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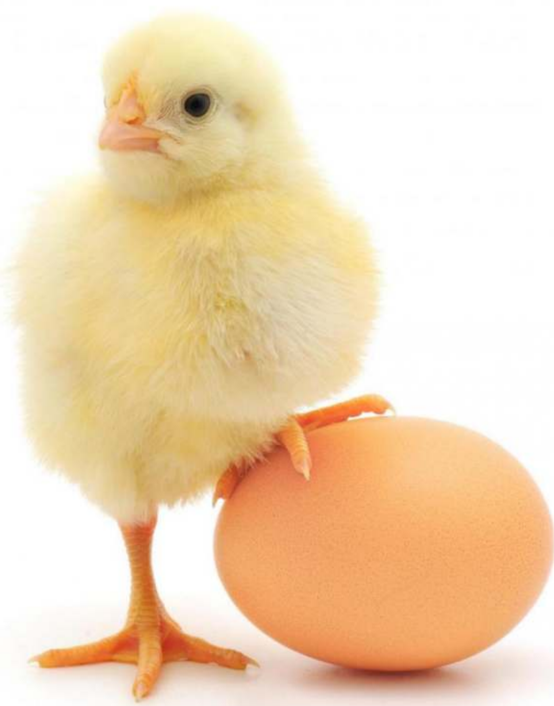

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Influence of Feed Form on Dietary Lysine and Energy Intake and Utilization of Broilers from 14 to 30 Days of Age

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Abstract: An experiment was conducted to evaluate the effects of feed form on lysine and dietary energy levels necessary for maximum body weight gain (BWG) and feed efficiency (FE) of male broilers from 14 to 30 d and to determine if birds realize a benefit in productive energy from consuming pelleted diets. A 2 x 3 x 2 factorial treatment arrangement was achieved by feeding diets in two forms (mash and steam-conditioned pellets) with three levels of digestible lysine (0.85, 0.95 and 1.05 % of the diet) and two dietary energy levels (3050 and 3200 kcal ME/kg). Male broiler chicks were provided a nutritionally adequate diet (3100 kcal ME/kg and 22.7% CP) from 0-13 d. Four pens of 32 birds were fed each dietary treatment. Mean body weight and feed consumption were obtained at 14 and 30 d. Average feed intake (AFI) was used to calculate lysine conversion ratio and calories consumed per bird. Pellet-fed birds consumed significantly less digestible lysine (P=0.0061) to achieve the same amount of BWG as the mash-fed birds. Pellet-fed birds exhibited a linear increase in BWG (P=0.0188) with increasing lysine concentrations, while mash-fed birds did not display a growth response at digestible lysine levels greater than 0.85%. Birds fed 3200 kcal ME/kg diets had greater BWG (P=0.006) than those fed 3050 kcal diets. No feed form x dietary energy level interaction was observed for any parameter. Feed form had no effect on AFI (P=0.3784). These findings suggest that improved BWG obtained with pelleted diets may be the result of reduced energy expenditure during meal consumption, indicating that feed form may influence perceived nutrient needs.

Key words: Broiler performance, lysine, energy, pellet

Introduction

Nutritionists have long been aware of the benefits of pelleting poultry rations (Pattern *et al.*, 1937; Calet, 1965; Moran, 1989; Jensen, 2000). However, relatively little is known concerning the effect of pelleting on dietary amino acid and energy needs of broilers. Reddy *et al.* (1962) suggested that pelleting a diet markedly increased its productive energy (PE) value, thereby making more calories available for protein and lipid synthesis. Increased PE value of pelleted diets, when compared to mash diets, may be attributed to the difference in energy expenditure during meal consumption. This supposition was supported by the observations of Jensen *et al.* (1962) who found birds fed pelleted diets consumed approximately the same quantity of feed as mash-fed birds, yet spent less time consuming feed per meal. Recent findings by McKinney and Teeter (2003) have confirmed this principle using a modern strain of broiler. McKinney and Teeter (2003) have reported that pelleting contributes 187 kcal ME/kg at 100% pellet quality (100% pellets), with the caloric value of the pellets diminishing with decreasing pellet quality. Consequently, as more energy is made available to the bird, dietary amino acids must increase proportionally in order to realize maximum protein synthesis and retention (Bellaver *et al.*, 2002; Lemme *et al.*, 2003).

