FEEDLOT COMPARISONS AND DIGESTIBILITY OF FOUR HYBRID GRAIN SORGHUMS FOR BEEF CATTLE FED ALL-CONCENTRATE RATIONS

by 4589

RICHARD LEE MCCOLLOUGH

B. S., Kansas State University, 1968

A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Approved by:

Calvin L. Drake
Major Professor

ACKNOWLEDGEMENT

I wish to take this opportunity to thank Dr. Calvin Drake, my major professor, for his patience, understanding and assistance in planning and completing this study. During the critical stages of this experiment he has given me his unselfish co-operation, advise, and well-considered criticism that has been most helpful in completing this study.

To the Head of The Department, Dr. D.L. Good, members of the staff, and secretaries, I wish to express my appreciation for the spirit of friendship and willingness with which they all availed themselves of their services and facilities at all times.

My sincere thanks also goes to Dr. Charles Deyoe and Dr. Robert Schalles, committee members, and to other graduate students who have helped with this project. I would like to pay special thanks to a local farmer Mr. Frank Rudolph for his co-operation in producing the grain for this project.

I wish to dedicate this work to my wife, Linda Kay, to my daughter, Tammy Kay, and to my parents who have given me the encouragement, and inspiration for the success of my academic career.

THIS BOOK CONTAINS SEVERAL DOCUMENTS THAT ARE OF POOR QUALITY DUE TO BEING A PHOTOCOPY OF A PHOTO.

THIS IS AS RECEIVED FROM CUSTOMER.

TABLE OF CONTENTS

LIST OF TABLES

Appendix

LIST OF PLATE

Chapter 1

INTRODUCTION

Sorghum grain production in the United States has increased from 200 million bushels in 1956 to 770 million bushels in 1967. Many factors have contributed to this three fold increase in production. First, the development of male-sterile types made hybrid sorghum seed possible. Hybrids have increased yield 25% over previously established varieties. Second, the increase in demand for sorghum grain for feedstuffs due primarily to an increase in livestock numbers. Thirdly, a decrease in the price of wheat and less demand for wheat in feedstuffs has caused land to be diverted from wheat production to sorghum grain. Fourthly, hybrid grain sorghums are more drouth resistant and respond more favorably to newly developed irrigation methods used in West Central United States than wheat. In 1969, Kansas harvested 182,896,000 bushels of sorghum grain.

To date most research has been concentrated on different processing methods for sorghum grain. Very little work has been conducted to improve the nutritional value of grain sorghum. Riewe (1966), Breuer _et al_. (1967), McGinty (1969), Nishimuta, Sherrod, and Furr (1969) and Drake _et al_. (1970) all report differences in the nutritional value of different varieties or types of grain sorghum for sheep and cattle.

A new white hybrid grain sorghum, Funk's G-766W, has been reported to be superior to regular red elevator-run (origin unknown) in feeding trials and digestibility studies Wilson (1968), Nishimuta _et al_. (1969), Drake _et al_. (1970), K.S. Eng (personal communication) and R. G. Hinders (personal communication). To the author's knowledge no work has been conducted comparing different hybrid grain sorghums to the new white hybrid.

This research was conducted to determine nutritive value of four different hybrid grain sorghum on feedlot preformance, carcass characteristics, and coefficients of digestion, when fed in an all-concentrate ration. The four hybrids studied were; Funk's G-766W (white over yellow endosperm), Acco R-109 (red over yellow endosperm), DeKalb E-57 (red over white endosperm), and Northrup King 222A (red over yellow endosperm).

Chapter II

REVIEW OF LITERATURE

Sorghum Grain Structure

Rooney and Clark (1968) stated that the sorghum grain kernel is a flatten sphere approximately 4.0 mm long by 3.5 mm wide by 2.5 mm thick. Kernel weight varies from 8 to 50 mg (average 28 mg). There are 164 to 252 thousand seeds per kg. The kernels or caryopsis are made up of three main parts: the outer covering, pericarp; the storage tissue, endosperm; and the germ, embryo.

