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Nutritional Value of a Highly Digestible Sorghum Cultivar for Meat-Type Chickens⊗

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The nutritional value of a newly discovered sorghum mutant cultivar (P851171), with high in vitro protein digestibility, was compared to those of corn and two normal sorghums (P721N and 611Y) in two chick feeding trials. Although 8−20 day protein efficiency ratios and net protein ratios of all three sorghums were inferior to those of corn, P851171 and 611Y had markedly greater mean true amino acid digestibilities (TAAD) than either corn or P721N. In a subsequent 42-day experiment, all three sorghums supported weight gains equal to those of the corn-fed chicks. Feeding suboptimal levels of dietary protein resulted in reduced weight gains and no observed benefits of P851171 or 611Y. Furthermore, chicks fed P851171 exhibited poorer feed/gain values as compared to those fed the other cereals. It is possible that the starch content/carbohydrate profile of P851171 was inferior to that of the other sorghums, which offset its superior TAAD and resulted in poorer broiler performance.

KEYWORDS: Sorghum; chicken; amino acid digestibility; nutritional value

INTRODUCTION

In terms of its energy content and protein digestibility, tannin-free sorghum grain is considered to be somewhat inferior to corn as a feedstuff for nonruminants. Thus, the discovery by Purdue researchers (*1*, *2*) of grain sorghum lines within a high-lysine population derived from the mutant P721Q that had higher than normal in vitro protein digestibilities was noteworthy. Initial animal studies aimed at evaluating the in vivo protein quality of two highly digestible (HD) varieties substantiated that they were superior to normal sorghum and similar to corn, based on protein efficiency ratios (PER) and net protein ratios (NPR) determined in a 9-day chick feeding trial (*3*).

Transmission electron microscopic studies by Oria et al. (*4*) provided a possible explanation for these observations by revealing that the protein bodies of an HD sorghum mutant cultivar had a remarkably different structure than that of normal genotypes. Mutant protein bodies were characterized by irregularly shaped lobes with deep invaginations or folds that, in many instances, reached the central area of the protein body. In addition, dark inclusions, representing the poorly digestible γ-kafirin protein, were observed at the base of the folds. In contrast, normal protein bodies were more spherical in shape and were characterized by a dark-stained γ-kafirin periphery or ring that was absent from the mutant cultivar. Oria et al. (*4*) suggested that, as compared to normal sorghums, digestive enzymes might have enhanced access to the prevalent α-kafirin storage proteins in the seeds of the HD sorghums.

Here, we report the results of the first comprehensive in vivo nutritional evaluation of an HD sorghum cultivar (P851171) using meat-type chicks. In addition to serving as the sole source of dietary protein in PER, NPR, and true amino acid digestibility (TAAD) determinations, P851171, as well as two normal sorghum cultivars (P721N and 611Y) and corn, was comparatively evaluated as a component of complete mixed diets fed to meat-type cockerels from day-old to market age (42 days).

MATERIALS AND METHODS

Feedstuff Analyses. Sorghum, corn, and soybean meal samples (1996 harvest), as well as all of the complete mixed feeds in the broiler grow-out study, were assayed for moisture (*5*), nitrogen (N) (*5*), and amino acid contents (*5*, *6*) by a commercial laboratory.

Protein Efficiency Ratio and Net Protein Ratio Determinations. Three replicate groups of six 8-day-old male New Hampshire × Columbian chicks were each fed one of five diets (**Table 1**) for a period of 12 days. Diets 1−4 (corn, P721N, P851171, and 611Y, respectively) contained 7% crude protein (CP), whereas diet 5 was N-free. All three sorghums were tannin-free by analysis (*8*). The chicks, which had been fed a 23% CP corn−soybean meal pretest diet during the first week posthatching, were housed in thermostatically controlled starter batteries with raised wire floors. Chicks were given free access to feed and water and were provided with 24 h of light daily. Weight gain and feed consumption were obtained on a group basis ($n = 3$ per diet).

