Amino Acid Composition and Energy Value of Immature Sorghum Grain[1]

C. W. DEYOE, F. K. SHOUP, G. D. MILLER, J. BATHURST, D. LIANG, P. E. SANFORD, and L. S. MURPHY[2], Kansas State University, Manhattan

ABSTRACT

Proximate and amino acid composition of mature and immature samples of sorghum grain were determined. The data indicate marked differences in amino acid content, immature sorghum grain having higher levels of lysine, aspartic acid, and glycine. Lower values for immature grain were observed for glutamic acid, proline, and leucine. Crude protein content of immature and mature sorghum grain was similar. Feeding studies indicate less available energy from immature than mature sorghum grain.

Data are limited on the effects of stage of maturity on the composition of cereal grains. Lee et al. (1) compared tests and selected a specific gravity measurement for determining the maturity of whole-kernel corn. Carbohydrate content of whole corn at different stages of development was reported by Earley (2), who found that reducing sugars decreased 2 weeks after pollination and followed that trend until maturity. Dextrin-starch content decreased 7 days after pollination, then increased rapidly during the second and third weeks. Starch increased during the sixth and seventh weeks after pollination, but did not increase further during the last 3 weeks of the sampling period. The increase in starch was attributed to rapid translocation of sugar to the kernels, most being converted immediately into dextrin and starch. Studies on corn proteins indicate that globulin, glutelin, and albumin are continuously diluted by zein during grain maturation (3). Studies on the feeding value of wheat frozen prior to harvesting (MacNaughton (4), Bell and Gidyk (5), and Whiting and Bezeau (6)) indicated that there was a reduction in the energy digestibility coefficients for poultry in frost-damaged wheat. Lambert et al. (7) found no differences in nutritional value of wheat harvested 15 to 18 days prior to combine-ripeness.

This study reports effects of immaturity on the proximate and amino acid composition and nutritional value of sorghum grain.

METHODS

Samples of immature hybrid sorghum grain, Paymaster Kiowa, Frontier 400C, TE-66, DeKalb C44b, Asgrow Ranger A, and RS-610, were obtained from the Kansas Agricultural Experiment Station Field, Newton, Kansas. The planting date for these hybrids was July 10, 1967. The freeze date, October 27, 1967, resulted in termination of growth, and the growing season was 104 days from emergence. The grain was in the late-dough stage and contained 35 to 40% moisture. Samples of immature grain from a local elevator during the same season and samples of mature

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[1]Contribution No. 686, Department of Grain Science; No. 740, Department of Dairy and Poultry Science; and No. 1091, Department of Agronomy, Kansas State Agricultural Experiment Station, Manhattan. Presented at the 54th Annual Meeting, Chicago, Ill., April-May 1969.

[2]Respectively: Professor, Instructor, Assistant Professor, Research Assistant, and Research Assistant, Department of Grain Science; Professor of Poultry Science; and Associate Professor of Agronomy, Kansas State University, Manhattan.

TABLE I. EXPERIMENTAL DIETS CONTAINING MATURE AND IMMATURE GRAIN FROM TWO HYBRIDS[a]

	Mature		Immature	
	Frontier	Paymaster	Frontier	Paymaster
Diets	1	2	3	4
Bushel Test Weight[b]	58.3	58.0	43.2	43.1
	%	%	%	%
Sorghum grain	60.6	58.5	59.3	60.4
Soybean meal (45%)	27.9	30.0	29.2	28.1
Alfalfa meal (17%)	2.0	2.0	2.0	2.0
Fish meal (60%)	4.0	4.0	4.0	4.0
Distiller's dried grains with solubles	1.5	1.5	1.5	1.5
Ground limestone	1.0	1.0	1.0	1.0
Dicalcium phosphate	1.0	1.0	1.0	1.0
Salt	0.5	0.5	0.5	0.5
Animal fat	1.0	1.0	1.0	1.0
Premix[c]	0.5	0.5	0.5	0.5

[a]Calculated to be isonitrogenous, 22% crude protein.

[b]Bushel test weight, lb. per bu.

