formulate more precise feeds, thereby lowering crude protein levels. In addition to the financial advantages of offering L-threonine as an ingredient, the move toward mandating lower nitrogen emissions in the United States is inevitable. In order to meet these limits the broiler industry will need to either reduce the number of birds placed or implement feeding practices that minimize the feeding of excess crude protein (nitrogen). These restrictions must be accomplished while still optimizing performance so that the industry remains competitive with international markets. Crystalline amino acids are commercially available to do this, but unfortunately, there is still a common belief that lowering the crude protein level negatively affects performance. The availability of L-Threonine, in conjunction with crystalline Lysine and Methionine, now offer the opportunity to lower feed cost and reduce excess crude protein levels of broiler feeds.

This paper is a summary of two studies from a series of studies that were conducted to demonstrate that L-Threonine can be successfully used in practical US type corn/ soy broiler diets. The studies were conducted using commercial strains of broilers chickens, and closely followed current industry norms such as, stocking densities, lighting programs etc. Corn-soy, poultry meal diets were used in all studies.

A similar design was used in the studies. Control diets, which closely followed current US diets in composition, energy, digestible amino acid levels and feeding program, formed the benchmark for comparison. The test diets were formulated to the same minimum digestible nutrient specifications. L-Threonine was then allowed to least cost into the diets until the next most limiting amino acids (isoleucine, valine, tryptophan) limited further reduction of intact protein. Crude protein levels of test diets were between 1 and 1.5 percentage points lower than the control diets. Digestible amino acids levels were set at ratios to lysine; threonine was set at a ratio of either 65% or 70% to lysine. The usual performance measurements were made during the growing period and carcass yields were measured at termination.

The results of the studies showed that the lower crude protein, L-Threonine supplemented broiler diets resulted in similar and in some cases slightly improved performance; body mass, feed conversion ratios and carcass yields. Financial returns were higher in the L-Threonine treatments. Birds also responded positively to the higher threonine levels. In one experiment additional L-Lysine.HCl was added to the treatments, positive responses were seen to the added lysine, which indicates that current US broiler feeds are marginal in lysine.

L-Threonine can be successfully used in practical broiler feeds. This results in lower crude protein feeds with a more ideally balanced amino acid profile as well as lower feed cost.

INTRODUCTION

Animal agriculture is under increasing pressure to lower production costs and reduce waste products, primarily nitrogen and phosphorous, from entering the environment. Amino acid manufacturers have recognized the significant role crystalline amino acids can play in lowering feed costs and when using them to precision feed, excess crude protein (nitrogen and ammonia) is significantly reduced.

Tremendous strides have been made in commercializing essential amino acids for these purposes. L-Threonine has been produced for some time, but production is currently being expanded which will ensure sufficient supply at a significantly lower cost. This will allow it to be used in practical, least cost US broiler diets.

The current trend to lower nitrogen excretion (in litter and air emissions) is forcing our industry to look for ways to minimize the feeding of excess crude protein in broiler feeds, while still maintaining adequate levels of amino acids to optimize performance.

Unfortunately, there is still a common belief that whenever crude protein levels are lowered performance is negatively affected. This is a result of a number of studies where researchers have lowered crude protein levels beyond practical formulation levels Neto *et al.,* 2000; Bregendhahl *et al.,* 2002 and then failed to supplement all limiting amino acids to sufficient levels. In some cases crude protein levels were lowered without supplementing amino acids other than lysine and methionine. Studies where practical diets, with reasonable crude protein reduction and care taken to maintain essential amino intake showed no significant differences in growth rate, body composition or breast meat yield Hai and Blaha, 1998; Hai and Blaha, 2000; MacLeod *et al.* 2003.

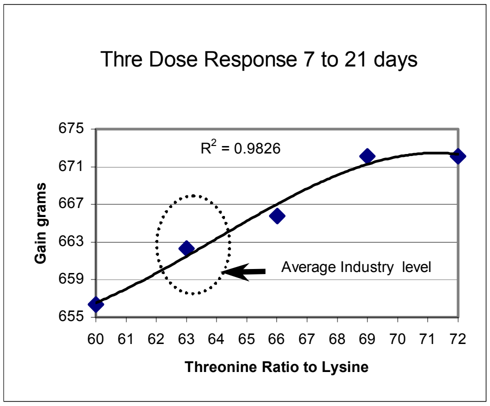
The objective of this research is to demonstrate to the broiler industry in the US that by embracing these technologies we can move toward lower crude protein, more efficient feed formulation, and achieve the same level of performance at a lower cost of meat.

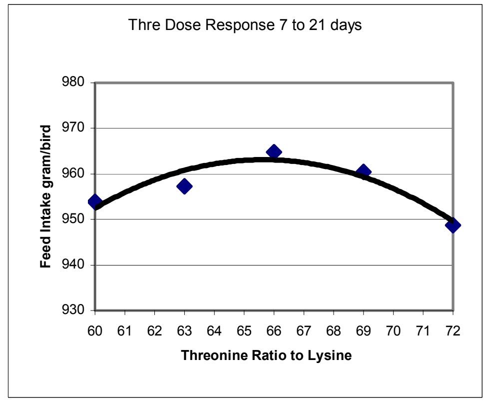
Defining Threonine Levels

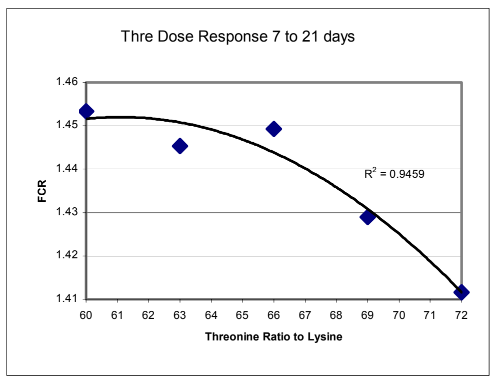
In order to effectively use L-Threonine it is critical that the threonine requirement be established. However, defining the requirements of the next limiting amino acids, valine, isoleucine, tryptophan and arginine is critical since they define the maximum replacement of intact protein (soybean meal, meat meal) with crystalline amino acids.