Each part can be subdivided. The outer most layer of pericarp is the epidermis or epicarp, which contains pigments and wax. The middle layer or mesocarp contains small starch granules embedded in a dense, proteinaceous network. The inner portion of the pericarp, endocarp, is composed of cross cells and tube cells. Swanson (1928) listed four parts of the pericarp: cuticle, epidermis, hypoderm, and mesocarp.

The next layer is sometimes pigmented and it has been called the nucellar layer by Swanson (1928), testa by Artschwager and McGuire (1949) and McGinty (1969), seed coat by Sanders (1955), and undercoat by the wet milling industry. The multitude of names has caused some confusion in the literature, especially those reports dealing with the pigments found in this structure. This layer will be referred to as seed coat in this thesis.

Swanson (1928) and McGinty (1969) reported that some varieties of sorghum have no seed coat present. Sanders (1955) studied the morphological development of six varieties of sorghum: Martin, Early Hegari, Combine Kafir 60, Texas Combine Kafir, Combine Kafir 54T, and Texioca 54. He found a seed coat present or a cutinous membrane which was the remains of a seed coat in all varieties studied. He noted varietal difference. Early Hegari was the only variety with pigments in the seed coat. Combine Kafir 54T had a nonpigmented layer that was partially cellular. Sanders found a seed coat present in all six varieties studied. Watson et al. (1955) studied the Martin variety and reported no seed coat present. Sanders (1955) reported Martin had a seed coat. The above confirms confusion concerning the presence of a seed coat. Blessin, Van Etten and Dimler (1953), Hale et al. (1969), and Brown (1959) report pigments in the seed coat can give sorghum grains a bitter tannin taste which lowers palatability.

Rooney and Clark (1968) state the endosperm of the sorghum kernel is composed of an aleurone layer and the peripheral, corneous, and floury endosperm. The aleurone layer located immediately beneath the seed coat is a layer of small, dense endosperm cells with a relatively high content of oil and protein. Rooney and Clark (1968) and Watson et al. (1955) stated the peripheral endosperm was located just beneath the aleurone layer and consists of a layer several cells thick which can be distinquished from horny and floury endosperm because of small starch granules which are enmeshed in a thick proteinaceous matrix. Watson et al. (1955) found the thickness of the peripheral endosperm influenced by environment and variety.

The starch of the horny or corneous and floury endosperm can be waxy (all amlyopectin) or 25% amylose and 75% amlyopectin which is normal for both corn and sorghum grains (Watson, 1959). The amylose content of 210 varieties of sorghum ranged from 21% to 28% as found by Deatherage, MacMasters and Rist (1955). Five varieties of waxy sorghum each had an amylose content of 1%.

MacMasters (personal communication) has listed the mature structure of sorghum and corn kernels to be as follows:

Pericarp

Epidermis
Mesocarp
Cross cells
Tube cells
Seed coat

Endosperm

Aleurone layer
Peripheral endosperm
Corneous (horny) endosperm
Floury endosperm

Embryo

Scutellum (cotyledon)
Embryonic axis

Hubbard, Hall and Earle (1950) hand dissected five varieties of sorghum grain (Martin, Westland, Midland, Cody (waxy Kafir), Pink Kafir) and found the following results: endosperm makes up from 80 to 84.6% (avg 82.3%) of the kernel, bran 7.3 to 9.3% (avg 7.9%) and germ 7.8 to 12.1% (avg 9.8%) of the kernel. Approximately 90% of the total starch and 80% of the total protein was found in the endosperm. The germ contained approximately 75% of the ether extract.

Chemical Composition

The chemical composition commonly used for all varieties of sorghum is as follows:

TABLE 1. CHEMICAL COMPOSITION OF SORGHUM

Reference	% Protein	% Fat	% Fiber	% NFE	% Ash
Morrison 1959	10.9	3.0	2.3	81.7	2.1
N.R.C. 1963	11.0	2.8	2.4	81.9	1.9
Crampton 1969	11.1	3.0	2.2	79.9	2.0

Miller (1958) has listed the ranges of the proximate analysis and Watson (1967) lists the averages as sited by Rooney and Clark (1969).

