

COMPARATIVE FEEDING VALUE OF GRAIN SORGHUM
AND CORN IN BEEF, SWINE, AND BROILER DIETS

by

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B. S., Western Illinois University, 1972

A MASTER'S THESIS

submitted in partial fulfillment of the
requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

Approved by:


Major Professor

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ACKNOWLEDGEMENTS

The author wishes to express sincere appreciation to Dr. Jack Riley, major professor, for his guidance and encouragement throughout the author's program. Appreciation is also expressed to Drs. Keith Bolsen, Gerry Posler, and Gerry Kuhl for support and advice while serving on my graduate committee.

I would like to thank and recognize the following individuals and their staffs for the assistance given during this project: Ron Pope, Beef Research Unit; Dr. Robert Hines, Swine Research Unit; Ken Anderson, Poultry Research Unit; and Lisa Nuzbach, Analytical Lab.

Appreciation is also expressed to Dr. Steve Galitzer for his assistance with the continuous culture fermenter. I want to thank Brett Kirch for his assistance and friendship during my graduate program.

I dedicate this manuscript to my wife, Jane, and our three children, Kelly, Gregg, and Grant. Without their support, love, and sacrifice my graduate program would not have been possible.

Table of Contents

iii

	Page
Introduction	1
Review of Literature.	4
A. Grain Sorghum Kernel Structure	4
B. Factors Affecting Nutritive Quality Of Grain Sorghum.	6
1. Tannin.	6
2. Endosperm Texture	7
3. Endosperm Type	8
4. Endosperm Color	10
5. Processing Methods.	11
C. Comparative Feeding Value Of Grain Sorghum And Corn	13
COMPARITIVE FEEDING VALUE OF GRAIN SORGHUM AND CORN IN BEEF, SWINE, AND BROILER DIETS	
A. Materials and Methods.	16
1. Source and Treatment of Grain Sorghums and Corn.	16
2. Cattle Feeding Trial.	17
3. Diet Digestibility Trial.	18
4. In Vitro Trials	18
5. Swine Feeding Trial	20
6. Broiler Feeding Trial	20
7. Statistical Analyses.	21
B. Results and Discussion	27
1. Cattle Feeding Trial.	27
2. Diet Digestibility Trial.	29
3. In Vitro Trials	30
4. Swine Feeding Trial	31
5. Broiler Feeding Trial	31
6. Conclusions	32
Literature Cited.	
	42
Appendix	
	49
Abstract	

List of Tables

iv

Table	Page
1. Descriptive characteristics of grain sorghums studied.	22
2. Lysine, methionine, and crude protein analyses of grain sorghum and corn fed in beef, swine, and broiler diets	23
3. Composition of experimental steer diets	24
4. Composition of experimental swine diets	25
5. Composition of experimental broiler diets . . .	26
6. Performance of finishing steers fed diets of grain sorghum or corn	34
7. Particle sizes of dry rolled grain sorghum diets fed to finishing steers	35
8. Effect of hybrid on grain sorghum kernel size .	36
9. Apparent dry matter digestibilities of grain sorghum or corn diets fed to finishing steers .	37
10. In vitro continuous culture VFA production of grain sorghum diets fed to finishing steers . .	38
11. Performance of finishing swine fed diets of grain sorghum or corn	39
12. Performance of broilers fed diets of grain sorghum or corn	40

List of Figures

v

Figure	Page
1. Comparative daily gains by time periods of steers fed diets of grain sorghum and corn. .	41
2. Comparative feed efficiencies of finishing steers fed diets of grain sorghum and corn. .	50
3. Comparative dry matter digestibilities of grain sorghum and corn diets fed to finishing steers.	51
4. Effect of variety on sorghum kernel size. . .	52
5. Comparative particle sizes of grain sorghum diets fed to finishing steers	53
6. Comparative feed efficiencies of finishing swine fed diets of grain sorghum and corn . .	54
7. Comparative feed efficiencies of broilers fed diets of grain sorghum and corn	55

Introduction

Grain sorghum (Sorghum bicolor L. Moench) production and feeding in Kansas has increased substantially in the last several years. In 1968, Kansas ranked second to Texas with 183 million bushels of grain sorghum produced (McCollough et al., 1971). In 1984 and 1985, Kansas was the leading state in the production of grain sorghum with 217 and 298 million bushels, respectively. The Nutrient Requirements of Beef Cattle (1984) estimates a NE_g of 1.37 Mcal/kg for grain sorghum containing more than 10% protein and a NE_g of 1.55 Mcal/kg for grade 2 corn (Zea mays indentata). This indicates a 12% advantage in feeding value for corn.

However, the relative feeding value of grain sorghum can be significantly affected by tannin content. Hybrids with high tannin content are commonly referred to as bird resistant. Bird resistant hybrids contain a testa layer with condensed tannins that result in decreased feed intake, reduced digestibility, and poorer performance than hybrids without a testa layer (Cousins et al., 1981; Damron et al., 1968; Maxson et al., 1973; McCollough et al., 1972; Myer et al., 1986; Rostagno et al., 1973). Modern hybrids commonly grown in Kansas do not contain a testa layer with condensed

tannins. Therefore, the feeding value of grain sorghums currently grown in Kansas may be greater than that indicated by NRC (1984). An understanding of the relative feeding value of common, commercial grain sorghum hybrids is critical to increasing the utilization of grain sorghum in the future. Increased feeding acceptance of grain sorghum will depend upon how it performs relative to corn, the accepted standard feed grain. Modern least-cost ration formulation in the livestock industry depends on up-to-date relative feeding values of currently available feedstuffs.

In the last several years, the availability and use of yellow endosperm grain sorghum hybrids has greatly increased. Interest in the relative feeding value of various endosperm types of grain sorghums has increased in response to claims of superior feeding values for homozygous yellow endosperm by commercial grain sorghum companies and producers. Studies by McCollough et al.(1972) indicated greater feeding value for yellow endosperm hybrids compared with white endosperm. However, the issue of endosperm type and color has become confused with pericarp color. Pericarp or seedcoat color is not an indication of endosperm color or type. Yellow endosperm grain sorghum may be either heterozygous or homozygous for the trait, with a variety of pericarp colors.

The size of the grain sorghum kernel influences digestibility and ease of processing (Hibberd and Wagner, 1983). If larger kernels have more starch and less protein, digestibility may be increased. Larger kernels may also process easier and more efficiently than smaller, harder kernels.