Prior to 1990 not much work was done on defining threonine dose response curves, however, since then various researchers have published threonine requirements for broiler chickens, (Baker *et al*., 1994; Kidd *et al*., 1996; Webel *et al*., 1996; Kidd and Kerr, 1996; Penz *et al*., 1997; Kidd *et al*., 1999; and Barkley and Wallis, 2001; Baker *et al*., 2002). In all of these trials use was made of the graded supplementation (additive) technique to measure the response to threonine. But for a few exceptions "total" rather than "digestible" threonine values were presented, this has a significant impact when considering that the basal test diets have low threonine levels from intact protein (80% digestible) and high crystalline threonine levels (100% digestible). This artificially skews the threonine dose response. Furthermore some of the researchers used semi-purified diets, which introduces the question of whether all other amino acid needs are being met and brings into question the validity of the threonine dose response curve.

A study, using a practical corn/ soy diet, was conducted at Univ. of Kentucky to establish the ratio of threonine to lysine. Ingredients were analysed and digestibility coefficients (Ajinomoto Heartland, 2001) were applied to these values. The basal feed, containing 1.0% digestible lysine, similar to a commercial broiler grower diet was formulated. To ensure threonine was first limiting up to the highest threonine level, DL-Methionine, L-Isoleucine, L-Valine, L-Arginine and L-Tryptophan were added to bring those amino acids up to 105% of minimum formulated levels. Birds in this study were housed in pullet rearing cages, 10 per cage with 6 replications per threonine level.







This study indicates that broiler chickens respond to higher levels of threonine than is currently being fed. General observations are that industry nutritionists are formulating, on a digestible basis, at between a 62 to 64 threonine to lysine ratio. Of particular interest is the effect of the higher threonine levels on improved FCR, this response has been seen in a number of studies, the latest being Dozier *et al.* 2003.

The reason that the industry nutritionists are formulating to these low threonine levels may be due to the industry's obsession with minimizing feed cost. Since threonine is the next limiting amino acid after methionine and lysine, it is a pressure point and without crystalline threonine being available, relaxing the constraint resulted in lower feed costs. Floor-pen and commercial studies have shown that this practice has lowered feed cost, but has resulted in lower profitability.

Practical studies to asses L-Threonine as a viable ingredient

A series of studies were conducted, with practical corn/ soy diets, to determine the point at which replacement of intact protein sources with crystalline amino acids negatively affected performance.

Study 1

The objective of the study was to confirm that L-Threonine can be used in practical US type corn/ soy broiler diets to replace threonine from intact protein and secondly to determine at what point the next limiting amino acid, after methionine, lysine and threonine becomes limiting.

MATERIAL AND METHODS

Industry nutrient specifications, feeding programs and ingredient inclusion levels were used as the foundation for the studies. The basal diets were formulated using industry digestible lysine levels; the next 7 most limiting essential amino acids were set at a ratio to lysine Appendix 1. The diets contained corn, soy, poultry or meat meal, fat, DL-Methionine and L-Lysine.HCl.

The test diets were formulated to the same minimum digestible amino acid levels as the control diet, poultry meal was fixed and L-threonine was allowed to least cost into the diet up to the point of the next limiting amino acid. This resulted in a crude protein reduction of around 1.2% points and an inclusion of about 600 grams of L-threonine per metric ton of feed. These two diets were then blended together to give a number of intermediate diets to create a dilution series. The object was to see if and at what point performance was negatively affected.

The idea being that with the exception of methionine, lysine and threonine that were fixed, all other amino acids were lowered with every dilution, an effect on performance would indicate that an amino acid other than these three had become limiting. This method would not identify which amino acid was limiting, but it offered a practical method of determining the maximum reduction in essential amino acid levels.

Ross x Ross 308 commercial broilers were used in the study.

Treatment	1	2	3	4	5
	Start Basal	Start 150	Start 300	Start 450	Start 600
Corn	60.0	61.2	62.4	63.5	64.7
Soybean	30.1	29.0	27.9	26.9	25.8
Poult Meal	3.5	3.5	3.5	3.5	3.5
Feed Fat	2.7	2.6	2.4	2.2	2.1
L-Lys	0.083	0.117	0.151	0.184	0.218
DL-Meth	0.201	0.211	0.220	0.230	0.239
L-Thr	0.0	0.015	0.03	0.045	0.06
Other	3.4	3.4	3.4	3.4	3.4
Cost	127.02	126.84	126.65	126.47	126.28
ME kcal/kg	3100	3100	3100	3100	3100
Protein	21.64	21.28	20.93	20.57	20.21
Arginine	1.52	1.49	1.46	1.42	1.39
Dig. Arg	1.30	1.27	1.24	1.21	1.18
Isoleucine	0.87	0.85	0.84	0.82	0.80
Dig. Ile	0.82	0.80	0.79	0.77	0.75
Lysine	1.24	1.24	1.24	1.24	1.24
Dig. Lys	1.10	1.10	1.10	1.10	1.10
Meth	0.58	0.58	0.59	0.59	0.59
Dig. Meth	0.52	0.52	0.52	0.53	0.53
M+C	0.94	0.94	0.94	0.94	0.94
Dig M+C	0.82	0.82	0.82	0.82	0.82
Thr	0.83	0.83	0.83	0.83	0.83
Dig. Thr	0.72	0.72	0.72	0.72	0.72
Trp	0.23	0.23	0.22	0.22	0.21
Dig. Trp	0.21	0.20	0.20	0.19	0.19
Valine	1.00	0.98	0.96	0.94	0.92
Dig. Val	0.91	0.90	0.88	0.86	0.84
Glycine	1.00	0.98	0.95	0.93	0.90
Avail. Phos	0.45	0.45	0.45	0.45	0.45
Calcium	1.00	1.00	1.00	1.00	1.00
Sodium	0.18	0.18	0.18	0.18	0.18