TABLE 2. PROXIMATE ANALYSIS RANGES AND AVERAGES

Source	% Range	% Avg
Starch	60-77	74.1
Protein (N x 6.25)	6.6-16	11.2
Fat	1.4-6.1	3.7
Ash	1.2-7.1	1.5
Crude Fiber	.4-13.4	2.6
Tannin	.003-.17	.1
NFE	65.3-85.3	---

Protein. Miller (1958) reported the protein of sorghum grains may range from 8 to 12%. Pickett (1969) reported a range of crude protein from 7 to 26% and lysine .86 to 3.36% of total protein from 400 lines of the world sorghum collection. Most lines with values above 20% protein were relatively low yielding material or grassy-type sorghums. In good agronomic types the range of protein was from 8 to 20%. Deyoe, Waggle and Sanford (1967) and Miller *et al.* (1964) have found that the protein content may differ because of climate, soil, cultural practices, and variety. Generally hybrids are lower in protein than the parent varieties. This was reported as due to an increase in starch content (Rooney and Clark, 1968). Miller *et al.* (1964) found that protein level of sorghum grains grown at various locations in Kansas under different conditions varied from 6.6 to 12.8% protein in 1961 and 5.9 to 12.1% protein in 1962.

Eng (1965) found that with three varieties of sorghum, RS-610, RS-621 and Ute which represent low, medium and high protein varieties respectively, there was a distinct varietal difference in terms of protein content. RS-610 contained 9.9% crude protein; RS-621, 11.5%; and Ute, 12.9% crude protein. Also within each variety as N fertilizer was increased protein content of the grain was increased.

Breuer et al. (1967) reported a range from 8 to 15% for crude protein for 28 parent varieties of sorghum grains grown in Texas. Hegari varieties appeared to be the lowest in crude protein, Kafirs were medium, and Martin and certain Fetertas were the highest in crude protein. When Martin was used as a seed parent the hybrids were also higher in crude protein content.

Deyoe and Shellenberger (1965) analyzed 15 different hybrid sorghum grains grown at two locations and found a significant difference in amino acids due to hybrids. The amino acids were reported as percent of sample and percent of protein. The amino acids of importance from a nutritive stand point are methionine which ranged from 1.22 to 1.97% and lysine which ranged from 1.81 to 2.49% reported as percent of protein.

Pickett (1968 unpublished data) working with 9 seed parent varieties of the world sorghum collection reported lysine to vary from 1.74 to 2.74% of the protein. This work is in agreement with Rooney and Clark (1968) who expected hybrids to have less variation in lysine and other amino acids because the majority of hybrids are from a small number of seed parents. Breuer (1969) reports that the majority of hybrids were developed from 30 seed parents.

Tannins. Varieties of sorghum grains with open heads and brown seeds are better adapted to humid areas of the world than those having compact heads and white seed or yellow seed. Characteristically, the brown seeded varieties are also high in tannin which may effect their palatability and nutritive value for livestock (Chang and Fuller, 1964).

Phenolic pigments, including tannins are found mainly in the pericarp of sorghum grains. A number of investigators have reported that these pigments may cause unpalatibility and bitterness (McClymont, 1952; Blessin et al.,1963; Chang and Fuller, 1964; and Dimler, 1965).

Barham et al. (1946) reported the tannin content of 13 varieties of grain sorghums. They found the extremes to be .003% for Atlas and .1667% for Early Sumac. Other popular varieties reported are: Feterita .0129%, Hegari .0049%, Wheatland .0080%, Atlas Sorgo .0030%, Pink Kafir .0048% and Leoti Red .1578%.

Brown (1959) attributed the bitter flavor of brown-seeded grain to tannins. Blessin, Van Etten and Dimler (1963) studied anthocyanogens (leucoanthocyanins) which are polyphenolic compounds that may be the precursors to condensed tannins. Anthocyanogens were detected in yellow milo (Martin, Midland and Westland) and Red Kafir, but not in white Kafir, waxy or yellow-endosperm varieties. The location of the anthocyanogens was traced to the pericarp.