These experiments were conducted to determine the relative feeding value of commercial grain sorghum hybrids commonly grown in Kansas. Heterozygous and homozygous yellow endosperm grain sorghums were compared with corn in poultry, swine, and cattle diets. The influence of kernel size on grain processing and animal performance was also studied.

REVIEW OF LITERATURE

GRAIN SORGHUM KERNEL STRUCTURE

Grain sorghum kernels can vary greatly in structure depending on genetics, environment or a combination of both factors.

Rooney and Miller (1981) reviewed the structural make-up of the grain sorghum kernel and the characteristics that determine its size, shape, color, texture, processing and feeding qualities. The grain sorghum kernel consists of three main components; the pericarp, endosperm and germ.

The pericarp is divided into four layers; the mesocarp, epicarp, cross cell layer and the tube cell layer. Pericarp color varies among hybrids of grain sorghum. Yellow colors come from a thin, clear pericarp that allows the yellow $rr\bar{Y}$ -endosperm to show through. White grain sorghum has a thicker mesocarp which masks the yellow endosperm color. The white color is controlled by a homozygous recessive gene $rryy$ or $R-yy$. Bronze colored grain sorghum is a combination of a thin, red pericarp with a yellow endosperm underneath. Brown colored grain sorghums have a pigmented testa layer being present below the pericarp. U.S. Yellow Grain Sorghum can be white, yellow, red, or bronze in color. Up to ten

percent of the kernels may have a pigmented testa layer and still qualify as U.S. Yellow Grain Sorghum.

A clorox bleach test can give an easy indication of the presence of a pigmented testa layer. Fifteen grams of grain sorghum, 15 grams of KOH, and 70 ml of 5% NaCl solution are placed in an erlemeyer flask and heated in a water bath for ten minutes. Kernels are then blotted dry. The kernels containing pigmented testa layers will turn black and can easily be distinguished from the lighter non-testa grain sorghum (Weak et al., 1972).

Pericarp thickness is controlled by the Z gene. The dominant gene gives a thin pericarp and the recessive rr results in a thick pericarp. Color pigments of the testa or endosperm are masked by a thick, starchy mesocarp. However, a thin, translucent pericarp allows the color of the testa and/or endosperm to affect the visual color of the kernels (Rooney and Miller 1982). The thickness of the pericarp may also affect its susceptibility to mold.

The endosperm is divided into four parts; the aleurone, peripheral endosperm, corneous endosperm and the floury endosperm. The aleurone layer is just below the pericarp and is important in aiding seed germination. It is also an area high in minerals, water soluble vitamins and oil. The peripheral endosperm contains starch granules embedded in a

protein matrix. Starch granules in this area are difficult to remove and the grain must be properly processed for this starch to be utilized by the animal. The corneous endosperm is a continuous interface between starch and protein. Starch granules in the corneous endosperm will often break apart before releasing from the connected protein. The floury endosperm is an area of lesser density in the grain sorghum kernel. The protein content in this portion is lower; however, the starch availability is high.

FACTORS AFFECTING NUTRITIVE QUALITY OF GRAIN SORGHUM

Tannin

Grain sorghums containing tannins are commonly termed as brown grain sorghum. However, tannins can be present in grain sorghums other than those classified as brown.

Only condensed tannins have been found in grain sorghum. Tannins are classified as condensed phenolic polymers that result from the condensation of flavan-3-ol units (Hahn et al., 1984).

Gupta and Haslan (1978) referred to the pigments of tannins as proanthocyanidins. The presence of a pigmented testa layer is controlled by the B_1 and B_2 genes. Before a

pigmented testa can be present, both the B₁ and B₂ genes must be dominant. The testa layer will be absent if either or both the B₁ or B₂ genes are recessive.

Brown grain sorghum is also commonly called bird resistant sorghum. Considerable research has examined grain sorghums varying in tannin content. The feeding of high tannin content grain sorghum usually results in decreased feed intake and poor animal performance (Cousins et al., 1981; Damron et al., Myer et al., 1986; Rostagno et al., 1972).

Some of the research has examined methods to overcome the nutritionally related problems of high tannin grain sorghums. Chemical treatments and grain processing have been used to improve the feed value of bird resistant hybrids. High moisture storage of high-tannin grain sorghum has reduced the tannin content by 27 to 30% for two crop years (Myer et al., 1986).

Since grain sorghum produced in Kansas no longer includes high tannin hybrids, tannin content is of little importance at present.

Endosperm Texture

The texture of grain sorghum endosperm is classified as corneous, intermediate, or floury. Grain sorghums with

intermediate texture are further qualified by the ratio of corneous to floury endosperm. Since growing conditions can affect texture, hybrid texture ratings are difficult to assign (Rooney and Miller, 1982).

Cohen and Tanksley (1973) compared three different endosperm textures with growing swine and found no significant differences in animal performance due to endosperm texture, grain sorghum with intermediate texture was 5.35% higher in digestible energy than the floury textured grain. Hibberd et al. (1982) showed that a floury, bird resistant, soft endosperm grain sorghum was analytically equivalent to a waxy endosperm grain sorghum in the first two years of a trial. Norris and Rooney (1970) concluded that grain sorghum with floury endosperm produced higher starch yields than those with other endosperm textures.

Endosperm Type

Endosperm or starch type is described as either normal or waxy. The normal endosperm grain sorghum contains 75% amylopectin and 25% amylose while that in waxy grain sorghum consists of approximately 100% amylopectin. The endosperm of waxy grain sorghum has a more uniform distribution of protein and starch, especially in the peripheral endosperm.

The starch of waxy endosperm grain sorghum is hydrolyzed more rapidly and protein digestibility is higher in the non-waxy hybrids (Walker and Lichtenwalner, 1977). Streeter et al. (1984) showed that post-ruminal nitrogen digestion was higher with waxy than normal endosperm grain sorghum. The effect of incremental dosages of the recessive waxy genes on the digestibility of grain sorghum was studied by Lichtenwalner, Ellis and Rooney (1978). Non-waxy grain sorghum was genetically identified as $WxWxWx$. The intermediate hybrids had two levels of the waxy genes, either $WxWxwx$ (1 dose) or $Wxwxwx$ (2 doses). The full waxy hybrids ($wxwxwx$) have three recessive genes, with two of these genes coming from the female parent and the other from the male. As the dosage of waxy gene increased, the following was observed: amylose content decreased, in vitro and in situ digestibility increased, rate of digestibility increased, but total digestibility was unaffected, and rate of gas production increased. Davis and Harbers (1974) reported differences in the hydrolysis of starch from waxy, yellow and high tannin grain sorghums as observed by scanning electron microscopy.