[c]Supplies per kg. of diet: 2,200 IU vitamin A; 1.650 ICU vitamin D_3; 8.8 mg. riboflavin; 16.19 mg. pantothenic acid; 26.4 mg. niacin; 308.0 mg. choline chloride; 9.68 γ vitamin B_{12}, 0.05% dl-methionine; 0.0125% amprolium; 0.0125% ethoxyquin; 5.0 mg. chlortetracycline; 50.0 p.p.m. Mn; 50.0 p.p.m. Fe; 25.0 p.p.m. Zn; 5.0 p.p.m. Cu; 1.5 p.p.m. I; and 0.5 p.p.m. Co.

Frontier 400C and Paymaster Kiowa grown near Manhattan also were collected. All samples were analyzed for moisture, fat, protein, and ash by AOAC methods (8). Carbohydrate content was estimated by difference. Bushel weights were determined with standard test-weight equipment.

Amino acid composition of samples was determined by ion-exchange chromatography as described by Waggle et al. (9).

Nutritional studies were conducted with day-old Strain-Cross White Rock chicks housed in wire-floor batteries. Chicks were randomly distributed into groups of sixteen birds, three replications per diet. Feed and water were supplied *ad libitum*.

Growth and feed utilization of chicks fed immature and mature sorghum grain were compared, and available energy was estimated for immature sorghum grain. Experimental diets (1 through 4)containing mature (bu. wt. 58.3 and 58.0 lb.) and immature (bu. wt. 43.2 and 43.1 lb.) Frontier 400C and Paymaster Kiowa are given in Table I. Adjustments in sorghum grain and soybean meal were made to maintain isonitrogenous diets. Table II gives composition of diets used to evaluate energy content of immature sorghum grain. Diets (5 through 8) calculated to contain 850, 900, 950, and 1,000 kcal. of productive energy were formulated for mature sorghum grain. In diets 9 through 12, sorghum grain (bu. wt. 35.1 lb.) replaced mature grain in diets 5 and 8 to evaluate energy availability of immature grain.

RESULTS AND DISCUSSION

Results of proximate analysis of samples varying in test wt. from 35.1 to 58.3 lb. per bu. are given in Table III. Data are grouped into immature samples with bu.

TABLE II. EXPERIMENTAL DIETS USED IN COMPARING AVAILABLE ENERGY FROM MATURE AND IMMATURE SORGHUM GRAIN

	Diets			
	5 and 9 %	6 and 10 %	7 and 11 %	8 and 12 %
Sorghum grain[a]	53.90	59.22	59.60	59.60
Soybean meal (50%)	27.82	27.18	27.12	27.07
Wood fiber[b]	8.28	3.60	1.69	0.00
Alfalfa meal (17%)	2.00	2.00	2.00	2.00
Distiller's dried grain with solubles	2.00	2.00	2.00	2.00
Fish meal (60%)	2.00	2.00	2.00	2.00
Dicalcium phosphate	2.00	2.00	2.00	2.00
Ground limestone	1.00	1.00	1.00	1.00
Animal fat	...	...	1.59	3.33
Salt	0.50	0.50	0.50	0.05
Premix[c]	0.50	0.50	0.50	0.50
Productive energy[d]	850.00	900.00	950.00	1,000.00

[a]Mature grain used in diets 5 through 8; immature grain (35.1 lb. bu. wt.) used in diets 9 through 12. [b]Diets 9 through 12.

[c]Supplied per kg. of diet: 2,200 IU vitamin A; 660 ICU vitamin D_3; 2.33 mg. riboflavin; 4.28 mg. pantothenic acid; 6.98 mg. niacin; 463.25 mg. choline chloride; 10.65 γ vitamin B_{12}; 0.0125% amprolium; 50.0 p.p.m. Fe; 25.0 p.p.m. Zn; 5.0 p.p.m. Cu; 1.5 p.p.m. I; and 0.5 p.p.m. Co. [d]Estimated values for control diets, kcal. per lb.