⊗ This paper is dedicated to the memory of John D. Axtell, Lynn Distinguished Professor of Agronomy, who passed away December 2, 2000.

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Table 1. Diet Compositions (Grams per 100 g of Diet) for the Protein Efficiency Ratio and Net Protein Ratio Assays

	diet[a]				
ingredient[b,c]	1	2	3	4	5
corn (8.23)	85.05				
P721N (11.15)		62.78			
P851171 (8.86)			79.01		
611Y (9.56)				73.22	
soybean oil	2.50	2.50	2.50	2.50	2.50
mineral mixture[d]	5.37	5.37	5.37	5.37	5.37
vitamin mixture[d]	0.20	0.20	0.20	0.20	0.20
choline-Cl	0.20	0.20	0.20	0.20	0.20
α-tocopheryl acetate	0.002	0.002	0.002	0.002	0.002
ethoxyquin[e]	0.0125	0.0125	0.0125	0.0125	0.0125
corn starch/dextrose (2:1, w/w)	6.665	28.935	12.705	18.495	91.715

[a] Diets 1–4 each contained 7% crude protein (CP); diet 5 was N-free. [b] CP percentages in parentheses. [c] P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [d] Fernandez and Parsons (*7*). [e] Santoquin, Monsanto Co., St. Louis, MO.

True Amino Acid Digestibility and Nitrogen-Corrected True Metabolizable Energy (TME_n) Assays. TAAD and TME_n values for the corn and sorghums were determined as previously reported (*9*) using cecectomized, adult Single Comb White Leghorn roosters.

Broiler Grow-Out Study. One-day-old, male meat-type (Cornish cross) chicks were obtained from a commercial hatchery, where they were vaccinated for Marek's disease. The birds were wing-banded and randomly assigned to one of eight diets (see below) during each of two consecutive 3-week periods. There were three pens of 36 cockerels each per diet. Each 1.52 × 2.44 m pen was bedded with fresh pine shavings and initially equipped with a gas brooder, a brooder guard, one satellite waterer, and two flat trays for feed. The brooder guards and feed trays were removed after 7 days, with the latter being replaced by one hanging cylindrical feeder. Newcastle-infectious bronchitis vaccine was administered in the water on day 10 of the experiment. An initial brooding temperature of 35 °C was employed with subsequent decreases of ∼2.8 °C per week until a temperature of ∼21 °C was reached. The room temperature was then maintained at ∼21 °C for the remainder of the experiment. The birds received 24 h of light during the first week and 23 h of light/1 h of darkness daily for the remainder of the study.

The starter diets (0−3 weeks) and finisher diets (4−6 weeks) were fed in the form of a dry mash and contained either 23 or 20% CP, or 20 or 17% CP, respectively, with corn, two normal sorghums (P721N and 611Y), and an HD sorghum (P851171) serving as the cereal sources (**Table 2**). Diets were formulated on the basis of analyzed amino acid contents of the cereals and soybean meal, and there was fairly good agreement between the calculated and determined dietary amino acid contents (**Table 3**). However, for some unknown reason, diets 1−3 contained higher than calculated levels of CP.

Chicks fed 23% CP diets from 0 to 3 weeks were fed 20% CP diets from 4 to 6 weeks, whereas those fed 20% CP diets from 0 to 3 weeks were fed 17% CP diets from 4 to 6 weeks. Thus, within each 3-week period, a 2 × 4 factorial arrangement of treatments was employed, and within each CP level, the four cereals were compared on an isonitrogenous basis. Feed and water were provided for ad libitum consumption throughout the experiment.

Statistical Analyses. A completely randomized design was employed, and data were subjected to analysis of variance procedures using the General Linear Models procedure of the SAS Institute (*10*). Duncan's multiple-range test (*11*) was used to detect differences among treatment means. Unless noted otherwise, differences at $P \leq 0.05$ were considered to be significant.