***The shaded area indicates minimum amino acid requirement

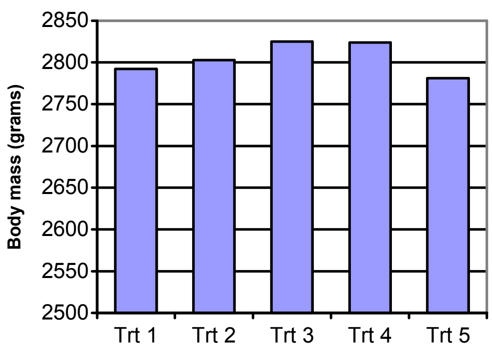
Treatment	1	2	3	4	5
	Grow Basal	Grow 150	Grow 300	Grow 450	Grow 600
Corn	63.1	64.2	65.4	66.6	67.7
Soybean	27.2	26.1	25.1	24.0	23.0
Poult Meal	3.5	3.5	3.5	3.5	3.5
Feed Fat	3.0	2.8	2.6	2.5	2.3
L-Lys	0.047	0.081	0.114	0.148	0.181
DL-Meth	0.157	0.166	0.175	0.184	0.193
L-Thr	0.00	0.015	0.030	0.045	0.060
Other	3.0	3.0	3.0	3.0	3.0
Cost	121.83	121.64	121.44	121.25	121.05
ME kcal/kg	3150	3150	3150	3150	3150
Protein	20.48	20.12	19.76	19.4	19.04
Arginine	1.43	1.40	1.37	1.33	1.30
Dig. Arg	1.22	1.19	1.16	1.13	1.10
Isoleucine	0.82	0.80	0.79	0.77	0.75
Dig. Ile	0.77	0.76	0.74	0.72	0.70
Lysine	1.14	1.14	1.14	1.13	1.13
Dig. Lys	1.00	1.00	1.00	1.00	1.00
Meth	0.52	0.52	0.53	0.53	0.53
Dig. Meth	0.46	0.46	0.47	0.47	0.48
M+C	0.87	0.87	0.87	0.87	0.87
Dig M+C	0.75	0.75	0.75	0.75	0.75
Thr	0.79	0.79	0.79	0.78	0.78
Dig. Thr	0.68	0.68	0.68	0.68	0.68
Trp	0.21	0.21	0.210	0.20	0.19
Dig. Trp	0.19	0.19	0.18	0.18	0.17
Valine	0.95	0.93	0.91	0.89	0.87
Dig. Val	0.87	0.85	0.83	0.81	0.80
Glycine	0.93	0.91	0.89	0.87	0.86
Avail. Phos	0.43	0.43	0.43	0.43	0.43
Calcium	0.90	0.90	0.90	0.90	0.90
Sodium	0.18	0.18	0.18	0.18	0.18

Treatment	1	2	3	4	5
	Finish Basal	Finish 150	Finish 300	Finish 450	Finish 600
Corn	69.7	70.7	71.78	72.8	73.8
Soybean	20.4	19.5	18.6	17.6	16.7
Feed Fat	3.1	3.0	2.8	2.7	2.5
L-Lys	0.064	0.094	0.123	0.153	0.182
DL-Meth	0.106	0.114	0.123	0.131	0.139
L-Thr	0.00	0.01	0.03	0.04	0.053
Other	3.0	3.0	3.0	3.0	3.0
Cost	115.92	115.76	115.60	115.44	115.28
ME kcal/kg	3225	3225	3225	3225	3225
Protein	17.79	17.48	17.16	16.85	16.53
Arginine	1.22	1.19	1.16	1.13	1.10
Dig. Arg	1.05	1.02	1.00	0.97	0.95
Isoleucine	0.70	0.68	0.67	0.65	0.63
Dig. Ile	0.66	0.64	0.62	0.61	0.59
Lysine	0.97	0.97	0.97	0.97	0.97
Dig. Lys	0.87	0.87	0.87	0.87	0.87
Meth	0.44	0.44	0.45	0.45	0.45
Dig. Meth	0.39	0.40	0.40	0.40	0.41
M+C	0.75	0.75	0.75	0.75	0.75
Dig M+C	0.63	0.63	0.63	0.63	0.63
Thr	0.68	0.68	0.68	0.68	0.68
Dig. Thr	0.58	0.58	0.58	0.58	0.58
Trp	0.18	0.18	0.17	0.17	0.16
Dig. Trp	0.16	0.16	0.15	0.15	0.14
Valine	0.83	0.81	0.80	0.78	0.76
Dig. Val	0.75	0.74	0.72	0.71	0.69
Glycine	0.87	0.86	0.84	0.82	0.81
Avail. Phos	0.42	0.42	0.42	0.42	0.42
Calcium	0.85	0.85	0.85	0.85	0.85
Sodium	0.18	0.18	0.18	0.18	0.18