One of the problems regarding the acceptance of waxy endosperm grain sorghum hybrids by producers is a trend for lower yields compared to non-waxy hybrids (McCullough et

al., 1972). Production of waxy grain sorghums will be limited if producers must sacrifice yields to receive a slight improvement in feed value.

McCollough et al.(1972) studied the feedlot performance of steers fed nine grain sorghum hybrids. Three hybrids classified as containing intermediate waxy, white endosperm resulted in an average feed efficiency that was 6.68% poorer than the average for the yellow, non-waxy endosperm hybrids. However, steers fed the white, part-waxy endosperm hybrids had a 4.32% better feed efficiency than those fed a white, non-waxy hybrid.

Endosperm Color

Endosperm color is classified as white, hetero-yellow, and full or homozygous yellow. Several studies by McCollough et al.(1971 and 1972) compared yellow and white endosperm hybrids. The yellow endosperm hybrids used in these studies were not classified genetically as heterozygous or homozygous for this trait. Yellow endosperm hybrids showed a consistent trend for improved feed efficiencies (ranging from 10.39% to 9.75% improvement) compared to white endosperm hybrids when fed to finishing cattle.

Present day production of grain sorghum is dominated by

yellow endosperm hybrids. In a University of Missouri grain sorghum classification survey, only six of one hundred twenty five commercial hybrids were classified as having white endosperm. The balance of the hybrids were either hetero-yellow or homozygous yellow for endosperm color. However, only fourteen of the hybrids were listed as containing homozygous yellow endosperms. Claims by some commercial grain sorghum companies, suggesting homozygous yellow endosperm hybrids to be superior in feeding value compared to varieties with heterozygous yellow endosperm has stimulated interest in the relative feeding value of various endosperm types. Improved amino acid levels and digestibilities are among the claims presented (Furrow, 1985).

Processing Methods

Grain sorghum can be processed in a number of ways to improve its feeding quality for cattle. The processing can involve either dry or wet grain. Dry processing methods include grinding, rolling, roasting and micronizing. Wet processing techniques include steam flaking, ensiling as high moisture grain, or reconstituting prior to ensiling. Hinman and Johnson (1974) compared grinding, dry rolling, micronizing and steam flaking in high concentrate beef cattle rations. Ruminal starch digestion did not differ

among methods; however, heat treating increased the rate of digestion as measured by in vitro fermentation. Dry rolling grain sorghum significantly decreased intestinal digestion and resulted in lower total tract starch digestion. The ratio of ruminal acetate to propionate was slightly lower in cattle fed the heat and pressure treated rations. Grinding grain sorghum was judged unacceptable for steers because of excessively fine particles. The ground grain had a mean particle diameter of 398 microns compared to 1023 microns for the dry rolled rations.

Brethour (1985) reported that finely rolling grain sorghum improved the feed efficiency of cattle by 7.7% compared to cattle fed coarse rolled grain. The finely rolled grain sorghum had a mean particle size of one mm compared to two mm for the coarse rolled grain. The main difference was the proportion of grain with a particle size of 2000 to 4000 microns (36% and 17% of the sample weight, respectively) resulting from the coarse and finely rolled processes. Reducing the average grain particle size to 475 microns improved milk yields of dairy cows (Bush et al. 1973).

Ware et al. (1977) indicated that feeding high moisture ensiled grain sorghum to steers resulted in more efficient gains compared to dry rolled grain sorghum.

Cattle fed reconstituted grain sorghum had greater dry matter, organic matter and nonprotein organic matter digestibilities than those fed ground grain sorghum (Buchanan-Smith et al.). However, processing did not affect digestibility in sheep indicating they were able to utilize ground grain sorghum better than cattle.

Allee et al.(1975) found that extruding, steam flaking, micronizing or high-moisture processing of grain sorghum did not improve gain or efficiency of weaned pigs compared to grain sorghum fed as a dry meal. High-moisture and field dried grain sorghum were shown to have equal feeding values for growing-finishing swine when compared on a dry matter basis (Trotter and Allee, 1976).

COMPARATIVE FEEDING VALUE OF GRAIN SORGHUM AND CORN

The comparative feeding value of corn and grain sorghum in much of the literature includes high-tannin sorghum hybrids no longer being produced or fed. This review will only deal with tannin-free grain sorghums. The relative feeding value of grain sorghum and corn is dependent on the species of livestock to which they are fed and how the

grains are processed. It should also be noted that U.S. No. 2 corn may contain 3% foreign material as compared to 8% for U.S. No.2 grain sorghum (Wagner, 1978). The 1984 NRC for beef cattle shows a 12% poorer feed value for grain sorghum than corn. However, steam flaking of grain sorghum would improve its NE_g by 14.8% compared to a 7.7% improvement from steam flaking corn (Riley, 1985).

Rostagno et al.(1973) fed chicks corn and grain sorghum for 21 days and found equal efficiencies. In some cases, grain sorghum may be lower in lysine and methionine than corn. Sanford et al.(1968) reported that chick growth was not significantly different when grain sorghum was supplemented with lysine and methionine and compared to corn in broiler rations. Other studies by Chang et al.(1963) and Damron et al. (1968) have shown equal performance in chicks fed corn or non-bird resistant grain sorghum hybrids.

In a swine trial by Cousins et al. (1981), feed efficiencies were not significantly different among pigs fed grain sorghum hybrids and corn. The feed to gain ratios of pigs fed these grains were 3.11, 3.12, and 2.99, respectively. Numerically the corn diet produced a 4% improved feed efficiency in this study.

Hibberd et al.(1982_a) isolated purified starch from grain sorghum hybrids differing in endosperm type and from

four corn hybrids. He found that rumen microbes digest purified starch from grain sorghum and corn at the same rate and extent. Therefore, he concluded that the slower ruminal digestibility of grain sorghum in normal feeding situations resulted from decreased starch availability to the microbes. Hibberd et al. (1982_b) also noted in another study that the protein content of grain sorghum was not significantly correlated with IVDMI ($r=.18$). This is in contrast to the 1984 NRC for beef cattle which indicates an inverse relationship between the protein and energy contents of grain sorghums.

Riley (1985) summarized cattle feeding trials by Brethour (1982), Mies and Summers (1979), and Hale et al. (1980) and concluded that the relative feeding value of grain sorghum was 93 to 96% the value of corn.