RESULTS

Protein Efficiency Ratio and Net Protein Ratio Feeding Trial. Chicks fed the corn-based diet exhibited significantly greater 12-day weight gains, feed conversion rates, and PER and NPR values as compared to the sorghum-fed chicks (**Table 4**). Among the three sorghums, P851171 supported significantly better chick performance than either P721N or 611Y. These findings are in contrast to previous work from our laboratory (*3*) in which chicks fed P851171 (1995 harvest) had PER and NPR values equal to those of corn-fed birds.

True Amino Acid Digestibilities and Nitrogen-Corrected True Metabolizable Energy Values. P851171 and 611Y had very similar TAAD values that were markedly greater than those of corn and P721N, compared either on an individual basis or as a group according to their indispensability (**Figure 1**). In addition, within each of the cereals, higher mean digestibilities were noted for the dispensable amino acids (Ala, Asx, Cys, Glx, Pro, Ser, and Tyr) as compared to the indispensable amino acids (Arg, His, Ile, Leu, Lys, Met, Phe, Thr, and Val). Overall mean

Table 2. Diet Compositions (Grams per 100 g of Diet) for the Broiler Grow-Out Study

	diet											
ingredient[a,b]	1	2	3	4	5	6	7	8	9	10	11	12
corn (8.23)	54.15				62.66				71.16			
P721N (11.15)		40.00				46.28				52.56		
P851171 (8.86)			50.34				58.24				66.14	
611Y (9.56)				46.65				53.97				61.30
soybean meal (49.32)	37.60	37.60	37.60	37.60	30.09	30.09	30.09	30.09	22.59	22.59	22.59	22.59
soybean oil	4.00	4.00	4.00	4.00	3.00	3.00	3.00	3.00	2.00	2.00	2.00	2.00
corn starch	0.06	14.06	3.80	7.43	0.10	16.31	4.44	8.64	0.19	18.61	5.13	9.89
dicalcium phosphate	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
limestone	1.30	1.30	1.30	.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
NaCl (plain)	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
DL-methionine	0.14	0.20	0.17	0.19	0.10	0.17	0.13	0.16	0.01	0.08	0.04	0.07
L-lysine·HCl		0.09	0.04	0.08		0.10	0.05	0.09		0.11	0.05	0.10
Dry Mold-Chek Plus 5762[c]	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Polyanox[c]	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
vitamin and trace mineral mix[d]	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30	0.30
Monensin-Na[e]	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075	0.075
calculated compositions												
crude protein (CP) (g/100 g of diet)	23.00	23.00	23.00	23.00	20.00	20.00	20.00	20.00	17.00	17.00	17.00	17.00
ME_n (kcal/kg)[f]	3125	3068	3084	3078	3140	3075	3093	3086	3157	3086	3104	3095

[a] CP percentages in parentheses. [b] P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [c] Agrimerica, Inc., Northbrook, IL. [d] DQ Broiler, Dawe's Laboratories, Chicago, IL. [e] Coban, Eli Lilly and Co., Indianapolis, IN. [f] Calculated from Table 9-1 in ref *13*.

Table 3. Calculated (Cal) and Determined (Det) Amino Acid and Nitrogen (N) Contents (Grams per 100 g of Diet) of the Corn- and Sorghum-Based Diets (Broiler Grow-Out Study)