Research determining the effects of pelleting and the subsequent improvement in PE value of the diet on amino acids needs is considerably limited. Jensen *et al.* (1965) determined that pelleting a diet marginal in protein or lysine accentuated a deficiency for the respective nutrient in broad breasted bronze turkeys. Bayley *et al.* (1968) observed similar results with crumbled broiler starter diets marginal in lysine. Results from the aforementioned studies suggest that pelleting provides an extra-caloric benefit for growth, thereby resulting in an imbalance between lysine and dietary energy. Lysine concentration is known to have a significant effect on partitioning of energy deposition (Batterham *et al.*, 1990). Greenwood *et al.* (2003) observed that performance of birds fed pelleted diets with digestible lysine levels above 0.95% was generally superior to that of birds fed mash diets regardless of lysine level. It is therefore conceivable that increasing the lysine concentration in pelleted diets will result in increased body weight gains (BWG) and feed efficiency (FE), compared to performance achieved with mash diets at the same lysine concentration.

The objectives of the present study were to determine the effect of feed form on digestible lysine and dietary energy necessary for maximum growth performance of male broilers from 14 to 30 d and to determine if PE obtained from consuming a pelleted diet could overcome a decrease in dietary energy.

Table 1: Composition (%) and calculated nutrient content of experimental diets

Ingredients	1 and 2	3 and 4	5 and 6	7 and 8	9 and 10	11 and 12
Yellow Corn	62.274	62.274	62.274	59.128	59.128	59.128
Soybean Meal	25.467	25.467	25.467	25.651	25.651	25.651
Corn Gluten Meal	6.742	6.742	6.742	6.954	6.954	6.954
Monocalcium Phosphate	1.346	1.346	1.346	1.355	1.355	1.355
Limestone	1.329	1.329	1.329	1.325	1.325	1.325
Peanut Meal	1.207	1.207	1.207	1.181	1.181	1.181
L-Lysine Hcl	0.000	0.127	0.255	0.000	0.127	0.255
Cornstarch	0.382	0.255	0.127	0.382	0.255	0.127
Salt	0.312	0.312	0.312	0.314	0.314	0.314
Vitamin/Mineral Premix[1]	0.250	0.250	0.250	0.250	0.250	0.250
Soy Oil	0.233	0.233	0.233	3.004	3.004	3.004
DL-Methionine	0.180	0.180	0.180	0.181	0.181	0.181
Sodium Bicarbonate	0.100	0.100	0.100	0.100	0.100	0.100
Coban 80[2]	0.059	0.059	0.059	0.059	0.059	0.059
L-Threonine	0.059	0.059	0.059	0.057	0.057	0.057
BMD-50[3]	0.050	0.050	0.050	0.050	0.050	0.050
Thiamin Premix[4]	0.005	0.005	0.005	0.005	0.005	0.005
Vitamin D3 Premix[5]	0.003	0.003	0.003	0.003	0.003	0.003
Calculated Analysis						
ME, kcal/kg	3050	3050	3050	3200	3200	3200
CP, %	22.30	22.46	22.58	22.30	22.46	22.58
Digestible Lys, %	0.85	0.95	1.05	0.85	0.95	1.05
Total Lys, %	0.95	1.05	1.15	0.95	1.05	1.15
Total Met, %	0.57	0.57	0.57	0.58	0.58	0.58
Total TSAA, %	0.94	0.94	0.94	0.94	0.94	0.94
Total Arg, %	1.28	1.28	1.28	1.28	1.28	1.28
Total Thr, %	0.86	0.86	0.86	0.86	0.86	0.86
Calcium, %	0.80	0.80	0.80	0.80	0.80	0.80
Av. Phosphorus, %	0.40	0.40	0.40	0.40	0.40	0.40[1]

[1]Supplied per kg of premix: biotin, 0.03 mg; choline, 385.55 mg; copper, 24.8 mg; folic acid, 0.69 mg; iodine, 3.31 mg; iron, 110.25 mg; manganese, 220.5 mg; niacin, 27.56 mg; pantothenic acid, 6.62 mg; selenium, 0.33mg; thiamin 2.21 mg; vitamin A, 7717.5 IU; vitamin B_{12}, 0.01 mg; vitamin B_6, 1.38 mg; vitamin D_3, 2103.75 ICU; vitamin E, 16.54 IU; vitamin K, 0.83 mg; zinc 220.5 mg. [2]Monensin sodium, 80 g/lb (110g/ton inclusion), Elanco Animal Health, Indianapolis, IN 46285. [3]Bacitracin methylene disalicylate, 50 g/lb (50 g/ton inclusion), Alpharma, Fort Lee, NJ 07024 [4]Supplied per kg of premix: thiamin, 22.050 mg. [5]Supplied per kg of premix: vitamin D_3, 15,000,000 ICU.