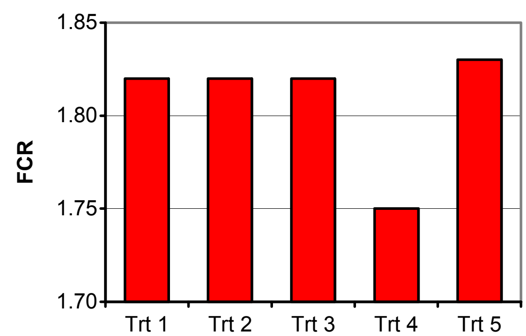
Treatment by sex on body weight, feed intake and FCR										
TRT	Sex	Body Mass (gram)			Feed Intake			FCR		Mort
		20	35	48	0 - 20	21 - 35	36 - 48	0 - 20	21 - 35	0 - 48	%
1	F	617	1535	2532	811	1684	2353	1.423	1.781	1.86	9.6
2	F	624	1570	2597	818	1682	2463	1.420	1.745	1.86	9.2
3	F	629	1559	2597	824	1728	2427	1.415	1.801	1.86	8.3
4	F	612	1552	2602	807	1641	2392	1.429	1.731	1.70	3.8
5	F	620	1532	2613	810	1714	2464	1.416	1.811	1.85	10.0
1	M	660	1719	3052	847	1974	3035	1.383	1.797	1.78	21.3
2	M	650	1700	3009	838	2045	2996	1.390	1.814	1.78	22.9
3	M	700	1689	3053	858	2057	2940	1.406	1.855	1.78	19.6
4	M	661	1696	3046	857	1927	2954	1.397	1.807	1.80	16.7
5	M	648	1648	2949	841	1975	2888	1.403	1.844	1.80	17.9
1	M & F	639	1627	2792	829	1829	2694	1.403	1.789	1.82	15.4
2	M & F	637	1635	2803	828	1864	2730	1.405	1.779	1.82	16.0
3	M & F	665	1624	2825	841	1893	2684	1.410	1.828	1.82	14.0
4	M & F	637	1624	2824	832	1784	2673	1.413	1.769	1.75	10.2
5	M & F	634	1590	2781	826	1845	2676	1.409	1.827	1.83	14.0
	SEM	0.008	0.01	0.033				0.011	0.046	0.033	3.29

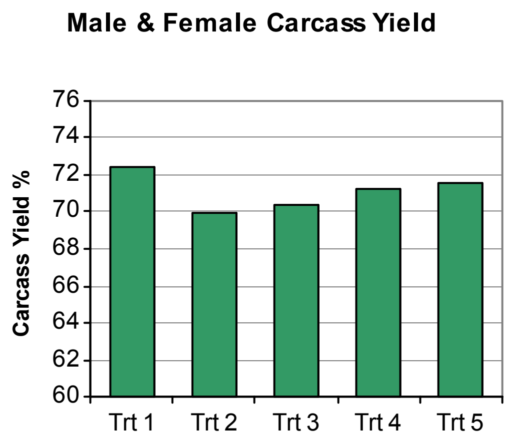
Table 3. Carcass Characteristics			
TRT	Carcass Yield %	Boneless Breast %	Fat %
1	72.39	24.59	1.99
2	69.97	24.83	1.86
3	70.40	24.42	2.02
4	71.20	24.80	1.98
5	71.52	24.22	2.15
SEM	1.24	0.31	0.13
Male	71.79	24.17	1.91
Female	70.58	24.91	2.13

Male & Female 48 day Body Mass



Male & Female 48 Day FCR





Conclusions

1) Growth performance parameters of male and female birds in this study are representative of results achieved with commercial roasters.
2) No statistical differences ($P<0.05$) were seen between treatments, which indicate that, even at the lower CP levels, the minimum requirements for all amino acids were met. This allows us to confidently use these as the minimum digestible amino acid levels in formulating diets for future research studies.
3) Males had better final bodyweight ($P<0.001$), overall feed efficiency ($P<0.001$) than females.
4) Mortality in this study was high due to heat stress in final week of study. Mortality was more pronounced in the higher protein treatments. Males had higher ($P<0.001$) mortality than females.
5) Substitution of synthetic amino acids, L-Lysine, DL-Methionine and L-Threonine for intact feedstuff protein (SBM) had no tendency ($P>0.10$) to affect growth performance or carcass yield. It must be emphasized that all diets were formulated on a digestible basis and care was taken to meet all minimum essential amino acid levels.
6) In addition the benefits of feeding lower CP feeds, diet cost is reduced when L-Threonine “least costs” into the diet.

<u>Study 2</u>

As with the first study the objective of the study was to confirm that L-Threonine can be used in practical US type corn/ soy broiler diets to replace threonine from intact protein, namely soybean meal, to the point of the next most limiting amino acids. In addition another set of treatments was added to evaluate whether the lysine levels of current US broiler feeds are adequate for optimal performance and profitability.

MATERIAL AND METHODS

This study was designed to compare the performance of birds fed practical US diets to diets formulated to the same minimum amino acid levels utilizing L-Threonine to meet essential amino acid levels of the diet. Ingredients used in the study were analyzed for crude protein and amino acids levels by the Ajinomoto Heartland laboratory and digestible amino acid coefficients (Ajinomoto Heartland, 2001) were applied to these values for diet formulation. Diets were re-analyzed post blending to confirm accuracy of feeds.

The study was a factorial arrangement with three threonine treatments, two lysine levels and two sexes. Sexed Cobb x Cobb 500 commercial broilers were used in the study.

Corn-soy, poultry meal diets were used in all treatments. Treatments 1 and 2 were formulated to the same minimum essential amino acid levels. The difference being that L-Threonine was excluded from treatment 1 but allowed to least cost into treatment 2, to the point that the next most limiting amino acids (isoleucine, valine and tryptophan) limited further inclusion. This resulted in lower crude protein level of approximately 1.2 percentage points (a 6% reduction in CP) over the practical diet. Soybean meal was replaced with corn and L-Lysine.HCl, DL-Methionine and L-Threonine. Threonine was formulated at a 65 ratio of threonine to lysine. This is generally above the ratios (62 to 64) commonly being fed in the US today. Previous in-house studies have shown responses to ratios us high as 69. To investigate a response to a higher threonine ratio, treatment 3 was added with the ratio of threonine to lysine at 70.

Lysine levels of treatments 1 to 3 were set at current industry standards, since these levels are generally lower than what the author believes are required to optimize performance and maximize profitability, additional L-Lysine.HCl was added to Treatments 1 to 3. Lysine levels were elevated by 0.05 percentage points to give treatments 4 to 6. Other than the added lysine the diets were identical.