TABLE III. SORGHUM GRAIN BUSHEL WEIGHT AND PROXIMATE COMPOSITION[a]

Weight lb./bu.	Variety and Bushel Test Weight	Crude Protein (NX6.25) %	Ash %	Ether Extract %	Crude Fiber %	NFE[b] %
	Low:					
35.1	Commercial	8.8	2.45	2.25	6.33	68.19
41.2	RS-610	10.0	2.02	2.02	3.63	70.34
42.4	TE-66	10.3	2.14	1.84	4.49	69.24
42.5	Asgrow Ranger A	10.4	1.99	1.89	3.78	69.88
43.1	Paymaster Kiowa	10.8	2.23	1.82	4.46	68.74
43.2	Frontier 400C	10.1	2.14	1.84	3.99	69.91
45.2	DeKalb C44b	9.6	2.14	1.84	4.29	70.13
45.2	Commercial	8.7	1.79	2.38	3.18	71.91
47.1	Commercial	9.2	1.78	2.47	3.37	71.17
48.3	Commercial	7.9	1.68	2.68	2.87	72.84
50.3	Commercial	10.2	1.69	2.78	2.68	70.62
51.3	Commercial	10.4	1.29	2.68	2.97	70.66
Average		9.7	1.94	2.20	3.83	70.30
St. Dev.		0.86	0.343	1.15	1.024	1.48
	Normal:					
58.0	Paymaster Kiowa	9.5	1.54	3.19	2.36	71.45
58.3	Frontier 400C	10.8	1.33	2.77	1.95	71.20

[a]Values adjusted to 12% moisture.

[b]Nitrogen-free extract (available carbohydrate) determined by difference.

TABLE IV. EFFECT OF SORGHUM GRAIN BUSHEL WEIGHT ON AMINO ACID CONTENT[a]

	Bushel Weight and Sample Code									
Amino Acid	41.2 68-5N	42.4 68-6N	42.5 68-3N	43.1 68-2N	43.2 68-1N	45.2 68-4N	Av.	58.3 68-3M	58.0 68-4M	Av.
	g./16 g. nitrogen									
Lysine	3.20	3.70	3.71	3.46	3.36	3.57	3.50	2.15	2.18	2.16
Histidine	1.62	1.68	1.67	1.50	1.58	1.71	1.63	2.32	2.25	2.24
Arginine	3.56	3.96	3.85	3.64	3.57	4.07	3.78	3.88	4.03	3.96
Aspartic acid	8.70	7.12	8.61	10.12	8.97	8.72	8.41	7.99	7.43	7.71
Threonine	3.57	3.72	3.72	3.60	3.53	3.72	3.64	3.71	3.57	3.64
Serine	4.67	4.87	4.84	4.73	4.78	4.92	4.80	5.13	5.10	5.12
Glutamic acid	19.00	19.46	19.32	19.82	19.24	19.68	19.42	24.76	24.24	24.50
Proline	6.31	6.43	6.54	7.74	6.45	6.23	6.62	10.82	8.41	9.62
Glycine	3.38	3.76	3.82	3.68	3.71	3.65	3.67	3.32	3.32	3.32
Alanine	8.82	8.88	9.08	9.13	9.14	8.81	8.98	10.94	10.58	10.76
Cystine	1.44	1.35	1.52	1.30	1.37	1.40	1.40	1.44	1.79	1.62
Valine	4.79	4.54	4.70	5.55	4.67	5.24	4.92	6.41	4.71	5.56
Methionine	1.75	1.82	1.78	1.87	1.58	1.86	1.78	1.29	1.75	1.52
Isoleucine	4.19	4.05	4.01	3.91	3.83	4.16	4.02	4.85	4.47	4.66
Leucine	10.60	9.00	10.05	9.52	10.22	10.30	9.95	15.02	14.78	14.90
Tyrosine	3.36	3.29	3.21	3.27	3.30	3.27	3.28	4.42	4.49	4.46
Phenylalanine	4.31	4.36	4.34	4.21	4.30	4.44	4.33	5.88	5.74	5.81

[a]Calculated on moisture-free basis.