Materials and Methods

Diet Formulation and Experimental Treatments: Treatment structure was a 2 x 3 x 2 factorial with two feed forms (mash vs. pellets), three digestible dietary lysine levels (0.85, 0.95 and 1.05%) and two dietary energy levels (3050 and 3200 kcal ME/kg) for a total of 12 dietary treatments (Table 1).

Two basal diets were formulated to provide dietary energy levels of 3050 and 3200 kcal ME/kg. Differences in dietary energy levels were obtained primarily through the addition of soybean oil at the expense of ground yellow corn. Soybean oil was excluded from the basals until the actual mixing of dietary treatments.

Amino acid content, as a percent of the diet, was held constant between basals. Diets were formulated to meet or exceed digestible essential amino acid recommendations provided by Degussa (2001). Total amino acid values and digestibility coefficients were obtained from an established feedstuffs database (Anonymous, 2001) for feedstuffs utilized in the present study. Total amino acid analyses of the aforementioned feedstuffs were in close agreement with the calculated values. Digestibility coefficients were applied to the calculated total amino acid values to obtain digestible dietary amino acid values used in the formulation of the basal diets.

Lysine treatments consisted of three graded levels of digestible dietary lysine: 0.85, 0.95 and 1.05%. Graduations of dietary lysine were achieved through the addition of L-lysine HCl at the expense of cornstarch. No attempt was made to make diets isonitrogenous, as dietary CP was allowed to fluctuate with increasing dietary lysine levels.

Feed Manufacturing: Common basal diets were mixed in a horizontal double ribbon mixer and then divided into

Table 2: Characteristics of experimental diets

				Pellet Characteristics				
				Bulk Density	HPT	PDI	Modified PDI	Fines
Diet	Form	%LYS	ME, kcal/kg	(kg/m3)	(°C)	(%)	(%)	(%)
1	Mash	0.85	3050	784.77	-	-	-	-
2	Pellet	0.85	3050	771.16	85.56	82.81	77.68	7.10
3	Mash	0.95	3050	776.28	-	-	-	-
4	Pellet	0.95	3050	775.64	83.06	83.29	79.78	8.30
5	Mash	1.05	3050	777.40	-	-	-	-
6	Pellet	1.05	3050	816.32	82.56	86.55	84.53	9.58
7	Mash	0.85	3200	806.71	-	-	-	-
8	Pellet	0.85	3200	801.11	82.50	83.88	81.25	12.75
9	Mash	0.95	3200	779.65	-	-	-	-
10	Pellet	0.95	3200	816.32	84.44	86.67	83.98	9.74
11	Mash	1.05	3200	790.38	-	-	-	-
12	Pellet	1.05	3200	808.47	83.50	87.57	82.80	11.00

aliquots representative of each dietary treatment. Aliquots were then added to a horizontal twin shaft, high speed, paddle-type mixer with a capacity of 454 kg. L-lysine HCl and cornstarch were added to each aliquot in graduations to achieve the desired range of digestible dietary lysine levels. Diets were subjected to a dry mix time of 120-s. For the mash series, the complete quantity of soybean oil was added at the mixer following the dry mix cycle and subjected to a 180-s wet mix cycle to obtain the respective dietary energy level. For the pelleted series, following the dry mix cycle, soybean oil was added to each diet at 0.23% and subjected to a 180-s wet mix cycle. The remaining soybean oil required to achieve the 3200 kcal ME/kg dietary treatments in the pelleted series was added post-pelleting to avoid the inverse relationship that fat added at the mixer has on pellet quality.

For pelleted treatments, the mash was steam-conditioned, using a short-term conditioner (0.31 x 0.91 m) set for a retention time of approximately 10-s, with a constant temperature of 82.2 °C (180 °F). Pellets were subsequently formed using a California Pellet Mill (Model HD Series 1000) with a 3.97 x 31.75-mm (5/32 x 1.25 in) die. Pellets were cooled with ambient air in a double pass cooler.