Tannins have an inhibitory effect on various enzymes. Enzymes are protein in nature. Lyr (1965) used tannic acid to precipitate amylase. Miller and Keen (1947) isolated an amylase inhibitor mainly found in bran fraction of sorghum grain. The inhibitor was extremely resistant to heat. The red-brown color could not be removed without loss of activity of the inhibitor. The inhibitor was soluble in water, alcohol and acetone and insoluble in ether. The inhibitor was inactivated by rumen fluid. Bell et al. (1962, 1965) found the activity of pectinase and cellulase was decreased by the presence of water soluble leaf pigments. Sericea which is high in tannin had the highest inhibiting effect. Lyr (1965) found polyphenols (tannins) had an inhibiting effect on the enzymes amylase, perioxidase, pectinase and cellulase.

Digestion Trials

Sheep. Riewe (1966) used sheep on an all sorghum grain diet to study the digestibility of nine varieties of sorghums commonly used in hybridization programs for hybrid grain sorghum production. Coefficients of digestion (COD) for energy, protein, and nitrogen free extract were not different. When the feeding rate was over 1.5% of the body weight, three out of five wethers went off feed.

Nishimuta, Sherrod and Furr (1969) studied the digestibility of waxy endosperm (Funk's 3758), and a white grain with a yellow endosperm (G-766) and regular red grain sorghum (origin not known) with sheep. Digestibility of organic matter, non-protein organic matter, gross energy, crude protein, and N-free extract were significantly higher for the waxy and white grains than for regular red. Crude fiber digestibility was significantly higher for the white grain. They reported that the starch was more uniform in the white sorghum (G-766) and concluded that improvement of digestibility of the white over regular red was probably related to the type and uniformity of the starch granules. Hale (unpublished data) found the same trends although he had a higher COD.

Cattle. McGinty and Riggs (1968) and McGinty (1969) reported the COD of eight different parent varieties of sorghum grain by steers fed an all-concentrate diet. The eight varieties studied were TX-09 Feterita (white starchy), 7078 (red soft starchy), TX-2536 (yellow, harder corneous), Martin (red, hard corneous), Combine Shallu (white, hard corneous), Darset #28 (brown, soft starchy), Shantung Brown Kaoliang (brown, soft starchy), and Double Dwarf White Waxy Feterita (white waxy, corneous).

The first trial Combine Shallu was not included. COD for dry matter, organic matter, non-protein organic matter, and apparent and true protein were significantly lower for Darset and Kaoliang (brown seeded varieties). Martin's COD were intermediate. In trial II Shallu was added to the above seven varieties. The results of experiment II were essentially the same as the first trial. Differences in digestibility of dry matter were not significant among TX-09, 7078, 2536, and Double Dwarf White Waxy Feterita. Martin and Shallu were intermediate while Darset and Kaoliang were lowest in digestibility of dry matter. Apparent digestible protein was significantly lower for the Darset and Kaoliang (brown seed varieties) than the other six varieties.

The COD reported in the previous trials for the regular red sorghum grain was in close agreement with Saba *et al.* (1964), McGinty, Breuer and Riggs (1966), Keating *et al.* (1965), and Brown, Tillman and Totusek (1968) when feeding an all-concentrate ration to steers.

Sherrod, Albin and Furr (1969) determined the net energy for maintenance (NE_m) and gain (NE_g) for waxy and regular sorghum grains for fattening cattle. The NE_m and NE_g for regular grain sorghum was 1.43 and .95 and for waxy 1.50 and 1.24 megcal/kg, respectively. The carcass data revealed that the waxy ration produced more backfat and required significantly less feed per kg of carcass gain which was 12.32 for regular grain and 10.97 kg feed/kg gain for waxy. They concluded that the waxy starch (all amylopectin) was apparently more available to enzymatic degradation in the digestion process.

Feeding Trials

Parent Varieties -- Rats. Sorghum grains Hegari, Dwarf Yellow, Shallu, Waxy Kafir, and Martin were compared to corn and wheat (Smith, 1930; Lamb, Michie and Rivers, 1966). Results showed unsupplemented ground sorghum grains were nutritionally inferior to ground corn and ground wheat for rats.