diet:	1		2		3		4		5		6		7		8		9		10		11		12	
cereal[a]:	corn		P721N		P851171		611Y		corn		P721N		P851171		611Y		corn		P721N		P851171		611Y	
CP (g/100 g of diet):	23		23		23		23		20		20		20		20		17		17		17		17	
amino acid	cal[b]	det[c]	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det	cal	det
Thr	0.91	0.94	0.88	0.91	0.90	0.93	0.89	0.84	0.78	0.77	0.76	0.77	0.78	0.75	0.76	0.75	0.66	0.65	0.63	0.65	0.65	0.62	0.64	0.64
Val	1.09	1.24	1.09	1.25	1.08	1.21	1.09	1.12	0.95	0.99	0.95	1.03	0.93	1.00	0.95	1.00	0.80	0.85	0.80	0.86	0.79	0.81	0.81	0.83
Ile	0.96	1.11	0.98	1.14	0.95	1.09	0.98	1.03	0.82	0.88	0.85	0.93	0.81	0.88	0.85	0.90	0.68	0.74	0.71	0.77	0.67	0.71	0.71	0.74
Leu	1.94	2.13	2.03	2.26	1.95	2.10	2.04	2.00	1.74	1.79	1.84	1.96	1.75	1.75	1.85	1.87	1.53	1.61	1.64	1.76	1.54	1.54	1.66	1.67
Phe	1.17	1.29	1.19	1.32	1.17	1.26	1.20	1.19	1.01	1.04	1.04	1.10	1.01	1.01	1.04	1.06	0.86	0.90	0.88	0.93	0.85	0.84	0.89	0.89
His	0.64	0.70	0.60	0.66	0.61	0.65	0.61	0.62	0.56	0.57	0.51	0.54	0.52	0.52	0.52	0.53	0.48	0.50	0.42	0.45	0.44	0.43	0.44	0.44
Lys	1.33	1.47	1.33	1.49	1.33	1.45	1.33	1.39	1.12	1.16	1.12	1.21	1.12	1.15	1.12	1.16	0.91	0.94	0.91	0.96	0.91	0.91	0.91	0.95
Arg	1.61	1.74	1.54	1.68	1.58	1.69	1.56	1.57	1.37	1.40	1.28	1.36	1.34	1.35	1.31	1.30	1.13	1.16	1.03	1.07	1.09	1.08	1.06	1.07
Met	0.51	0.54	0.54	0.56	0.52	0.51	0.53	0.51	0.43	0.39	0.47	0.48	0.44	0.42	0.46	0.44	0.30	0.28	0.34	0.34	0.31	0.29	0.33	0.32
Cys	0.39	0.41	0.36	0.40	0.38	0.40	0.37	0.34	0.35	0.34	0.31	0.35	0.34	0.32	0.32	0.34	0.31	0.30	0.27	0.31	0.30	0.28	0.28	0.29
Trp	0.32	0.32	0.32	0.32	0.33	0.34	0.32	0.34	0.27	0.24	0.27	0.27	0.28	0.27	0.28	0.28	0.22	0.20	0.22	0.23	0.23	0.21	0.23	0.22
$N \times 6.25$[d]	23.0	25.4	23.0	25.6	23.0	25.4	23.0	23.9	20.0	21.0	20.0	21.0	20.0	20.7	20.0	20.7	17.0	17.6	17.0	17.7	17.0	17.3	17.0	17.8

[a] P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [b] Calculated on the basis of analyzed values of the cereals and soybean meal. [c] Values from one analysis. [d] Mean values of two analyses.

Table 4. Protein Efficiency Ratios and Net Protein Ratios of Chicks Fed Corn- or Sorghum-Based Diets from 8 to 20 Days of Age

performance criteria[b]	diet[a] 1 corn	2 P721N	3 P851171	4 611Y
wt gain (g)	60.2 ± 2.8a	25.4 ± 3.4d	44.2 ± 2.0b	36.0 ± 0.5c
feed intake (g)	246.2 ± 8.0a	187.2 ± 15.6b	227.4 ± 4.7a	227.7 ± 12.6a
feed/gain (g/g)	4.10 ± 0.09a	7.57 ± 0.65c	5.17 ± 0.20b	6.32 ± 0.23c
PER[d]	3.5 ± 0.1a	1.9 ± 0.2c	2.8 ± 0.1b	2.3 ± 0.1c
NPR[e]	3.8 ± 0.1a	2.3 ± 0.2c	3.1 ± 0.1b	2.6 ± 0.1c

[a] See **Table 1** for dietary compositions. P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [b] Values are mean ± SE of three groups of six chicks each per diet. [c] Means within a row with no common letter differ significantly ($P \leq 0.05$). [d] PER = g of wt gain/g of crude protein consumed. [e] NPR = (g of wt gain – g of wt gain of N-free diet)/g of crude protein consumed. The average 12-day weight gain of chicks fed the N-free diet was –5.0 g.