A five phase feeding program was used, Starter (0-14 days), Grower 1 (15-24 days), Grower 2 (25-33 days), Finisher (34-42 days) and Withdrawal (43-49 days). Feed intake was measured for each of these periods. Body weights and feed conversion were determined on days 24, 42 and 49. Carcass characteristics were determined on 3 birds per pen.

The study was conducted at a contract research facility in the US during the months of October to December. Birds were housed in a 72 pen curtain sided house on used litter. Treatments were replicated 6 times with 100 birds per pen, stocked at commercial stocking rates of 0.80 sq ft/ bird. A commercial type lighting program was followed.

	Starter Diet					
Dietary Content	**Standard Lysine**			**High Lysine**		
	Control No Thr	*With Thr 65%*	*With Thr 70%*	*Control No Thr*	*With Thr 65%*	*With Thr 70%*
Corn	61.9	65.8	65.8	61.9	65.8	65.8
Soybean	29.5	26.1	26.1	29.5	26.1	26.1
Poultry meal	3.5	3.5	3.5	3.5	3.5	3.5
Feet fat	2.2	1.7	1.7	2.2	1.7	1.7
L-Lysine.HCl	0.07	0.18	0.18	0.13	0.24	0.24
DL-Meth	0.26	0.26	0.26	0.26	0.26	0.26
L-Threonine	0	0.05	0.11	0.00	0.05	0.11
Other	2.5	2.5	2.5	2.5	2.5	2.5
Cost	129.85	128.51	130.13	129.85	128.51	130.13
Calculated Composition						
ME kcal/kg	3110	3110	3110	3110	3110	3110
Protein	21.4	20.2	20.2	21.4	20.2	20.2
Dig. Lys	1.10	1.10	1.10	1.15	1.15	1.15
Dig. Met	0.55	0.55	0.56	0.55	0.55	0.56
Dig. M+C	0.83	0.83	0.83	0.83	0.83	0.83
Dig. Cys	0.28	0.27	0.27	0.28	0.27	0.27
Dig. Thr	0.71	0.71	0.77	0.71	0.71	0.77
Dig. Try	0.21	0.19	0.19	0.21	0.19	0.19
Dig. Arg	1.30	1.20	1.20	1.30	1.20	1.20
Dig. Ile	0.81	0.75	0.75	0.81	0.75	0.75
Dig. Val	0.90	0.84	0.84	0.90	0.84	0.84
Avail. Phos	0.45	0.45	0.45	0.45	0.45	0.45
Calcium	0.90	0.90	0.90	0.90	0.90	0.90
Sodium	0.20	0.20	0.20	0.20	0.20	0.20

Dietary Content	Grower 1 Diet					
	Standard Lysine			High Lysine		
	Control No Thr	*With Thr 65%*	*With Thr 70%*	*Control No Thr*	*With Thr 65%*	*With Thr 70%*
Corn	65.9	69.7	69.7	65.9	69.7	69.7
Soybean	26.0	22.5	22.5	26.0	22.5	22.5
Poultry meal	3.5	3.5	3.5	3.5	3.5	3.5
Feet fat	1.9	1.4	1.4	1.9	1.4	1.4
L-Lysine.HCl	0.08	0.19	0.19	0.14	0.25	0.25
DL-Meth	0.20	0.23	0.23	0.20	0.23	0.23
L-Threonine	0.0	0.05	0.10	0.0	0.05	0.10
Other	2.43	2.43	2.43	2.43	2.43	2.43
Cost	**124.59**	**123.83**	**125.18**	**125.46**	**124.69**	**126.04**
Calculated Composition						
ME kcal/kg	*3130*	*3130*	*3130*	*3130*	*3130*	*3130*
Protein	20.0	18.8	19.0	20.0	18.8	19.0
Dig. Lys	1.02	1.02	1.02	1.07	1.07	1.07
Dig. Met	0.50	0.52	0.52	0.50	0.52	0.52
Dig. M+C	0.77	0.77	0.77	0.77	0.77	0.77
Dig. Cys	0.27	0.25	0.25	0.27	0.25	0.25
Dig. Thr	0.66	0.66	0.72	0.66	0.66	0.72
Dig. Try	0.19	0.17	0.17	0.19	0.17	0.17
Dig. Arg	1.20	1.10	1.10	1.20	1.10	1.10
Dig. Ile	0.75	0.69	0.69	0.75	0.69	0.69
Dig. Val	0.84	0.78	0.78	0.84	0.78	0.78

Dietary Content	Grower 2 Diet					
	Standard Lysine			High Lysine		
	Control No Thr	*With Thr 65%*	*With Thr 70%*	*Control No Thr*	*With Thr 65%*	*With Thr 70%*
Corn	70.6	73.9	73.9	70.6	73.9	73.9
Soybean	21.1	18.1	18.1	21.1	18.1	18.1
Poultry meal	3.5	3.5	3.5	3.5	3.5	3.5
Feet fat	1.7	1.3	1.3	1.7	1.3	1.3
L-Lysine.HCl	0.10	0.19	0.19	0.16	0.26	0.26
DL-Meth	0.15	0.18	0.18	0.15	0.18	0.18
L-Threonine	0.0	0.04	0.10	0.0	0.04	0.10
Other	2.83	2.83	2.83	2.83	2.83	2.83
Cost	**118.35**	**117.70**	**119.21**	**119.31**	**118.71**	**120.71**
Calculated Composition						
ME kcal/kg	*3150*	*3150*	*3150*	*3150*	*3150*	*3150*
Protein	18.1	17.0	17.0	18.1	17.0	17.0
Dig. Lys	0.91	0.91	0.91	0.96	0.96	0.96
Dig. Met	0.44	0.44	0.44	0.44	0.44	0.44
Dig. M+C	0.68	0.68	0.68	0.68	0.68	0.68
Dig. Cys	0.25	0.24	0.24	0.25	0.24	0.24
Dig. Thr	0.59	0.59	0.64	0.59	0.59	0.64
Dig. Try	0.17	0.15	0.15	0.17	0.15	0.15
Dig. Arg	1.06	0.97	0.97	1.06	0.97	0.97
Dig. Ile	0.66	0.61	0.61	0.66	0.61	0.61
Dig. Val	0.76	0.71	0.71	0.76	0.71	0.71