COMPARATIVE FEEDING VALUE OF GRAIN SORGHUM
AND CORN IN BEEF, SWINE, AND BROILER DIETS

MATERIALS AND METHODS

Cattle, swine, and poultry feeding trials were conducted with four grain sorghum hybrids and one corn hybrid during the spring of 1986. Animals were housed at the respective research units at Kansas State University, Manhattan.

Source And Treatment Of Grain Sorghums And Corn. Four hybrids of grain sorghum (table 1), differing in pericarp color and endosperm color, were grown under similar dryland conditions at Manhattan in 1985. The grain sorghum hybrids were: 1) Funk's 550 (F 550), 2) Cargill 70 (C 70), 3) Northrup-King 2778 (NK 2778), and 4) DeKalb 42Y (DK 42Y). The corn hybrid, Pioneer 3377, was selected and obtained in 1985 from one source near Manhattan. Each grain sorghum was harvested at approximately 13% moisture and stored in steel bins until processed. High moisture DK 42Y (HM DK 42Y) was harvested at about 28% moisture and stored whole in an oxygen-limiting Harvestore structure for use only in the cattle trial. Composite grain samples for each of the

hybrids were analyzed¹ for amino acid composition and crude protein (CP) content (table 2). These values were used to formulate the experimental diets.

Cattle Feeding Trial. Thirty five crossbred steers with an average weight of 410.8 kg were allotted by weight in a randomized complete block design to one of seven treatments: 1) DR F 550, 2) DR C 70, 3) DR NK 2778, 4) DR DK 42Y, 5) HM DK 42Y, 6) corn + urea, and 7) corn. Diet composition is presented in table 3. All diets except corn (10% CP), were formulated to provide a minimum of 11% CP on a DM basis (actual range was 11.2 to 13.8% CP). Each diet contained 37.5 mg of monensin and 13.2mg of tylosin per kg of grain mix which provided approximately 250 to 300 mg/hd/d of monensin and 90 to 104 mg/hd/d of tylosin. Diets were fortified to meet NRC (1984) requirements for calcium, phosphorus and vitamin A. Dry grain sorghums were processed with an 18 groove per inch Wagner roller mill, except the HM DK 42Y which was rolled with a Harvestore roller mill prior to feeding. All steers had received a Ralgro implant over 60 d prior to the start of the trial. Steers were housed in individual pens with solid concrete floors.

1 Analytical Biochemistry Laboratories Inc.,
Box 1097, Columbia, MO.

Initial and final weights were determined by the average of two weights taken on consecutive d prior to the AM feeding. Interm single d weights were taken on d 28 and 61.

Diet Digestibility Trial. Starting on d 22 of the steer finishing trial, chromic oxide was fed as an inert marker to determine the apparent digestibility of the seven diets. Forty grams of a 12.5% chromic oxide pelleted supplement was top dressed twice daily at the time of feeding (Appendix A). A 7 d adaption period preceded a 7 d fecal collection period. Diets were fed at 100% of ad libitum intake during both the adaptation and collection periods. Fecal grab samples were collected twice daily. An advancing 2 h schedule was used to minimize diurnal variations in digestion (Appendix A). Daily fecal samples were composited and dried in a forced draft oven at 55 C prior to being ground. Ten g of each of the seven daily samples were composited for fecal chromic oxide analysis.

In Vitro Trials. Two in vitro experiments were conducted to compare the four dry grain sorghum hybrids and the HM DK 42Y fed in the cattle feeding trial. In the first experiment, a two-stage in vitro dry matter disappearance was conducted (Tilley and Terry, 1963). In the second experiment, a modified continuous culture fermentation system (Slyter, 1964) was used to measure volatile fatty

acid (VFA) production of the experimental grain sorghum diets. Ten 500 ml flasks were filled to the overflow port with ruminal fluid strained through one layer of cheesecloth. The donor animal was a fistulated Holstein steer maintained on a diet of 25% corn, 25% grain sorghum, and 50% alfalfa hay. Fermentation flasks were infused continuously with a modified buffer (McDougall, 1949) plus urea, delivered by a peristaltic pump at a rate of .6 ml per minute, resulting in a liquid turnover rate of 1.73 per 24 h. The five grain sorghum diets were randomly assigned in duplicate to the 10 flasks. A mixture of 6.9 g of each respective grain-supplement mixtures and 1.7 g of sorghum silage (DM basis) was introduced into the flasks twice daily at 12 h intervals. Respective samples of the dry rolled (DR) grain sorghums and HM DK 42Y fed in the cattle finishing trial were used for the grain portion in the fermenters. The as-fed grain portions were not processed further prior to use in the fermenters. However, the silage portion of the diet was processed with a Hobart model 4812 processor to pass through a 3.18 mm diameter screen. Effluent was acidified to stop fermentation with 20 ml of a 42% phosphoric acid solution. Effluent from the collection flasks was removed daily with 10 ml samples taken for VFA analyses on d 5, 6 and 7 of the fermentation.

Swine Feeding Trial. One hundred fifty crossbred pigs with an average initial weight of 43.6 kg were fed in a 76 d finishing trial. Pigs were randomly allotted by litter, sex, and weight to three replications of five dietary treatments. The same dry grain used in the cattle trials were ground through a hammer mill equipped with a 4.76 mm screen prior to mixing with the balance of the diet ingredients. All diets (table 4) contained equal amounts of grain and supplement fed at ad libitum in self feeders. Pigs were housed in a modified open-front finishing unit with 10 pigs (five gilts and five barrows) per pen. Pens were partially slatted with concrete.

Broiler Feeding Trial. Two hundred eighty broilers were randomly allotted to one of five dietary treatments at 3 d of age. Birds were weighed, wing banded, and placed in electrically heated brooders with raised wire floors. Seven replicates with eight birds per cage were assigned to three batteries. Treatment replicates were blocked by cage level to minimize locational effects. All sorghum grains were ground in a hammer mill equipped with a 4.76 mm screen and the corn treatment was ground through a 6.35 mm screen, prior to mixing into the experimental diets. Equal amounts of grain and soybean meal were used in all starter and grower diets (table 5). On d 21, the birds were weighed,

placed in growing batteries with raised wire flooring, and switched to the grower diets. Treatment replicates were blocked in the same manner as previously described. On d 44 of the trial, all birds were weighed off test and slaughtered.

Statistical Analyses. Animal performance data were analyzed using a General Linear Models (GLM) procedure (SAS, 1982). Means were separated by the predicted difference (PDIFF) option of GLM.