TAAD values, averaged across the 17 amino acids, were ~15–18% higher in P851171 and 611Y versus corn and P721N (**Table 5**). In contrast, P721N had the highest TME_n value, which was similar to that of 611Y but significantly greater than that of corn or P851171 (**Table 5**).

Broiler Grow-Out Study. All three sorghums supported weight gains equal to those of corn-fed chicks at all stages of the study (**Table 6**), and the only significant effect of cereal type on growth occurred during the first 21 days, when birds fed P721N out-gained those consuming corn. As expected, suboptimal levels of dietary CP resulted in reduced weight gains and feed conversion regardless of cereal source. However, there were no beneficial effects associated with feeding the HD cultivar (P851171) or 611Y, which also had superior TAAD values, at the deficient dietary CP levels. Moreover, the finding that birds fed P851171 exhibited consistently poorer feed conversion as compared to the other sorghums and corn was unexpected.

Finally, it was observed that chicks fed P851171 at control CP levels had 100% livability during the entire 6-week study (**Table 6**). This unique lack of mortality, combined with normal livability rates in the HD sorghum group fed deficient levels of CP, resulted in a significantly higher overall livability value (97.22%; averaged across both dietary protein regimes) for the P851171 group versus the other three groups.

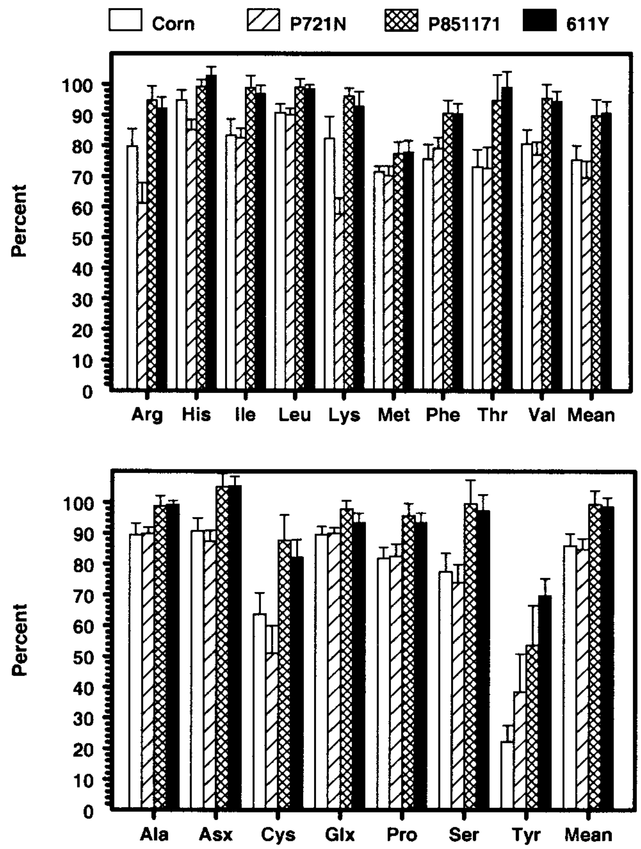

Figure 1. True amino acid digestibilities (TAAD) of corn and the three sorghums: (top) individual and mean indispensable amino acid TAAD values; (bottom) dispensable amino acid TAAD values. P721N and 611Y are normal sorghums; P851171 is a highly digestible sorghum. Values are mean ± SE of five, five, four, and four birds for corn, P721N, P851171, and 611Y, respectively.