Parent Varieties -- Sheep. Riewe (1966) compared the feed value of Hegari, TX-414, Martin, and Kafir to corn for sheep. All of the sorghum grain rations were significantly lower than corn in average daily gain and feed conversion. The lambs on sorghum grain ate 11.7% more grain and required 24.3% more feed to produce a pound of gain than lambs on corn rations. Martin required 11% more feed than Early Hegari, Texas-414 or Combine Kafir to produce a pound of gain.

Brewer et al. (1967) studied four parent varieties 7078, TX-414, Kafir, Martin and their hybrids 610 (7078 x Kafir), 608 (7078 x Martin), 624 (414 x Kafir) and 625 (414 x Martin). Average daily gain was essentially the same for all varieties and their hybrids for fattening lambs. Martin was again utilized with lowest efficiency. The hybrids 608 and 625 with Martin as seed parent appeared to be used less efficiently than the hybrids 610 and 624 for which Kafir served as the seed parent.

Parent Varieties -- Cattle. Weber, Aicher and Kessler (1951) compared Midland (Pink Kafir Dwarf x Yellow milo), Westland, and Pink Kafir to corn for fattening cattle. The two combine sorghums (Midland and Westland) were equal to corn for average daily gain and feed per pound of gain. Pink Kafir took approximately 30 pounds less feed to put on a hundred pounds of gain than corn or Midland or Westland.

Brethour and Duitsman (1955) fed Texas 09 (feterita, floury endosperm), Texioca 54 (waxy endosperm), and RS-610 (a popular hybrid) to fattening steers. Intake was more for RS-610. The waxy sorghum grain resulted in slightly but not significantly greater gain and improvement in feed efficiency. No advantages were noted with floury endosperm type Texas 09.

Hybrids -- Cattle. Hale et al. (1964) compared two hybrid grain sorghums Texas and Willcox to Hegari (parent variety) and steamed flaked barley.

When comparing Hegari, Texas, and Willcox varieties, Hegari had the highest ADG and best feed efficiency record. The two hybrids had similar ADG but Texas appeared to be more efficient than Willcox hybrid.

Riewe (1969) fed fattening cattle four hybrids of grain sorghum RS-608 (Martin x 7078), RS-625 (Martin x TX-414), RS-610 (Kafir x 7078) and RS-626 (Kafir x TX-414). Using a ration of 67.5% sorghum grain, 15% cotton seed meal, and 16% ammoniated rich hulls he found the Kafir derivative RS-610 produced significantly higher ADG and feed intake than other hybrids. The other Kafir derivative RS-626 had a poorer feed efficiency and ADG than Martin derivatives. The RS-626 fed to fattening cattle contradicts the observation by Breuer et al. (1967) who fed RS-626 to fattening lambs and found RS-626 to be better than Martin seed parent derivatives.

Bird Resistant Sorghum. Hale et al. (1969) studied the effect of steam flaking on a bird resistant (Arkansas 614) sorghum grain. The first 56 days on test the fattening ration contained 40% roughage and there were no differences in gain or feed efficiency. After 112 days on test, the steers fed bird resistant sorghum gained .15 lb less per day and required slightly more feed than the steers fed regular sorghum grain. This would suggest the bird resistant grain in high grain rations may not be as efficient as regular milo when both rations are steam flaked. They also conducted in vitro gas production studies on ground grain and steam processed regular and bird resistant sorghum grains. Steam flaking of the bird resistant grain increased gas production four times over ground grain and made it almost equal to the regular steam flaked sorghum grain for gas production.

Feeding Trials -- Waxy. Sherrod et al. (1969) found that waxy Funk's 3758 required 9% less feed per lb of gain and was significantly more efficient than regular sorghum grain for a fattening ration. The waxy grain produced significantly more fat in the final body composition.

Feeding Trials -- White. K. O. Wilson (personal communication, 1968) compared white sorghum grain (Funk's 765W) to a red hybrid (Funk's 744) with 24 lactating Holstein cows. The white grain produced significantly more milk over a nine week period.