Dietary Content	Finisher Diet					
	Standard Lysine			High Lysine		
	Control No Thr	*With Thr 65%*	*With Thr 70%*	*Control No Thr*	*With Thr 65%*	*With Thr 70%*
Corn	75.5	78.9	78.9	75.5	78.9	78.9
Soybean	16.8	13.7	13.7	16.8	13.7	13.7
Poultry meal	3.5	3.5	3.5	3.5	3.5	3.5
Feet fat	1.4	0.9	0.9	1.4	0.9	0.9
L-Lysine.HCl	0.10	0.20	0.20	0.17	0.27	0.27
DL-Meth	0.12	0.14	0.14	0.12	0.14	0.14
L-Threonine	0.0	0.05	0.09	0.0	0.05	0.09
Other	2.62	2.65	2.65	2.62	2.65	2.65
Cost	**112.65**	**112.01**	**113.22**	**113.63**	**112.09**	**114.15**
Calculated Composition						
ME kcal/kg	*3175*	*3175*	*3175*	*3175*	*3175*	*3175*
Protein	16.4	15.3	15.3	16.4	15.3	15.3
Dig. Lys	0.81	0.81	0.81	0.86	0.86	0.86
Dig. Met	0.38	0.40	0.40	0.38	0.40	0.40
Dig. M+C	0.61	0.61	0.61	0.61	0.61	0.61
Dig. Cys	0.23	0.22	0.22	0.23	0.22	0.22
Dig. Thr	0.53	0.53	0.57	0.53	0.53	0.57
Dig. Try	0.14	0.13	0.13	0.14	0.13	0.13
Dig. Arg	0.94	0.85	0.85	0.94	0.85	0.85
Dig. Ile	0.59	0.54	0.54	0.59	0.54	0.54
Dig. Val	0.69	0.64	0.64	0.69	0.64	0.64

Dietary Content	Withdrawal Diet					
	Standard Lysine			High Lysine		
	Control No Thr	*With Thr 65%*	*With Thr 70%*	*Control No Thr*	*With Thr 65%*	*With Thr 70%*
Corn	77.3	80.3	80.3	77.3	80.3	80.3
Soybean	14.8	12.0	12.0	14.8	12.0	12.0
Poultry meal	3.5	3.5	3.5	3.5	3.5	3.5
Feet fat	1.8	1.3	1.3	1.8	1.3	1.3
L-Lysine.HCl	0.12	0.21	0.21	0.18	0.27	0.27
DL-Meth	0.11	0.13	0.13	0.11	0.13	0.13
L-Threonine	0.0	0.04	0.08	0.0	0.04	0.08
Other	2.48	2.51	2.51	2.48	2.51	2.51
Cost	**108.48**	**107.92**	**109.00**	**109.37**	**108.85**	**109.93**
Calculated Composition						
ME kcal/kg	*3220*	*3220*	*3220*	*3220*	*3220*	*3220*
Protein	15.5	14.6	14.6	15.5	14.6	14.6
Dig. Lys	0.77	0.77	0.77	0.82	0.82	0.82
Dig. Met	0.36	0.37	0.37	0.36	0.37	0.37
Dig. M+C	0.58	0.58	0.58	0.58	0.58	0.58
Dig. Cys	0.22	0.21	0.21	0.22	0.21	0.21
Dig. Thr	0.50	0.50	0.54	0.50	0.50	0.54
Dig. Try	0.13	0.12	0.12	0.13	0.12	0.12
Dig. Arg	0.88	0.80	0.80	0.88	0.80	0.80
Dig. Ile	0.56	0.51	0.51	0.56	0.51	0.51
Dig. Val	0.66	0.61	0.61	0.66	0.61	0.61

RESULTS AND DISCUSSION

Body Mass

Females: No significant differences were seen between treatments 1 to 3, (low lysine group). Treatment 6 "**high lysine, high threonine**" was significantly heavier than treatment 5, **"high lysine low threonine".** With the exception of treatments 5, birds on the higher lysine treatment tended to higher body mass. No differences were seen between the control groups and the lower crude protein, L-Threonine supplemented treatments.
Males: Treatment 4 "**high lysine control**" were significantly heavier that treatments 1,2 & 5. As with the females, other than treatment 5, the higher lysine group tended to heavier body mass. No differences were seen between the control groups and the lower CP L-Threonine supplemented treatments.

FCR

Females: No significant differences were seen between treatments. Birds on the higher lysine group tended to lower feed conversion.
Males: No significant differences were seen between treatments. Birds on the higher lysine group tended to lower feed conversion.