Table 1. DESCRIPTIVE CHARACTERISTICS OF GRAIN SORGHUMS STUDIED

Variety	Abbreviation	Color	
		pericarp	endosperm
Funk's 550	F 550	white	hetero-yellow
Cargill 70	C 70	red	hetero-yellow
Northrup-King 2778	NK 2778	red	yellow
DeKalb DK 42Y	DK 42Y	yellow	yellow

Table 2. LYSINE, METHIONINE AND CRUDE PROTEIN ANALYSES OF GRAIN SORGHUMS AND CORN FED IN BEEF, SWINE, AND BROILER DIETS

	Grain Sorghum				Corn
	F 550	C 70	NK 2778	DK 42Y	
	% DM Basis				
Lysine	.25	.25	.24	.27	.27
Methionine	.15	.16	.15	.17	.14
Crude protein	13.4	10.3	12.2	11.6	8.26

Table 3. COMPOSITION OF EXPERIMENTAL STEER DIETS

Ingredient	Diets (% DM Basis)		
	Grain sorghum	Corn + Urea	Corn - Urea
Sorghum grain, rolled	78.74	-----	-----
Corn, rolled	-----	78.31	78.74
Sorghum silage	15.00	15.00	15.00
Soybean meal	3.58	3.57	3.58
Urea	-----	.44	-----
Limestone	1.09	1.09	1.09
Potassium chloride	.20	.20	.20
Salt	.29	.29	.29
Trace mineral premix ^a	.02	.02	.02
Tylosin premix ^b	.06	.06	.06
Monensin premix ^c	.02	.02	.02
Animal fat	.99	.99	.99
Vitamin A premix ^d	.01	.01	.01

^a Contained 11% Ca, 10% Mn, 10% Fe, 10% Zn, 1% Cu, .3% I and .1% Co.

^b Contained 22.1 g/kg of tylosin.

^c Contained 132.3 g/kg of monensin.

^d Contained 30,000 IU of Vitamin A/gram.

Table 4. COMPOSITION OF EXPERIMENTAL SWINE DIETS

Ingredient	Diet (% as-fed basis)	
	Growing	Finishing
Grain ^a	75.70	75.85
Soybean meal	20.85	20.85
Dicalcium phosphate	1.40	1.40
Limestone	.95	.95
Salt	.50	.50
Trace mineral premix ^b	.25	.25
Vitamin mineral premix ^c	.10	.10
Antibiotic ^d	.25	---
Antibiotic ^e	---	.10

^aGrain sources: grain sorghum F 550, C 70, NK 2778, DK 42Y and Pioneer 3377 corn.

^bContained 11% Ca, 10% Mn, 10% Fe, 10% Zn, 1% Cu, .3% I and .1% Co.

^cEach kg of premix contained the following: vitamin A 882,000 IU; vitamin D 66,150 IU; vitamin E 4,410 IU; riboflavin 992 mg; d-pantothenic acid 2,646 mg; choline 88 g; niacin 5,513 mg; B₁₂ 4.8 mg; menadione dymethylpyrimidinol bisulfite 551 mg.

^dAntibiotic contained 44 g chlortetracycline, 44 g sulfamethazine and 22 g penicillin/kg.

^eAntibiotic contained 44g chlortetracycline/kg.

Table 5. COMPOSITION OF EXPERIMENTAL BROILER DIETS

Ingredient	Diet (% as-fed basis)	
	Starter	Grower
Grain ^a	46.05	55.05
Soybean meal	46.05	37.03
Dicalcium phosphate	2.40	2.40
Limestone	1.00	1.00
Calcium carbonate	.60	.60
KSU poultry premix ^b	.50	.50
D-L methionine	.20	.20
Amprol 25	.05	.05
Trace mineral premix ^c	.10	.10
Soybean oil	3.00	3.00

^aGrain sources: grain sorghum F 550, C 70, NK 2778, DK 42Y and Pioneer 3377 corn.

^bVitamin A, 661,500 I Units; vitamin D₃, 396,900 IC Units; riboflavin, 3,528 mg; d-pantothenic acid 6,492 mg; niacin, 10,584 mg; choline chloride 35,280 mg; vitamin B₁₂, 1.06 mg; /pound.

^cContained 11% Ca, 10% Mn, 10% Fe, 10% Zn, 1% Cu, .3% I and .1% Co.

Results and Discussion

Cattle Feeding Trial. The performance of finishing steers fed diets containing grain sorghum or corn are shown in table 6. Dry matter intakes (DMI) of steers did not differ among diets; however the daily consumption of F 550 diet tended to be the lowest (8.16 kg). Average daily gains (ADG) of the steers were not statistically different among diets and ranged from 1.42 to 1.59 kg. The dry grain sorghum diets tended to produce lower cattle ADG as compared with HM DK 42Y or corn diets. Feed efficiencies of the steers ranged from 5.41 to 6.39 kg of DM/kg of gain among diets, but means were not statistically different, although cattle fed the dry grain sorghum diets tended to have the poorest feed efficiencies. Average feed efficiency of steers fed the dry sorghum grains was 8.5% poorer than those consuming the corn diet, while the high-moisture DK 42Y diet fed cattle had an improved feed efficiency of 3.6% compared with steers on the corn diet. These results are consistent with data reported in a review by Hale and Prouty (1980). Their summary showed dry rolled grain sorghum to be 6% less efficiently utilized by cattle than dry rolled corn. In a summary of eight trials comparing finely rolled grain sorghum and rolled corn, Brethour (1982) reported that grain

sorghum was utilized 6.7% less efficiently than corn by feedlot cattle.

All steers used in this experiment were fed high moisture grain sorghum growing diets in a previous trail. The steers fed the dry grain sorghum diets had more difficulty switching from the high moisture grain growing diets as indicated by lower gains the first 28d (figure 1).

During the finishing trial, it was observed that steers consuming the F 550 hybrid were sorting the diet; therefore the grain portion of the dry grain sorghum diets were compared for differences in particle size (table 7). In addition, composite sample of the refused portion of the F 550 diet was compared with the original (as-fed) F 550 diet for differences in particle size. The dry grain sorghums' F 550, NK 2778, and the refused F 550 had fewer ($P < .05$) large particles >2380 microns compared to the other hybrids. The C 70 and DK 42Y sorghums did not differ in particles >2380 microns in size. The refused F 550 had over twice as many particles < 1190 microns than the as fed grain portion. Dry rolling of the F 550 kernels resulted in a greater proportion ($P < .05$) of the particles < 1190 microns (17.8%) as compared with C 70, NK 2778 and DK 42Y (14.56, 11.28 and 12.62%, respectively). The greater proportion of fine particles < 1190 microns with F 550 may have been the reason

for the cattle sorting the grain in their bunks and the trend toward lower feed intake. Studies by Brethour (1985) suggested that decreasing the particle size of dry rolled grain sorghum may decrease cattle feed intake and improve feed efficiencies.