K. S. Eng (personal communication), R. G. Hinders (personal communication) and Drake et al. (1970) have conducted fattening trials with cattle where a white sorghum grain (Funk's G-766W) was compared to regular red (elevator run) sorghum grain. They observed essentially no difference in ADG but an improvement in feed efficiency in favor of the white grain. Drake et al. (1970) found the white grain required .79 lb less feed to produce a pound of gain.

LITERATURE CITED

Artschuager, E. and R. C. McGuire. 1949. Cytology of reproduction in Sorghum valgare. J. Agr. Res. 78:659.

Barham, H. N., J. A. Wagoner, C. L. Campbell, and E. H. Harclerode. 1946. The chemical composition of some sorghum grains and the properties of their starches. Kan. Agr. Exp. Sta. Tech. Bul. 61.

Bell, T. A., J. L. Etchells and W. W. G. Smart, Jr. 1965. Pectinase and cellulase enzyme inhibitor from sericea and certain other plants. Bot. Gaz. 125:40.

Bell, T. A., J. L. Etchells, C. F. Williams and W. L. Porter. 1962. Inhibition of pectinase and cellulase by certain plants. Bot. Gaz. 123:220.

Blessin, C. W., C. H. Van Etten and R. J. Dimler. 1963. An examination of anthocyanogens in grain sorghums. Cereal Chem. 40:241.

Brethour, J. R. and W. W. Duitsman. 1965. Utilization of feterita-type and waxy-endosperm sorghum grains in all-concentrate rations fed to yearling steers. Kan. Agr. Exp. Sta. Bul. 482. p. 34.

Breuer, L. H. 1969. The nutritive value of different varieties of sorghum grain. The Cattleman 55:12. p. 44.

Breuer, L. H., M. C. Riewe, J. D. Smith, C. K. Dohme, T. M. Taylor, and J. C. Harper. 1967. Sorghum grain utilization research. Proc. 22nd Ann. Tex. Nutr. Conf. p.215.

Brown, A. R. 1959. Sorghum Grain Newsletter. Kan. Agr. Exp. Sta. Hays, Kan. 2:13.

Brown, G. W., Jr., A. D. Tillman and R. Totusek, 1968. Digestibility, nitrogen retention and energy values of sorghum grain and corn rations at three levels of intake. J. Anim. Sci. 27:170.

Chang, S. I. and H. L. Fuller. 1964. Effect of tannin content of grain sorghums on their feeding value for growing chicks. Poul. Sci. 43:30.

Crampton, E. W. and L. E. Harris. 1969. Applied Animal Nutrition (2nd Ed.) W. H. Freeman and Co., San Francisco, California. p. 688.

Deatherage, W. L., M. M. MacMasters, C. E. Rist. 1955. A partial survey of amylose content in starch from domestic and foreigh varieties of corn, wheat and sorghum and some other starch bearing plants. Trans. Am. Assoc. Cereal Chem. 13:31.

Deyoe, C. W., J. A. Shellenberger. 1965. Amino acids and protein in sorghum grains. J. Agr. Food Chem. 13:446.

Deyoe, C. E., D. H. Waggle and D. E. Sanford. 1967. Protein and amino acid relationships in sorghum grain. Proc. Grain Sorghum Res. and Util. Conf. p. 26.

Dimler, R. J. 1965. Utilization research on grain sorghum. Proc. Grain Sorghum Res. and Util. Conf. p. 17.

Drake, C. L., V. P. Carlson, P. H. Wilson and D. M. Allen. 1970. White sorghum grain (Funk's G-766W) and elevator-run red sorghum grain compared for fattening cattle. Kan. Agr. Exp. Sta. Bul. 536. p. 38.

Eng, K. S. 1965. The relationship of grain sorghum variety and nitrogen fertilization to the feeding value of the grain. Proc. 20th Ann. Tex. Nutr. Conf. p. 40.

Hale, W. H., B. Taylor, W. J. Saba, E. K. Keating and K. Palmer. 1964. The value of three varieties of milo compared with steam-rolled barley in a high-grain fattening ration. Ariz. Cattle Feeder's Day Rpt. p.32.