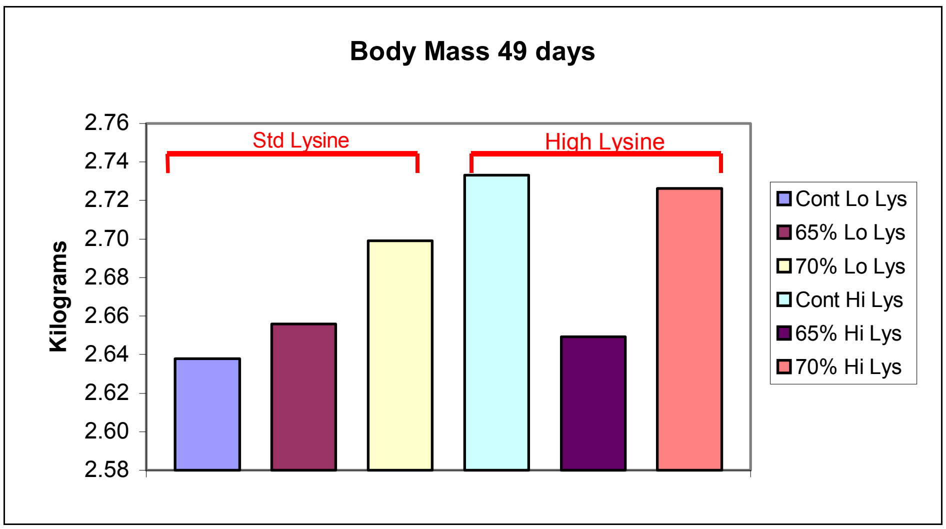
Live Performance Results

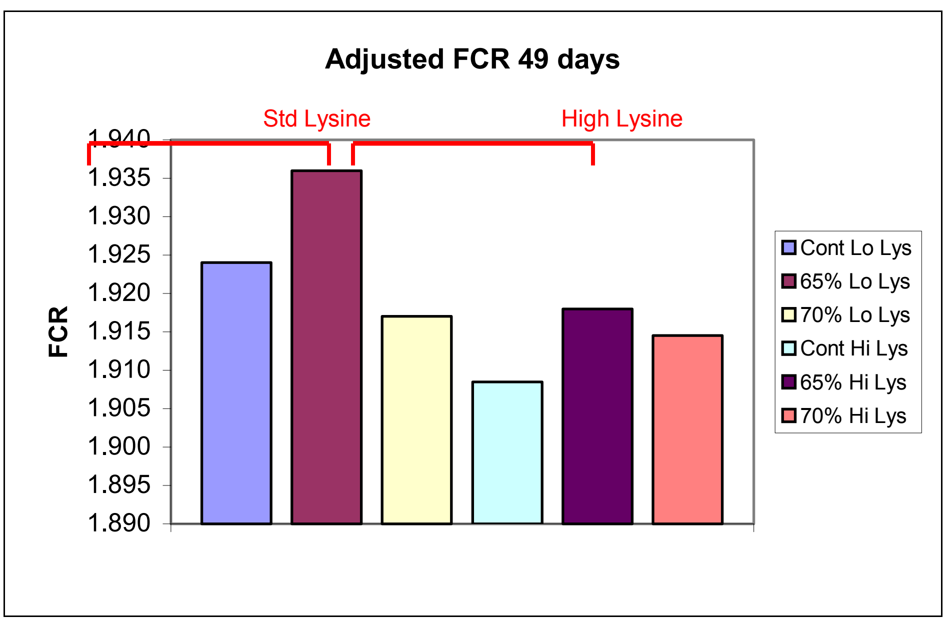
		Body Mass kilograms			FCR			Mortality
	Treatment	**Day 25**	**Day 42**	**Day 49**	**Day 25**	**Day 42**	**Day 49 Wt Adj**	**Day 49**
Female								
	Cont Lo Lys	1.04	2.19	2.49^{gh}	1.454	1.867	1.959^{g}	7.2
	65% Lo Lys	1.05	2.20	2.51^{gh}	1.464	1.868	1.961^{g}	6.0
	70% Lo Lys	1.04	2.23	2.54^{gh}	1.467	1.852	1.932^{g}	5.8
	Cont Hi Lys	1.06	2.22	2.54^{gh}	1.444	1.862	1.932^{g}	4.3
	65% Hi Lys	1.03	2.22	2.48^{h}	1.472	1.836	1.948^{g}	7.2
	70% Hi Lys	1.06	2.25	2.58^{g}	1.460	1.861	1.916^{g}	6.0
Male								
	Cont Lo Lys	1.12	2.46	2.78^{l}	1.417	1.790	1.904^{k}	5.8
	65% Lo Lys	1.14	2.50	2.80^{l}	1.434	1.801	1.919^{k}	6.5
	70% Lo Lys	1.15	2.52	2.86^{kl}	1.424	1.798	1.892^{k}	8.2
	Cont Hi Lys	1.18	2.59	2.93^{k}	1.405	1.769	1.863^{k}	9.2
	65% Hi Lys	1.16	2.51	2.82^{l}	1.431	1.791	1.902^{k}	6.7
	70% Hi Lys	1.14	2.53	2.87^{kl}	1.436	1.798	1.888^{k}	8.2
Combined Sexes								
	Cont Lo Lys	1.08	2.32	2.64	1.436	1.829	1.924	6.5
	65% Lo Lys	1.10	2.35	2.66	1.449	1.835	1.936	6.3
	70% Lo Lys	1.10	2.37	2.70	1.446	1.825	1.917	7.0
	Cont Hi Lys	1.12	2.40	2.73	1.425	1.816	1.909	6.8
	65% Hi Lys	1.10	2.37	2.65	1.452	1.814	1.918	7.0
	70% Hi Lys	1.10	2.39	2.73	1.448	1.830	1.915	7.1