Table 8 illustrates the effect of hybrid on sorghum kernel size. The weight of 100 grain sorghum kernels was used to determine the apparent difference in kernel size. The F 550 hybrid had the heaviest 100 kernel weight (3.39 g) while DK 42Y the lightest (2.09 g) ($P < .001$). The larger F 550 kernels appears to be the reason for the lower proportion of particles >2380 microns and the greater proportion of particles <1190 microns in size compared with the other grain sorghum hybrids examined.

Diet Digestibility Trial. Apparent DM digestibilities, based on chromic oxide marker, were significantly different ($P < .10$) among the experimental diets (table 9). The F 550 sorghum grain had the highest cattle DM digestibility of the dry sorghum grain diets. This is consistent with the trend for improved feed efficiency of cattle fed the F 550 diet compared with steers consuming the other dry grain sorghum diets (table 6). In studies by Brethour (1985), cattle fed finely rolled grain sorghum had better feed efficiencies than those fed coarsely rolled grain sorghum. Steers

consuming HM DK 42Y had a 2.5% greater DM digestibility than those fed the most highly digestible dry grain sorghum (74.5 vs. 72.0%). The digestibility data supports the relative cattle feed efficiencies observed for these two diets (HM DK 42Y, 5.42 kg vs F550, 5.83 kg). The apparent cattle DM digestibilities of the dry grain sorghums (mean of four hybrids), HM grain sorghum and corn diets were significantly different ($P < .05$) (69.8, 74.5, and 71.2%, respectively) and are consistent with the steer feed efficiencies observed for each of the grain types (table 6).

In Vitro Trials. Volatile fatty acid production measured with the continuous culture fermenter was not significantly different among the experimental grain sorghum diets fed in the steer finishing trial (table 10). The HM DK 42Y had a mean VFA production of 92.3 mM per ml compared with the dry grain sorghum diets which ranged from 83.1 to 85.7 mM per ml. The trend for higher VFA production by HM DK 42Y is consistent with the slightly improved cattle feed efficiency and increased digestibility of the HM sorghum grain diet as compared with the dry grain sorghum diets. The IVDMD values of F 550, C 70, NK 2778, Dk 42Y, and HM DK 42Y grain sorghums used in the steer diets were 75.2, 78.1, 78.7, 82.0, and 74.4%, respectively. These IVDMD values are inconsistent with in vitro VFA production rates, in situ

apparent DM digestibilities and cattle feed efficiencies observed. This lack of correlation between the IVDMD values and the other cattle performance indexes may be due to the extra fine grinding of samples used in the Tilley and Terry procedure.

Swine Feeding Trial. The performance of swine on the finishing diets is contained in table 11. Daily feed intake of the pigs was not significantly affected by diet and ranged from 2.96 to 3.08 kg among the experimental diets. Daily pig gains showed little variation across diets and ranged from 845 g to 876 g. Feed efficiencies were significantly affected by grain source ($P < .10$). The F 550 diet was significantly more efficiently utilized by pigs than the C 70 and NK 2778 diets. The average feed efficiency of pigs on the four grain sorghum diets was 2.8% poorer than that on the corn diet, ranging from 4.3% poorer feed conversion to a .6% improvement. These data agree with the work of Cousins et al. (1981) who reported that two low-tannin grain sorghums were 4% less efficiently used by swine than corn.

Broiler Feeding Trial. The performance of broilers fed grain sorghum and corn diets is reported in table 12. Feed intake of chicks was significantly affected by grain source ($P < .05$). Chicks fed the corn diet had a lower feed intake

than those consuming the C 70, NK 2778, and DK 42Y diets. Broiler daily gain and feed efficiency was not affected statistically by diet. Chicks on the corn diet had the best feed efficiency of 2.15 while the grain sorghums had feed/gain ratios of 2.19, 2.32, 2.21, and 2.19 for F 550, C 70, NK 2778 and DK 42Y diets, respectively. The grain sorghum diets were 3.7% less efficiently utilized by broilers than the corn diet. These data are consistent with a report by Chang and Fuller (1964) indicating low-tannin sorghum grains had 3% poorer feed efficiency in chicks than the basal corn diet. All feed/gain ratios of broilers reported in this trial were poorer than expected and were possibly the result of a respiratory virus contracted during the fourth week of the trial, plus excessive feed wastage.

Conclusions. Results of these trials do not indicate any apparent advantage for homozygous yellow endosperm grain sorghum compared with heterozygous yellow endosperm hybrids ($P > .05$). The heterozygous yellow endosperm hybrid, F 550, tended to produce improved feed efficiencies compared with the other three grain sorghums studied. In the cattle feeding trial, F 550 had larger kernels ($P < .001$), and when processed (dry rolled), contained more particles < 1190 microns in size ($P < .01$) which may have been responsible for the trend in improved cattle feed efficiency, higher DM

digestibility, and greater in vitro VFA production compared with the other dry processed grain sorghum hybrids. The F 550 diet was more efficiently utilized ($P < .10$) than the other grain sorghums fed in the swine feeding trial. Grain sorghum diets fed to swine and broilers were 2.8 and 3.7% less efficiently used, respectively, than the corn diets. The comparative feed efficiencies of grain sorghum and corn diets fed to cattle, swine, and broilers does not support the customary 12 to 16% price discount of grain sorghum relative to corn.

Table 6. PERFORMANCE OF FINISHING STEERS FED DIETS OF GRAIN SORGHUM OR CORN

Item	Diets								SE ¹
	Grain sorghum								
	Dry				High Moisture		Corn (+)	Corn (-)	
	F 550	C 70	NK 2778	DK 42Y	DK	42Y	Urea	Urea	
No. steers	5	4	5	5	5	5	5		
ADG, kg	1.42	1.42	1.47	1.45	1.57	1.57	1.59	.086	
Daily intake, kg.	8.16	8.90	8.78	9.25	8.51	9.16	8.55	.476	
Feed/gain ²	5.83	6.15	5.98	6.39	5.42	5.83	5.41	.30	

¹Standard error of mean.