DISCUSSION

The present paper describes the first comprehensive in vivo nutritional evaluation of an HD sorghum cultivar (P851171) using meat-type chicks. Our original hypothesis was that P851171 would support broiler performance equal to that of corn and the other sorghums at optimal dietary CP levels but, due to greater TAAD, would out-perform corn and the normal sorghums at suboptimal dietary CP levels. However, this

Table 5. Overall Mean True Amino Acid Digestibility and Nitrogen-Corrected True Metabolizable Energy Values of the Corn and Sorghums

performance criteria	cereal[a,b] corn	P721N	P851171	611Y
overall mean TAAD[c] (%)	77.8 ± 4.6b	74.3 ± 4.8b	92.7 ± 5.1a	93.1 ± 3.5a
TME_n[d] (kcal/g of dry matter)	4.023 ± 0.011bc	4.143 ± 0.014a	3.965 ± 0.019c	4.089 ± 0.039ab

[a] P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [b] Means within a row with no common letter differ significantly ($P \leq 0.05$). [c] Values are mean ± SE of five, five, four, and four birds for corn, P721N, P851171, and 611Y, respectively. [d] Values are mean ± SE of five birds each.

Table 6. Weight Gains, Feed Conversion, and Livability of Male Broilers Fed Corn- or Sorghum-Based Diets

dietary treatment		days 0–21[a,b]			days 21–42[a,b]			days 0–42[a,b]		
cereal[c]	protein content[d] (%)	wt gain (g)	feed/gain (g/g)	livability (%)	wt gain (g)	feed/gain (g/g)	livability (%)	wt gain (g)	feed/gain (g/g)	livability (%)
corn	23/20	796.0	1.40	98.15	1673.8ab	1.84d	96.30	2469.7	1.69	94.44b
P721N	23/20	814.5	1.36	97.22	1662.5ab	1.86cd	97.25	2476.9	1.69	94.47b
P851171	23/20	798.6	1.45	100.00	1702.2a	1.87cd	100.00	2500.8	1.74	100.00a
611Y	23/20	802.3	1.30	95.37	1692.6a	1.90c	99.07	2494.9	1.70	94.44b
corn	20/17	774.2	1.45	97.22	1564.2c	2.03b	96.30	2338.4	1.82	93.52b
P721N	20/17	805.5	1.41	94.44	1613.2bc	2.02b	98.15	2418.8	1.80	92.59b
P851171	20/17	776.6	1.47	95.37	1559.9c	2.11a	99.07	2336.5	1.89	94.44b
611Y	20/17	795.3	1.45	95.37	1552.8c	2.02b	99.07	2348.0	1.82	94.44b
pooled SE		13.3	0.03	1.54	15.6	0.02	1.39	20.7	0.01	1.85

Probabilites

source of variation	wt gain (g)	feed/gain (g/g)	livability (%)	wt gain (g)	feed/gain (g/g)	livability (%)	wt gain (g)	feed/gain (g/g)	livability (%)
cereal (C)	0.0344	0.0098	0.3445	0.6585	0.0055	0.1196	0.2486	0.0001	0.0101
protein content (P)	0.0272	0.0017	0.0327	0.0001	0.0001	0.8300	0.0001	0.0001	0.0210
C × P	0.7601	0.1170	0.3237	0.0115	0.0084	0.7971	0.0602	0.5183	0.0162
main effect means									
cereal									
corn	785.1b	1.42ab	97.69	1619.0	1.94b	96.30	2404.1	1.76b	93.98b
P721N	810.0a	1.38b	95.83	1638.1	1.94b	97.70	2448.1	1.75b	93.53b
P851171	787.8ab	1.46a	97.69	1632.4	1.99a	99.54	2420.2	1.82a	97.22a
611Y	798.8ab	1.37b	95.37	1623.0	1.96b	99.07	2421.8	1.76b	94.44b
protein content									
23/20	802.8a	1.38b	97.69a	1683.0a	1.87b	98.15	2485.8a	1.71b	95.84a
20/17	787.8b	1.44a	95.60b	1572.4b	2.04a	98.15	2360.2b	1.83a	93.75b