Pelleted treatments, regardless of oil addition, were added back to the horizontal paddle mixer for an additional mix cycle to ensure that all pelleted diets had undergone similar friction and physical disruption capable of generating more fines in the diet. Low dietary energy treatments were subjected to a 120-s dry mix cycle, while the high dietary energy treatments received a post-pellet application of fat (soybean oil at 2.77% of the diet) and were subjected to a 180-s wet mix cycle.

Birds and Housing: Day-old male broiler chicks of a slow-feather strain were distributed to floor pens and maintained on a corn-soybean meal based mash diet (22.7% CP, 3100 kcal ME/kg) until 13 d. Birds were fasted on the evening of the 13 d for 10 h prior to being assigned to dietary treatments. At 14 d, 32 birds were randomly allotted to each of 48 floor pens (1.47 x 1.93 m) in a curtain-sided, positive-pressure ventilated house. Four pens were assigned to each of the dietary treatments. Each pen contained nipple drinkers and a Choretime® feed pan adapted to a hopper. Feed and water were provided *ad libitum*. Feeders were checked three times daily to ensure a constant feed flow to the pans. Birds were maintained on a lighting schedule of 16h L:8h D during the test period. Mortalities were collected and recorded as they occurred. Birds were fasted on the evening of the 29 d for 10 h prior to the 30 d weighing.

Measurements: Pelleted treatments were measured for hot pellet temperature (HPT), standardized pellet durability index (PDI), modified pellet durability index (mod. PDI) and fines (%). Pellets were collected for 15-s into an insulated container directly from the pellet mill with a HPT (°C) recorded after 15-s. Standardized and modified PDIs were determined using procedures detailed in the ASAE Standard S269.4 (ASAE, 1997). Percentage of fines in the diet was evaluated by collecting the fifth bag of the dietary treatment bagged at the sacking bin. Bag contents were split using a riffle divider. Fines were sieved using a No. 6 ASTM. Collected fines were taken as a percentage of the original weight of the pre-sifted feed. Bulk densities (kg/m^3) were obtained for both mash and pelleted treatments. Pellet quality, fines content of the diet and bulk densities of mash and pelleted treatments are summarized in Table 2.

Body weight gain (BWG), total feed intake (TFI) and feed efficiency (FE) were measured from 14 to 30 d in order to evaluate growth performance. Feed efficiency was corrected for the weight of mortality. Average feed intake

(AFI) was calculated from TFI. Average feed intake was adjusted for mortality to more accurately reflect the access of individual birds in a pen to feed during the testing period using the following equation:

$$AFI = (TFI / TBD) * D$$

Where:

TFI = total feed intake (kg),
TBD = total bird days (d),
D = duration of test period (d).

Each day of the test period was assigned a number beginning with a 1 for the initial starting point of the study. This number reflected the days that each bird in a pen had access to feed. When a mortality occurred, the bird received the respective number for the date on which it expired. TBD was calculated as the number of living birds/pen at the conclusion of the trial x duration of the testing period + the numbers assigned to mortalities.

Digestible lysine intake:unit of body weight gain (lysine conversion ratio) and calorie intake:bird were calculated to determine the effect of the dietary treatments on dietary lysine and energy intake and efficiency of utilization. Lysine conversion ratio (g:100g) was calculated as {(AFI x digestible lysine, as a % of diet, /100) ÷ (BWG/100)}. Calorie intake:bird (kcal ME/bird) was calculated as AFI x kcal ME/kg of the diet.

Statistical Analysis: Experimental design was a randomized complete block. Pen served as the experimental unit for all analyses. All data were analyzed using the General Linear Models procedure of SAS (1994). The model considered the main effects of feed form, digestible lysine and ME. All possible two-and three-way interactions were examined. Level of significance was fixed at $P<0.05$. Significant differences among means were separated by repeated t-tests using the lsmeans option of SAS (1994).

