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ABSTRACT

An experiment was conducted to assess effects of phase-feeding (PF) on crude protein (CP) intake, excretion, and retention of broilers. Six birds were housed individually and were fed diets formulated using recommendations from National Research Council (NRC) or linear regression equations. Two PF treatments were prepared: standard (PF) and low (PF10), in which predicted lysine, sulfur amino acids, and threonine recommendations were reduced by 10%. For PF and PF10, two diets (high-nutrient and low-nutrient density) were blended in variable quantities to produce rations matching predicted amino acid requirements over two intervals. Birds were fed a single NRC grower and finisher diet or a series of PF and PF10 diets that were switched every other day. With the exception of weight gain, which was lower for PF than for birds fed the NRC and PF10 diets, no differences in growth performance were observed. Both PF diets reduced CP intake numerically from 21-43 d and 21-63 d, and significantly from 43-63 d ($P < 0.055$). Retention of CP was not impacted by diet although there was a tendency toward increased CP retention in birds fed the PF10 diet from 43-63 d ($P = 0.071$). Excretion of CP during the finisher period was reduced ($P < 0.05$) for birds fed PF and PF10 diets, and total CP excretion was numerically reduced (4.0% and 8.6%, respectively). These data indicate that in addition to economic benefits, PF may result in environmental benefits.

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INTRODUCTION

The National Research Council (NRC, 1994) provides amino acid (AA) recommendations for poultry producers, but these recommendations typically do not follow industry practices and are segregated into three periods (starter, grower, and finisher) that do not match those used in current production systems. Because broiler AA requirements decrease steadily with age, an opportunity exists to use phase-feeding (PF) as an alternative means of feeding broilers. Previous research (Pope and Emmert, 2002; Pope et al., 2002b; Warren and Emmert, 2000) indicated that PF did not negatively impact growth performance or carcass yield compared to broilers fed diets based on NRC (1994) requirements. Further, PF appeared to reduce dietary feed costs during the grower and finisher phases. By limiting excess dietary amino acids, PF may also reduce nitrogen excretion, as demonstrated previously with swine (Boisen et al., 1991). Reduction of nitrogen excretion is an environmental benefit and could potentially reduce ammonia production in broiler houses.

MATERIALS AND METHODS

All procedures were accepted by the University of Arkansas Institutional Animal Care and Use Committee. A trial was conducted to evaluate nitrogen excretion of broiler chickens fed: 1) a series of two diets formulated to contain NRC (1994) recommendations for lysine (Lys), sulfur amino acids (SAA), and threonine (Thr); 2) a series of 21 diets (PF) formulated to contain Lys, SAA, and Thr levels predicted by linear regression equations, with dietary AA levels lowered every other day; and 3) a series of 21 diets (PF10) formulated to contain 10% less Lys, SAA, and Thr than those contained in PF diets, with dietary AA levels lowered every other day. Prior to the experimental period (21 to 63 d), chicks were fed a common starter diet from 0 to 21 d that was formulated to meet essential nutrient recommendations (NRC, 1994). Regression equations from Emmert and Baker (1997) were modified to reflect male requirements (Emmert and Baker, 1997; Warren and Emmert, 2000) and were used to predict every other day PF (Treatment 2) as follows: digestible Lys, $y = 1.22 - 0.0095x$; digestible

MEET THE STUDENT-AUTHOR

I graduated in May 2002 with a B.S. degree in poultry science and currently am working on a master's degree in poultry science with an emphasis in nutrition. Dr. Jason Emmert was my undergraduate mentor for the crude-protein excretion study and is now my major professor for my graduate degree. I became involved with research while working in Dr. Emmert's lab. He was able to get me excited about conducting research experiments, and eventually I decided to get a master's degree under his supervision.

L. Niki Loupe

I graduated from Crossett High School in 1998 as an honor graduate. I was very active in high school clubs and organizations and immediately got involved in activities when I arrived at the University of Arkansas. As an undergraduate, I was fortunate to be one of our College Ambassadors and a Razorback Belle. I was also active in several organizations such as the Poultry Science Club, Golden Key National Honor Society, Associated Student Government, and Sigma Alpha Sorority.

As an undergraduate and graduate student, I have had the opportunity to compete nationally with my research at several scientific meetings. I recently received an award for my poster at the International Poultry Scientific Forum that was held in Atlanta, Georgia.

I am grateful to have had this opportunity to do research as an undergraduate. It helped me decide to get a master's degree in poultry nutrition after I graduated with a bachelor's degree.

methionine and cystine, y = (0.88 – 0.0063x)/2; and digestible Thr, y = 0.8 – 0.0053x, where y = digestible AA level, and x = midpoint (day) of the desired age range. Treatment 1 consisted of two NRC diets fed from 21 to 42 and 42 to 63 d (Table 1). In treatments two and three, an initial high-nutrient (HN) diet was formulated to contain predicted Lys, SAA, and Thr requirements for broilers from 21 to 23 d of age (Table 2). A low-nutrient (LN) diet was also prepared for treatments two and three, and was formulated to contain predicted Lys, SAA, and Thr requirements for broilers from 61 to 63 d of age (Table 2). Nineteen intermittent diets for treatments two and three were prepared by blending the respective HN and LN diets in variable quantities.