²100% DM basis.

Table 7. PARTICLE SIZES OF DRY ROLLED GRAIN SORGHUMS FED TO FINISHING STEERS

Particle size	Grain sorghum				Refused	SE ¹
	F 550	C 70	NK 2778	DK 42Y	F 550	
	————— % of wt —————					
>2380 microns	4.31 ^b	8.73 ^d	5.73 ^c	9.18 ^d	3.12 ^a	.18
<1190 microns	17.81 ^c	14.56 ^b	11.28 ^a	12.62 ^a	36.04 ^d	.42

¹Standard error of mean.

abcd Means in the same row with different superscripts differ (P<.01).

Table 8. EFFECT OF HYBRID ON GRAIN SORGHUM KERNEL SIZE¹

	Hybrid				SE ²
	F 550	C 70	NK 2778	DK 42Y	
100 kernel wt, g	3.39 ^a	2.71 ^b	2.85 ^b	2.09 ^c	.06

¹Mean of three replications.

²Standard error of mean.

abc Means without different superscripts differ (P<.001).

Table 9. APPARENT DRY MATTER DIGESTIBILITIES OF GRAIN SORGHUM AND CORN DIETS FED TO FINISHING STEERS

Grain Sorghum				Corn (+) Moisture DK 42Y	Corn (-) Urea	SE ¹ Urea
Dry		High				
F 550	C 70	NK 2778	DK 42Y			
DM Digestibility, %						
72.0 ^a	67.7 ^c	69.4 ^{bc}	69.7 ^{bc}	74.5 ^a	70.7 ^{bc}	71.7 ^{ab} 1.5

¹Standard error of mean.

abc Means with different superscripts differ, (P<.10).

Table 10. IN VITRO CONTINUOUS CULTURE DAILY VFA PRODUCTION
OF GRAIN SORGHUM DIETS FED TO FINISHING STEERS

	— Dry grain —				High Moisture		
	F 550	C 70 NK 2778	DK 42Y	DK 42Y	DK 42Y	SE ¹	
VFA, mM/ml	85.7	83.1	83.9	83.8	92.3	4.1	

¹Standard error of mean.

Table 11. PERFORMANCE OF FINISHING SWINE FED DIETS OF GRAIN SORGHUM OR CORN.

	Diets				Corn Pioneer 3377	SE ¹
	Grain Sorghum					
	F550	C70	NK2778	DK42Y		
Average Daily Feed Intake, kg	2.99	3.08	3.04	2.98	2.96	.07
ADG, g	876	859	845	833	860	15
Feed/Gain	3.42 ^a	3.59 ^b	3.59 ^b	3.57 ^b	3.44 ^{ab}	.05

¹Standard error of mean.

^{a, b}Means with different superscripts differ, (P<.10).

Table 12. PERFORMANCE OF BROILERS FED DIETS OF GRAIN SORGHUM OR CORN

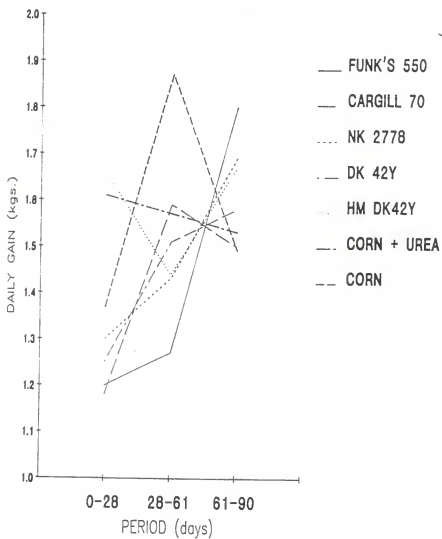
	Diets					SE ¹
	Grain sorghum				<u>Corn</u>	
	F 550	C 70	NK 2778	DK 42Y		
Gain, g	1725	1721	1733	1742	1667	30
Feed intake, g	3784 ^{ab}	3984 ^b	3833 ^b	3821 ^b	3575 ^a	82
Feed/gain	2.19	2.31	2.21	2.19	2.15	.1

¹Standard error of mean.

^{a,b}Means with different superscripts differ, (P<.05).

Figure 1.

COMPARATIVE DAILY GAINS BY TIME PERIODS OF STEERS FED DIETS OF GRAIN SORGHUM AND CORN



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Appendix A

Diet Digestibility Trial

1. Formulation for chromic oxide pellets:

% (as-fed basis)

12.5 chromic oxide (Cr_2O_3)
62.5 ground corn
25.0 dry cane molasses
100.0

2. Calculations for digestion coefficients:

Ratio = % chromium in feed/% chromium in feces

Dry matter digestibility = $(1 - \text{ratio}) * 100$

3. Feces collection schedule:

Friday	8 am	8 pm	
Saturday	10 am	10 pm	
Sunday	-	12 pm	(noon)
Monday	12 am (midnight)	2 pm	
Tuesday	2 am	4 pm	
Wednesday	4 am	6 pm	
Thursday	6 am	8 pm	
Friday	8 am		

Figure 2.

COMPARATIVE FEED EFFICIENCIES OF FINISHING STEERS FED DIETS OF GRAIN SORGHUM AND CORN

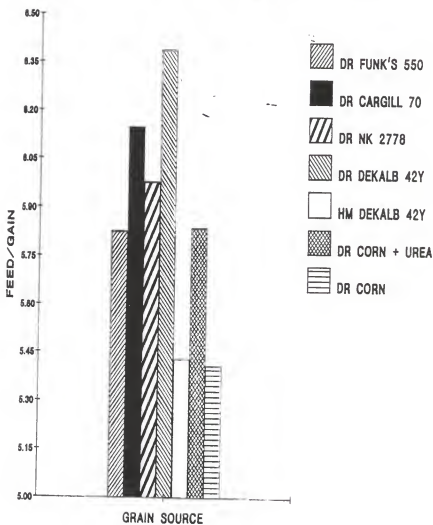


Figure 3. **COMPARATIVE DRY MATTER DIGESTIBILITIES OF GRAIN SORGHUM AND CORN DIETS FED TO FINISHING STEERS**

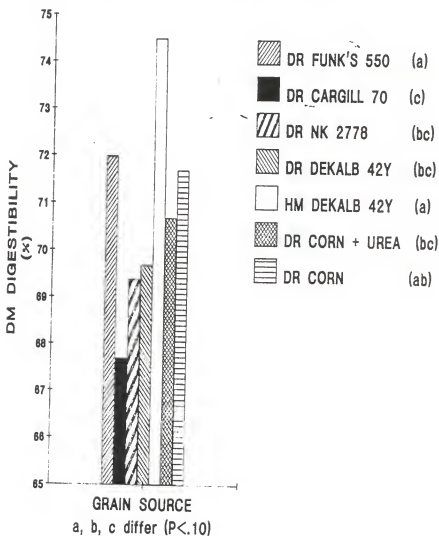


Figure 4.