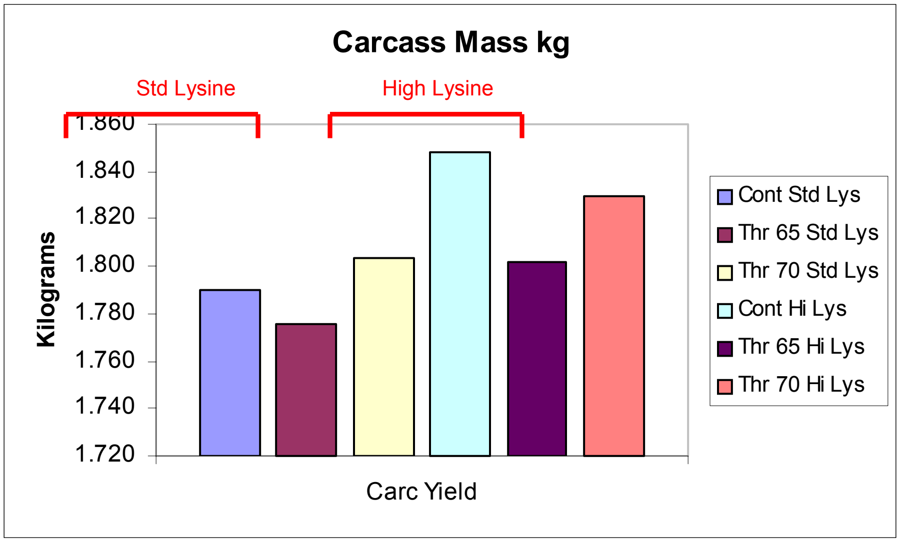
Carcass Yield

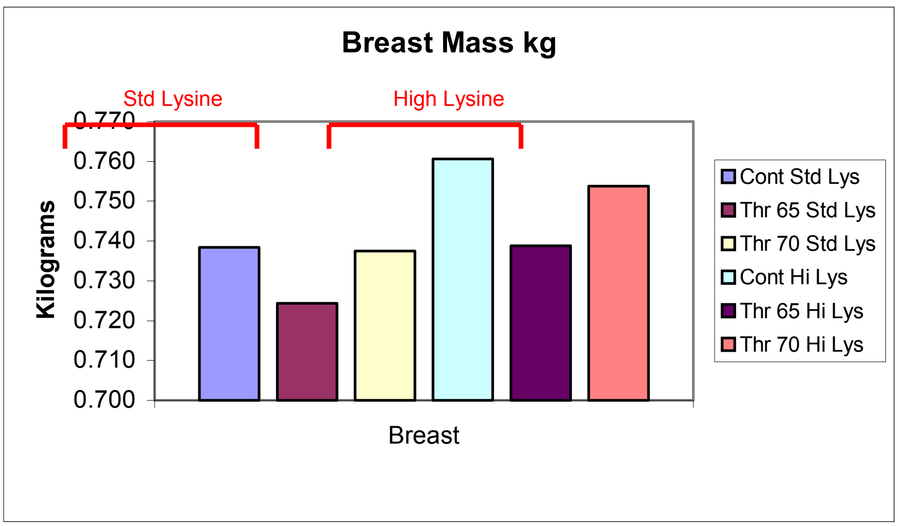
Combined Sexes

Treatment	**Yield in Kilograms** Carcass	Bone-in Breast	Boneless Breast
Cont Lo Lys	1.790	0.738	0.498
65% Lo Lys	1.776	0.724	0.483
70% Lo Lys	1.804	0.737	0.495
Cont Hi Lys	1.848	0.761	0.514
65% Hi Lys	1.802	0.739	0.498
70% Hi Lys	1.830	0.754	0.506









Financial Impact of Treatments

A financial impact study was conducted on the results of this study. The financial model, which includes current input costs for all production parameters and sales prices for whole and cutup components. Mix of 85% cutup to 15% whole birds was used. Current ingredient costs were used in diet formulation.

Standard Lysine: Return of birds on the lower CP L-Threonine supplemented diet (Trt's 2 & 3) was higher than the control diet. An addition advantage was seen at the higher threonine treatment (Trt 3).

Higher Lysine: A considerable increase in profitability was seen in the higher lysine treatments over the standard lysine levels.

Per Barn Assessment	**No. Birds 30000**					
	Trt 1	**Trt 2**	**Trt 3**	**Trt 4**	**Trt 5**	**Trt 6**
	Standard Lysine			**High Lysine**		
Per Barn Costs	**Control**	**Thr 65**	**Thr 69**	**Trt 1 + Lys**	**Trt 2 + Lys**	**Trt 3 + Lys**
Feed Cost	$ 22,527	$ 22,679	$ 23,023	$ 23,321	$ 22,597	$ 23,397
Grow-out Cost	$ 34,442	$ 34,442	$ 34,442	$ 34,442	$ 34,442	$ 34,442
Total Cost	**$ 56,970**	**$ 57,121**	**$ 57,465**	**$ 57,763**	**$ 57,040**	**$ 57,839**
Per Barn Returns						
Whole Bird	$ 11,140	$ 11,217	$ 11,399	$ 11,543	$ 11,188	$ 11,514
Cut Up	$ 56,062	$ 56,243	$ 57,059	$ 58,029	$ 56,178	$ 57,648
Total Returns	**$ 67,203**	**$ 67,460**	**$ 68,458**	**$ 69,572**	**$ 67,366**	**$ 69,162**
Per Barn Revenue	**$ 10,233**	**$ 10,339**	**$ 10,993**	**$ 11,808**	**$ 10,327**	**$ 11,323**
Per Barn Treat. Loss	**$ -**	**$ 105**	**$ 760**	**$ 1,575**	**$ 93**	**$ 1,090**
Return $ per bird	0.3411	0.3446	0.3664	0.3936	0.3442	0.3774
Difference $ per bird	**$ -**	**$ 0.004**	**$ 0.025**	**$ 0.053**	**$ 0.003**	**$ 0.036**
Diff. per million birds	**$ -**	**$ 4,000**	**$ 25,000**	**$ 53,000**	**$ 3,000**	**$ 36,000**

Conclusion

Replacing intact protein, soybean meal with corn, L-Threonine, L-Lysine and DL-Methionine to balance essential amino acid levels in practical US type broiler diets resulted in similar live weight performance as and gave a financial advantage.

Increasing lysine levels above current levels resulted in improved production and financial performance.

L-Threonine can be successfully used in practical broiler feeds. This results in lower crude protein feeds with a more ideally balanced amino acid profile. In order for this concept to be effective, attention must be paid to the next most limiting acids, isoleucine, valine, tryptophan and arginine.

Appendix 1

Digestible Amino Acid Ratios to Lysine used in Formulations:

Threonine	64 to 70%
Methionine	45%
Meth + Cyst	75%
Tryptophan	15.5%
Isoleucine	67%
Valine	78%
Arginine	103%

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