At 21 d of age, six male chicks were weighed, individually housed in wire cages, and assigned to each of the dietary treatments. Broilers were weighed at 63 d of age for determination of growth performance. Excreta were collected every other day to determine the impact of PF and PF10 on CP and AA excretion and retention. All excreta were collected in aluminum pans (placed under each cage), frozen, lyophilized, and analyzed for CP and AA.

This experiment was analyzed as a completely randomized design with individual birds considered the experimental unit. The General Linear Models (GLM) procedure of SAS® was used to conduct an analysis of variance on all data. When a significant main effect was detected, differences among treatment means were established using the least significant difference multiple-comparison procedure.

RESULTS AND DISCUSSION

The concept of PF is to frequently decrease dietary amino acid levels throughout grow-out; thus, PF may reduce CP excretion. Previous studies (Pope and Emmert, 2002; Pope et al., 2002a, b; Warren and Emmert, 2000) have shown no differences in growth performance between NRC (1994) and PF treatments. In addition, PF has shown the potential for economic benefits throughout the starter, grower, and finisher phases. In the current experiment, we assessed the impact of PF on CP intake, excretion, and retention.

Concurrent with this experiment, an experiment was conducted using the same diets with birds grown in floor-pens (Pope et al., 2002a). No differences ($P > 0.05$) in growth performance or carcass yield were observed among treatments, and performance was similar to the 18 birds used in the CP study. In the CP study, no significant differences ($P > 0.05$) in CP intake were observed during the grower or finisher periods (Table 3). However, overall CP intake was numerically reduced in birds fed PF and PF10 diets (5.2 and 6.3% reductions, respectively). Excretion of CP was not impacted by PF during the grower period, but PF and PF10 regimens led to significant ($P < 0.05$) reductions in CP excretion during the finisher period and numerical reductions overall (4.1 and 8.8% reductions, respectively; Table 3). Interestingly, with the exception of the grower period, CP retention was not impacted by diet.

Amino acid intake, excretion, and retention were analyzed for the overall experiment (21-63 d). No differences were seen for Lys intake or excretion among treatments, but Lys retention was significantly increased ($P = 0.05$) by PF and PF10 compared to the NRC treatment (Table 4). For Cys, intake and excretion were not affected by diet, but retention was numerically improved by PF and PF10 ($P = 0.07$). Threonine intake was reduced ($P = 0.04$) by PF and PF10, but no differences among treatments were observed for Thr excretion and retention.

Previous research has not been conducted with broilers to evaluate the impact of PF on crude protein intake, excretion, and retention. However, Boisen et al. (1991) reported decreased nitrogen excretion with pigs fed a nutritional regimen similar to our PF approach. Considerable research efforts are ongoing to reduce nutrient excretion and thereby lessen the impact of animal production on the environment. Although differences in CP excretion in this experiment may appear minimal on a per-bird basis, when applied on a commercial scale the potential impact could be tremendous. For instance, using our values (Table 3), total crude protein excretion for a broiler house containing 20,000 birds (grown to nine weeks of age) would be reduced by 560 and 1,200 kg by PF and PF10, respectively. Over the course of one year, PF and PF10 would be expected to reduce CP excretion (of birds in a single broiler house, assuming four growth cycles per year) by approximately 2,240 and 4,800 kg, respectively.

In summary, PF supports growth performance when compared to the NRC (1994) requirements and appears to decease CP excretion. Along with the potential economic benefits previously reported, decreasing CP in the excreta could have a tremendous environmental benefit. Phase-feeding is a program that should be considered by poultry producers as a way to decrease cost and lessen the impact of poultry production on the environment.

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Table 1. Composition of experimental diets fed to broilers from 21 to 63 d of age.

Ingredient	NRC[z]	NRC[z]	PF HN[y]	PF LN[y]	PF10 HN[x]	PF10 LN[x]
	(%)					
Corn	61.99	68.02	59.34	73.21	61.51	77.38
Soybean meal	31.69	25.67	37.32	20.57	32.17	16.37
Poultry fat	3.00	3.00	3.00	3.00	3.00	3.00
Vitamin mix[w]	0.20	0.20	0.20	0.20	0.20	0.20
Mineral mix[w]	0.10	0.10	0.10	0.10	0.10	0.10
Dicalcium PO_4	1.20	1.20	1.20	1.20	1.20	1.20
Limestone	1.30	1.30	1.30	1.30	1.30	1.30
NaCl	0.30	0.30	0.30	0.30	0.30	0.30
Choline Cl (60%)	0.10	0.10	0.10	0.10	0.10	0.10
L-Lysine•HCl	---	---	---	---	0.020	0.041
DL-Methionine	0.069	0.038	0.135	0.016	0.102	0.003
L-Threonine	0.047	0.072	0.003	0.003		0.009

[z] NRC diets contained Lys, SAA, and Thr levels recommended by NRC (1994).