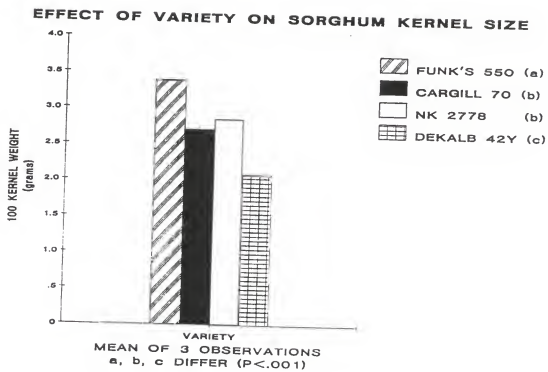


Figure 5.

COMPARATIVE PARTICLE SIZES OF GRAIN SORGHUM DIETS FED TO FINISHING STEERS

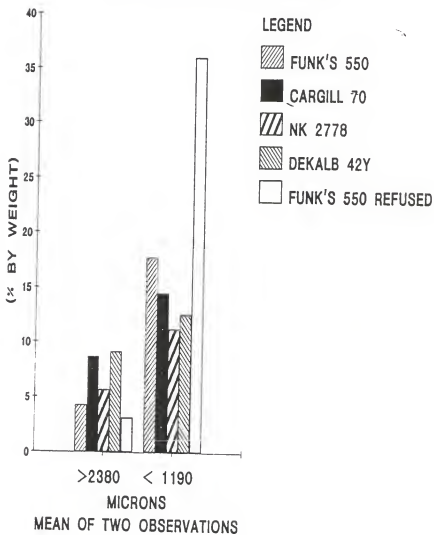


Figure 6.

COMPARATIVE FEED EFFICIENCIES OF FINISHING SWINE FED DIETS OF GRAIN SORGHUM AND CORN

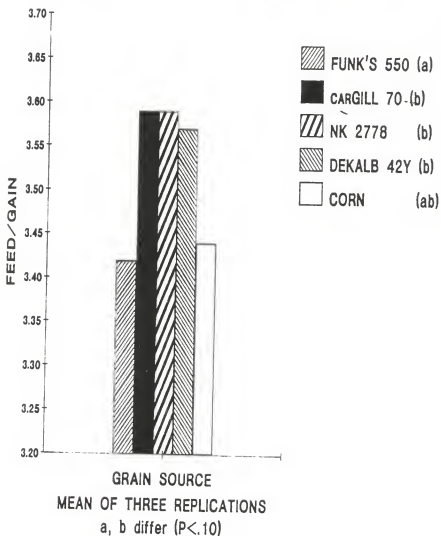
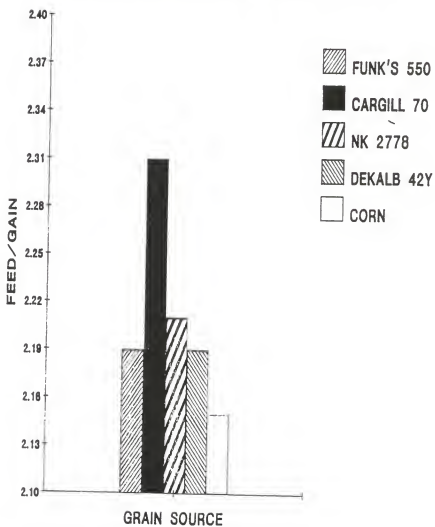


Figure 7.

COMPARATIVE FEED EFFICIENCIES OF BROILERS FED DIETS OF GRAIN SORGHUM AND CORN



COMPARATIVE FEEDING VALUE OF GRAIN SORGHUM
AND CORN IN BEEF, SWINE, AND BROILER DIETS

by

GARY G. GOLDY

B. S., Western Illinois University, 1972

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Sciences and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1987

Funk's (F 550) and Cargill (C 70), heterozygous yellow endosperm (Yy) grain sorghum hybrids and Northrup-King (NK 2778) and DeKalb (DK 42Y), homozygous yellow endosperm (YY) grain sorghum hybrids were compared with corn (Pioneer 3377) in three trials with cattle, swine, and broilers. Thirty-five individually fed crossbred steers (410.8 kg) were used in a 90-day finishing trial (5 steers per diet) to compare dry rolled (DR) F 550, C 70, NK 2778, DK 42Y, high moisture ensiled (HM) DK 42Y, and corn with and without added urea. Cattle diets were 78% grain, 15% sorghum silage and 7% supplement (DM basis). Feed/gain (F/G), daily gain (ADG) and dry matter intakes of steers did not differ among diets; however, cattle on the DR grain sorghum diets tended to give slower gains and poorer feed efficiencies than those on the corn diets. The F 550 had larger kernels ($P < .001$) and, when processed, resulted in more particles under 1190 microns ($P < .01$) which may have been responsible for the improved F/G, DM digestibility, and in vitro volatile fatty acid (VFA) production relative to the other dry processed grain sorghum hybrids. The HM DK 42Y gave slightly improved F/G and increased diet digestibility and in vitro VFA production compared with the DR grain sorghums. Cattle fed the DR grain sorghums were 8.5% less efficient, while those fed the HM DK 42Y had a 3.6% improved efficiency compared with

steers on the corn diet. Cattle on the corn diet (10% CP) without added urea tended to have improved F/G and higher diet digestibility compared with cattle fed the urea supplemented corn diet (11.2% CP). The F 550 resulted in improved ($P < .10$) F/G in finishing swine. Daily gain and feed intake were not influenced by hybrid in the swine trial. Broiler feed intake was decreased ($P < .05$) on the corn diet compared with C 70, NK 2778, and DK 42Y diets. Swine and broilers fed the grain sorghum diets were 2.8% and 3.7% less efficient, respectively, than those fed the corn diets. There were no differences ($P > .05$) in the feeding values of Yy and YY endosperm grain sorghum hybrids fed in the cattle, swine, and broiler diets.