Results

The effects of feed form on digestible lysine and dietary energy utilization necessary for maximum growth performance is described in Table 3. Increasing dietary digestible lysine concentration influenced FE ($P=0.0250$), with a significant improvement in FE obtained by feeding diets containing 1.05% digestible lysine compared with the 0.85% treatments. Digestible lysine conversion ratio increased linearly ($P<0.0001$) with increasing lysine concentrations, indicating that lysine is utilized less efficiently for weight gain as the concentration of dietary lysine increases. As anticipated, birds fed pelleted diets converted feed more efficiently to weight gain ($P=0.0086$) than birds fed mash diets (Table 3). Birds fed pelleted diets also had a significantly lower lysine conversion ratio ($P=0.0061$) than birds fed mash diets, as noted by the pellet fed birds consuming less digestible lysine to achieve the same amount of body weight gain as the mash-fed birds. Chiba *et al.* (1991) observed that lysine efficiency (gain:lysine intake) increased linearly with increases in digestible energy (DE) for swine from 20 to 50 kg, leading the authors to suggest that the amino acid content of the diet should be adjusted according to changes in the dietary energy content.

Findings of the present study infer that altering the form of the diet accounts for an improvement in the PE value of the diet, thereby increasing the need for a higher dietary lysine concentration. This conclusion is supported by a significant feed form x digestible lysine interaction ($P=0.0188$) observed for BWG. Lysine level had no effect on BWG for birds fed mash diets, yet BWG increased linearly with increasing dietary lysine concentrations for the pelleted treatments. Weight gain was maximized with a digestible lysine concentration of 0.85% for birds fed mash diets, while maximum BWG was achieved with a digestible lysine concentration of 1.05% for the pellet fed birds.

Birds fed dietary energy levels of 3200 kcal ME/kg gained significantly more weight ($P=0.0249$) than birds fed 3050 kcal ME/kg (Table 3). A significant digestible lysine x dietary energy interaction ($P=0.0398$) was observed for AFI. No difference in AFI was noted for birds fed 3050 kcal ME/kg at any lysine concentration, yet birds fed the 3200 kcal ME/kg diet at the lowest level of lysine consumed significantly more feed than birds fed the respective level of lysine in a 3050 kcal ME/kg diet. These findings are in agreement with those of Solberg (1971), who observed increases in feed intake by chicks fed diets moderately deficient in lysine. A similar response to dietary energy was observed for calories consumed per bird, as this measurement is a function of AFI. Birds fed 3200 kcal ME/kg at the two lower levels of dietary lysine consumed significantly more calories ($P=0.0419$) than birds at any lysine concentration in the 3050 kcal ME/kg series of treatments.

Although dietary energy had an obvious effect on growth performance and nutrient intake, no significant feed form x dietary energy interactions were observed. Pelleting each dietary treatment appeared to numerically improve FE over the respective mash treatment, but the effect was not significant ($P=0.3664$). Based on the authors' previous experience with feed form studies, four replications per treatment may have been inadequate to detect a significant difference in FE in the present trial.

Discussion

Jensen (2000) suggested that the dietary lysine concentration should be increased in pelleted diets in order for pellet-fed birds to achieve the same intake of lysine per g of body weight as mash-fed birds. For this hypothesis to hold true, the difference in feed intake between the two forms would have to be a significant factor. The response to pelleted diets in the present

Table 3: Effects of dietary lysine, dietary energy and feed form on live performance of male broilers from 14 to 30 d.

% LYS	Mash			Pellet			Mean		
	ME, kcal/kg			ME, kcal/kg			ME, kcal/kg		
	3050	3200	Mean	3050	3200	Mean	3050	3200	Mean
BWG (kg)									
0.85	0.988	1.000	0.994^{c}	0.995	1.008	1.001^{c}	0.991	1.004	0.998^{b}
0.95	1.004	1.032	1.018^{c}	1.042	1.060	1.051^{b}	1.023	1.049	1.035^{a}
1.05	1.007	1.019	1.013^{c}	1.065	1.111	1.088^{a}	1.036	1.065	1.050^{a}
Mean	1.000	1.017	1.008^{y}	1.034	1.060	1.047^{x}	1.017^{b}	1.038^{a}	
AFI (kg)									
0.85	1.764	1.855	1.809	1.712	1.859	1.786	1.738^{c}	1.857^{a}	1.798
0.95	1.799	1.835	1.817	1.786	1.803	1.794	1.792^{bc}	1.819^{ab}	1.806
1.05	1.839	1.733	1.786	1.747	1.796	1.771	1.793^{bc}	1.764^{bc}	1.779
Mean	1.801	1.808	1.804	1.748	1.819	1.784	1.774	1.813	
FE (g:g)									
0.85	0.562	0.537	0.549	0.582	0.544	0.563	0.572	0.541	0.556^{b}
0.95	0.557	0.562	0.559	0.585	0.586	0.585	0.571	0.574	0572^{ab}
1.05	0.549	0.590	0.570	0.608	0.614	0.611	0.579	0.602	0.590^{a}
Mean	0.556	0.563	0.559^{b}	0.592	0.581	0.587^{a}	0.574	0.572	
LCR (g:100g)									
0.85	1.523	1.578	1.550	1.464	1.575	1.519	1.493	1.576	1.535^{c}
0.95	1.702	1.689	1.700	1.633	1.625	1.629	1.668	1.657	1.662^{b}
1.05	1.922	1.787	1.854	1.724	1.698	1.711	1.823	1.743	1.783^{a}
Mean	1.716	1.685	1.700^{b}	1.607	1.633	1.620^{a}		1.661	1.659
Calories Consumed (kcal/Bird)									
0.85	5382	5936	5659	5222	5947	5585	5302^{d}	5941^{a}	5622
0.95	5485	5874	5679	5448	5770	5609	5467^{cd}	5822^{ab}	5644
1.05	5610	5543	5577	5327	5749	5538	5469^{cd}	5646^{bc}	5557
Mean	5492	5784	5638	5332	5822	5577	5412^{y}	5803^{x}	