[y] Phase-feeding (PF) diets were formulated to contain Lys, SAA, and Thr levels predicted by linear regression equations (Table 2) for 21-to-23-d-old [PF high-nutrient (HN)] or 61-to-63-d-old [PF low-nutrient (LN)] broilers. Experimental diets were produced by blending PF, HN, and PF LN diets in variable quantities (see Materials and Methods).

[x] Adjusted phase-feeding (PF10) diets were predicted by linear regression equations and lowered by 10% (Table 2) for 21-to-23-d-old (PF10 HN) or 61-to-63-d-old (PF10 LN) broilers. Experimental diets were produced by blending PF10 HN and PF10 LN diets in variable quantities (see Materials and Methods).

[w] Emmert et al. (1999).

Table 2. Calculated digestible amino acid levels fed to broilers from 21 to 63 d.

		Digestible content, % of diet[z]				CP,	ME_n,[y]
Diet	Days	Lysine	Methionine	Cystine	Threonine	%	kcal/kg
NRC[x]	21 to 42	0.88	0.33	0.31	0.66	19.6	3,114
NRC[x]	42 to 63	0.75	0.30	0.26	0.60	17.4	3,169
PF HN[w]	21 to 23	1.01	0.37	0.37	0.68	21.8	3,062
PF LN[v]	61 to 63	0.63	0.24	0.24	0.47	15.4	3,218
PF10 HN[w]	21 to 23	0.91	0.33	0.33	0.62	19.8	3,109
PF10 LN[v]	61 to 63	0.57	0.22	0.22	0.42	13.8	3,256

[z] Digestible amino acid, CP, and dietary ME content calculated from the analytical values for total Lys, SAA, and Thr in corn and soybean meal and published digestibility coefficients.

[y] Metabolizable energy values for corn, soybean meal, and poultry fat were assumed to be 3,350, 2,440, and 8,800 kcal MEn/kg, respectively.

[x] Although the NRC (1994) provides total dietary AA recommendations, digestible AA levels were calculated after formulation of diets to meet total NRC (1994) recommendations for dietary Lys, SAA, and Thr.

[w] Phase-feeding high-nutrient (PF HN and PF10 HN) diets were formulated to contain Lys, SAA, and Thr levels predicted by linear regression equations for 21-23-d-old broilers. Experimental diets were produced by blending HN and LN diets in variable quantities.

[v] Phase-feeding low-nutrient (PF LN and PF10 LN) diets were formulated to contain Lys, SAA, and Thr levels predicted by linear regression equations for 61 to 63-d-old broilers. Experimental diets were produced by blending HN and LN diets in variable quantities.

Table 3. Crude protein intake, excretion, and retention of broilers from 21 to 63 d.[z]

	Grower period (21 to 43 d)			Finisher period (43 to 63 d)			Overall (21 to 63 d)		
Treatment	Intake	Excretion	Retention	Intake	Excretion	Retention	Intake	Excretion	Retention
	(g)	(g)	(%)	(g)	(g)	(%)		(g)	(g) (%)
NRC	710	314	56	728	371	49	1439	685	53
PF	666	319	52	697	338	52	1364	657	52
PF10	676	317	54	672	308	54	1348	625	54
Pooled SD[y]	77	49	4.0	38	32	4.2	89	73	2.8
NRC vs PF and PF10			P = 0.06			P = 0.02			

[z] Values are means of six broilers housed individually.

[y] SD = Standard deviation.

Table 4. Amino acid intake, excretion, and retention of broilers from 21 to 63 d.[z]

	Lysine			Methionine			Cysteine			Threonine		
Treatment	Intake	Excretion	Retention	Intake	Excretion	Retention	Intake	Excretion	Retention	Intake	Excretion	Retention
	(g)	(g)	(%)	(g)	(g)	(%)	(g)	(g)	(%)	(g)	(g)	(%)
NRC	73.3	11.6	84.3	26.0	3.60	86.2	24.5	5.54	75.5	55.7	12.2	78.1
PF	74.3	10.3	86.1	26.3	3.54	86.5	24.4	5.52	77.4	51.0	12.0	76.5
PF10	72.7	9.90	86.5	26.3	3.58	86.5	25.7	5.58	78.5	51.9	11.4	78.1
Pooled SD[y]	4.72	1.80	1.74	1.72	0.71	2.20	1.58	0.83	2.28	3.35	1.72	2.21
NRC vs PF and PF10			P = 0.05						P = 0.07	P = 0.04		

[z] Values are means of six broilers housed individually.

[y] SD = Standard deviation.