Hale, W. H., B. Theurer, W. J. Saba, B. Taylor, H. Essig. 1969. Bird resistant milo and wheat in high-concentrate steer fattening ration. Ariz. Cattle Feeder's Day Rpt. p. 7-1.

Hubbard, J. E., H. H. Hall and F. R. Earle. 1950. Composition of the component parts of the sorghum kernel. Cereal Chem. 27:415.

Keating, E. K., W. J. Saba, W. H. Hale and Bruce Taylor. 1965. Further observations of the digestion of milo and barley by steers and lambs. J. Anim. Sci. 24:1080.

Lamb, M. W., J. M. Michie, J. M. Rivers. 1966. A comparison of the nutritive value of three sorghum grains with that of wheat. Cereal Chem. 43:447.

Lyr, J. 1965. On the toxicity of oxidized polyphenols. Phytopathologische Zeitschrift. 52:229.

McClymont, G. L. 1952. Studies on nutrition of poultry. III. Toxicity of grain sorghum for chicks. Australian Vet. J. 28:229.

McGinty, D. D. 1968. Factors affecting the digestibility of varieties of sorghum grains by cattle. Ph.D. Thesis. Texas A&M Univ. College Station, Texas.

McGinty, D. D. 1969. Variation in digestibility of sorghum varieties. Proc. Grain Sorghum Res. and Util. Conf. p. 20.

McGinty, D. D., L. H. Breuer, J. K. Riggs. 1966. Digestibility of dry and reconstituted grain sorghum by beef cattle. Beef Cattle Res. in Tex. Prog. Rpt. 2424. p. 37.

McGinty, D. D. and J. K. Riggs. 1968. Variation in digestibility of sorghum grain varieties. J. Anim. Sci. 27:1170 (Abstr.).

Miller, B. S. and E. Kneen. 1947. The amylase inhibitor of Leoti sorghum. Arch. Biochem. 15:251.

Miller, D. F. 1958. Composition of Cereal grains and forages. Natl. Academy Sci., Natl. Res. Council. Pub. 585. Washington, D. C.

Miller, G. D., C. W. Deyoe, T. L. Walter and F. W. Smith. 1964. Variations in protein levels in Kansas sorghum grains. Agron. J. 56:302.

Morrison, F. B. 1959. Feeds and Feeding. (22nd Ed.). The Morrison Publ. Co. Clinton, Iowa.

Nishimuta, J. F., L. B. Sherrod and R. D. Furr. 1969. Digestibility of regular, waxy and white sorghum grain rations by sheep. Proc. Western Sect. Am. Soc. Anim. Sci. 20:259.

N. R. C. 1963. Nutrient Requirements of Domestic Animals. No. 4. Nutrient Requirements of Beef Cattle. National Research Counceil, Washington, D.C.

Pickett, R. C. 1969. Variation in amino acid content of sorghum from world collection. Proc. Grain Sorghum Res. and Util. Conf. p. 18.

Riewe, M. E. 1966. Utilization of several varieties of sorghum grain by sheep. Proc. 21st Ann. Tex. Nutr. Conf. p. 89.

Riewe, M. E. 1969. Feedlot results with different varieties and hybrids of grain sorghum. The Cattlemen 55:13. p. 52.

Rooney, L. W. and L. E. Clark. 1968. The chemistry and processing of sorghum grain. Cereal Sci. Today 13:258.

Saba, W. J., W. H. Hale, F. Hubbert, J. Kiernot and B. Taylor. 1964. Digestion of milo and barley by cattle. J. Anim. Sci. 23:533.

Sanders, E. H. 1955. Developmental morphology of the kernel in grain sorghum. Cereal Chem. 32:12.

Sherrod, L. B., R. C. Albin and R. D. Furr. 1969. Net energy of regular and waxy sorghum grains for finishing steers. J. Anim. Sci. 29:997.

Smith, M. C. 1930. The comparative nutritive value of yellow corn and the grain sorghum Hegari and yellow milo. J. Agr. Res. 40:1129.

Swanson, A. F. 1928. Seed coat structure and inheritance of seed color in sorghums. J. Agr. Res. 37:577.