Source of Variation	AWG		AFI		FE		LCR		Calories/Bird	
	P>F	SEM	P>F	SEM	P>F	SEM	P>F	SEM	P>F	SEM
FORM	0.0002	0.006	0.3784	0.016	0.0086	0.007	0.0061	0.019	0.4017	50.7
LYS	0.0001	0.008	0.6185	0.020	0.0250	0.008	<.0001	0.024	0.6011	62..2
FORM X LYS	0.0188	0.028	0.9851	0.012	0.5129	0.037	0.2654	0.034	0.9772	88.8
ME	0.0249	0.006	0.0962	0.016	0.8826	0.007	0.9258	0.019	<.0001	50.7
FORM X ME	0.6221	0.009	0.1682	0.023	0.3664	0.010	0.3089	0.027	0.1792	71.7
LYS X ME	0.7611	0.011	0.0398	0.028	0.0834	0.012	0.0648	0.034	0.0419	88.1
FORM X LYS X ME	0.6095	0.016	0.3023	0.039	0.7995	0.017	0.7465	0.048	0.2964	125.5

^{a,b,c,d,x,y}Within comparisons, means with no common letters differ significantly ($P<0.05$).

study was still observed in the absence of a difference in feed intake between feed forms. The lack of an appreciable difference in bulk density most likely contributed to the similar feed intakes between mash and pellet fed birds (Table 2). These findings are contrary to those reported by Reddy *et al.* (1962), claiming that mechanically increasing diet density was responsible for the observed increase in PE value of the diet.

McKinney and Teeter (2003) concluded that the PE value of pelleting is mediated by bird energy expenditure, thus suggesting that increasing the PE value of a diet would allow for a reduction in dietary energy without compromising growth performance and FE. While the benefits of feeding pelleted diets over mash diets are well-documented and readily accepted by the commercial poultry industry, a high percentage of research concerning the amino acid or energy needs of growing broilers has been conducted using mash diets. Greenwood *et al.* (2003) reported that estimated digestible lysine needs (95% of asymptote of quadratic model) of pellet-fed birds were 13% and 9% higher than those of mash fed birds for BWG and FE, respectively. Results of the present study suggest that pelleting a diet potentially provides more energy for weight gain, thus increasing the efficiency of lysine utilization, as well as increasing the lysine needs for BWG. These findings indicate that feed form should be considered as a factor affecting the response of birds to dietary amino acid or energy levels, thus influencing the perceived nutrient needs of the bird.

Further research is necessary to determine the extent that feed form influences the outcome of dose-response studies intended to determine amino acid needs, as well as studies focussed on decreasing safety margins of amino acids in order reduce N excretion. If feeding pelleted diets of high quality (i.e. low level of fines) increases the energy available for growth, then lower amino acid recommendations determined through feeding purified, semi-purified, or conventional mash diets may be inadequate to achieve the growth rates and FE desired by the poultry industry. The economical potential for improving broiler performance through feeding higher dietary amino acid concentrations in order to take advantage of the increase in PE with good quality pellets, may justify the additional diet costs associated with the increased amino acid concentration.

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