[a] Mean values of three pens of 36 birds per diet. [b] Means within a column with no common letter differ significantly ($P \leq 0.05$). [c] P721N and 611Y are normal sorghums; P851171 is an HD sorghum. [d] 23/20 = 23% crude protein from days 0–21 and 20% crude protein from days 21–42; 20/17 = 20% crude protein from days 0–21 and 17% crude protein from days 21–42.

hypothesis must be rejected because chicks fed P851171 had poorer feed/gain values as compared to those of birds fed the other three cereals regardless of dietary CP level [an exception was 21−42 days (23/20 CP regimen); **Table 6**]. Moreover, at suboptimal dietary CP levels, there was no benefit of feeding broilers P851171.

The reason for the unexpectedly poor feed conversion rates of broilers fed the HD sorghum in the grow-out trial most likely involves the energy component of the grain. Subsequent work has revealed that P851171, which possesses a dense floury kernel endosperm texture that is partially vitreous, contains less starch than P721N on a percentage basis [58 vs 66%, respectively (1997 harvest); B. R. Hamaker, unpublished data]. Thus, it appears that P851171's superior protein digestibility was more than offset by its lower starch content, which also translated into a lower TME_n value (**Table 5**) as compared to the other cereals evaluated in this study.

In addition to the quantity of starch in P851171, overall carbohydrate digestibility/availability may also have been impaired. On the basis of a recent study that demonstrated that grain sorghum can contain almost 10% nonstarch polysaccharides (pentosan + cellulose + pectin) by weight (*12*), it is possible that, compared to the other cereals employed in the present study, P851171 may also contain greater than normal amounts of nonstarch polysaccharides. In this regard, it would be of interest to re-evaluate the nutritional quality of the cereals employed herein in the presence and absence of a dietary carbohydrase-containing enzyme supplement such as Avizyme 1500 (Finnfeeds International, Fenton, MO) that contains amylase and xylanase.

In contrast to the poorer than expected performance of the chicks fed P851171 during the 42-day grow-out experiment, the superior TAAD of 611Y (**Figure 1** and **Table 5**) and the excellent growth and feed conversion exhibited by the P721N-fed chicks (**Table 6**) were unanticipated findings. The 611Y cultivar was provided by Cargill Hybrid Seeds (Minneapolis, MN) and, to our knowledge, its amino acid availabilities for poultry had previously not been determined. Moreover, the unexpected excellent performance of the P721N-fed chicks may have been due in part to the large amount of cornstarch that was included in diets 2, 6, and 10 (**Table 2**). P721N contained much higher levels of CP than corn or the other sorghums and, because the diets were formulated such that each cereal provided the same amount of CP while the level of soybean meal was held constant within each group of four diets (23, 20, or 17% CP), cornstarch was added to balance the diets in volume. As a result, the available energy in the P721N-based diets was most likely increased. This problem will be obviated in future studies by comparing normal and HD sorghums of similar CP contents.

Unlike the high-lysine sorghum cultivars of the 1970s, which held great promise but ultimately failed to find commercial application because of poor agronomic performance and poor kernel properties, HD sorghum genotypes are apparently without the former shortcomings, although there is room for further improvements in kernel properties. However, as suggested herein, the main (nutritional) problem with the HD sorghum cultivars may lie in their starch quantity and carbohydrate profile. Thus, Purdue University's sorghum breeding efforts are currently being focused on increasing the kernel hardness and starch density of several HD cultivars, including P851171. With further improvement of its nutritional qualities/kernel characteristics, HD sorghum grain could compete very favorably with corn in both domestic and overseas markets. Moreover, the improved protein digestibility of HD lines would offer an additional advantage over normal sorghum in terms of reduced N pollution potential from animal wastes.

ABBREVIATIONS USED

CP, crude protein; N, nitrogen; NPR, net protein ratio; PER, protein efficiency ratio; TAAD, true amino acid digestiblity; TME_n, nitrogen-corrected true metabolizable energy.

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