[b]Samples are (68-5N) RS-610, (68-6N) TE-66, (68-3N) Asgrow Ranger A, (68-2N) Paymaster Kiowa, (68-1N) Frontier 400C, (68-4N) DeKalb C44b, (68-3M) Frontier 400C, and (68-4M) Paymaster Kiowa, respectively.

wts. below 51.3, and mature samples. Maturation was stopped by a killing frost and is reflected by the bu. test wt. Comparisons of crude protein content indicate no difference between mature and immature sorghum grain, and there are no trends related to decreasing bu. test wt. Ash content was highest in the more immature grain and may indicate early deposition of minerals and development of the grain structures normally highest in ash. Lower ether-extract values in grain between 42.4 and 45.2 may indicate rapid starch synthesis and deposition, whereas higher ether-extract values between 45.2 and 51.3 are probably associated with development of aleurone tissue and other parts of the endosperm containing higher levels of lipids.

The tendency toward higher fiber levels in immature grain indicates the relative proportions of bran and pericarp and the remainder of the kernel. Carbohydrates determined as nitrogen-free extract (NFE) are an indication of starch, since complex carbohydrates are included in fiber. The data show lower values (NFE) in the immature grain, whereas values for grain above 45.2 lb. per bu. are similar to those of mature grain.

Amino acid composition of immature samples collected from the Newton Experiment Field and comparable mature samples are presented in Table IV. Average lysine values for immature grain were higher than those of mature grain. Higher values for aspartic acid, glycine, and methionine were also observed in immature grain. Values lowered most in immature grain were glutamic acid, proline, and leucine. The higher level of lysine indicates that prolamine synthesis was limited.

Data on performance of chicks fed isonitrogenous diets (Table V), containing immature and mature Frontier 400C and Paymaster Kiowa, indicated poorer growth in groups fed immature grain. Significant differences ($P < 0.01$) were found in 8-week weights. Similar effects on feed conversion also were observed.

Growth of chicks fed immature sorghum grain was poorer at each estimated energy level (Table VI). The data indicate that immature sorghum grain (35.1 lb. per bu.) used in this study contained less productive energy than the mature grain. The comparative weight gains of diets 5 and 12 would indicate the immature sorghum grain to contain approximately 150 kcal. per lb. less productive energy than mature sorghum grain. The results of Earley (2) have indicated an increase in starch through the sixth and seventh weeks after pollination in corn. The decrease

TABLE V. PERFORMANCE OF CHICKS ON DIETS CONTAINING NORMAL AND LOW TEST-WEIGHT SORGHUM GRAIN

Diet[a]	Bushel Weight lb.	Weight Gain[b]		Feed Conversion[c]	
		4 Weeks g.	8 Weeks g.	4 Weeks g.	8 Weeks g.
1 Frontier 400C	58.3	584.0d	1,568.9gh	1.79	2.20
2 Paymaster Kiowa	58.0	568.9de	1,625.3g	1.92	2.25
3 Frontier 400C	43.2	556.0ef	1,508.5h	1.89	2.35
4 Paymaster Kiowa	43.1	540.0f	1,496.6h	1.94	2.37

[a]Each diet fed to three groups of eight male and eight female chicks per group.

[b]Values followed by the same letter are not significantly different at the 1% level.

[c]Grams of feed consumed per g. of weight gain.

TABLE VI. GROWTH OF CHICKS FED MATURE AND IMMATURE SORGHUM GRAIN[a]

Grain Condition and Diet No.	Productive Energy[b]	Gain[c], 4 Weeks g.	Feed Conversion[d], 4 Weeks
Mature			
5	850	535.0d	2.01hi
6	900	565.4e	1.94ij
7	950	570.5e	1.93ij
8	1,000	585.2e	1.87j
Immature			
9	850	467.2f	2.19g
10	900	470.4f	2.10h
11	950	518.9d	2.04hi
12	1,000	520.3d	1.97ij

[a]Mature grain, 58.0 lb. per bu.; immature grain, 35.1 lb. per bu.

[b]Energy values estimated using productive energy values of mature grain and other ingredients for poultry, kcal. per lb.

[c]Grams of feed per g. gain.

[c,d]Values followed by same letter not significantly different at 5% level.

in productive energy may have been due to reduced deposition of starch in the immature grain.

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