Watson, S. A. 1959. The present importance and bright future of grain sorghum. Cereal Sci. Today 4:231.

Watson, S. A. 1967. Starch Chemistry and Technology. R. Whistler and E. Paschall, Eds. Vol. II. Academic Press, New York. p. 1 - 51.

Watson, S. A., E. H. Sanders, R. D. Wakely and C. B. Williams. 1955. Peripheral cells of the endosperm of grain sorghum and corn and their influence on starch purification. Cereal Chem. 32:165.

Weber, A. D., L. C. Aicher and F. B. Kessler. 1951. Comparative values of Midland milo, Westland milo, Pink Kafir, and corn for fattening cattle. Kan. Agr. Exp. Sta. Circ. #271. p.5.

Chapter III

FEEDING VALUE OF FOUR DIFFERENT HYBRID GRAIN SORGHUMS FOR FATTENING CATTLE

Sorghum grain is the major feed grain used in cattle fattening rations in the Midwest. New hybrid grain sorghums are being developed to improve productivity and nutritive value. One of these new hybrids, Funk's G-766W has a white pericarp over a yellow endosperm. Improvement in feed efficiency for fattening cattle has been reported for Funk's G-766W when compared to regular red (elevator-run) grain sorghum (Drake et al. 1970; K. S. Eng, personal communication; and R. G. Hinders, personal communication). A significant increase in milk production was found for Funk's 765 (white grain) when compared to a red hybrid (K. O. Wilson, 1968).

This study was designed to compare a white hybrid grain sorghum (Funk's G-766W) to three red hybrids produced in large quantities in Kansas. The red hybrids were: Acco R-109 (red over yellow endosperm), DeKalb E-57 (red), Northrup King 222A (red over yellow endosperm). Comparisons were made on the basis of agronomic productivity, feedlot performance and carcass characteristics.

Experimental Procedure

Grain Sorghum Production. Four hybrid grain sorghums were produced under similar conditions with irrigation near Manhattan, Kansas. On June 9, 1969 all four hybrids were planted at the rate of 7.85 kg/ha (7 lbs/A) in .91 m (36 in) rows. The sorghum was rotary hoed, sprayed with 2, 4-D, cultivated twice, and hilled for irrigation. One hundred and sixty-eight kg N/ha (150 lbs N/A) were applied preplant as anhydrous ammonia with 10 kg N (9 lbs/A), 24.6 kg P_2O_5 (22 lbs/A), 17.9 kg K_2O (16 lbs/A) and 5.6 kg Zn (5 lbs/A) supplied per hectare as starter fertilizer. Agronomic performance data were gathered to compare yields of hybrids. Expected yield data was calculated by hand harvesting 6.1 m (20 ft) of a .91 m (36 in) row. Six randomly selected plots per hybrid were threshed seperately and grain per plot was weighed. The grain was harvested and stored seperately until fed.

The grain was dry rolled, and incorporated into isonitrogenous, all-concentrate rations (12% crude protein dry matter basis). The rations contained approximately: sorghum grain, 98%; salt, 1%; trace mineral premix, .05%; urea, .5%; limestone, .5%; with 7.8 mg chlorotetracycline and 1,653 I.U. vitamin A per kg ration (Table 1). Urea was used to make the rations isonitrogenous. Proximate analysis of the four hybrid grain sorghums is presented in table 2.

Feedlot Cattle. During the winter of 1969-70 sixty head of Hereford steers with an average weight of 346 kg were randonly allotted by weight into 12 lots of five head each. Ten head were group fed (non-sheltered) and five head were individually fed (sheltered) per treatment. The cattle were adjusted to an all-concentrate ration during a four week period using sorghum silage and regular elevator-run red grain sorghum. Each steer was implanted with 30 mg stilbesterol. The first six days of the trial 1.36 kg of a synethic roughage (Ruff-tabs by Farmland Industry) was fed. Automatic waters were available in each pen. The steers were individually weighed and beginning and ending weights were the means of weights on two consecutive days. They were individually weighed at 28 day intervals during the 126 day test period. All cattle were slaughtered and carcass data were taken. Statistical analysis were by analysis of variance (Snedecor, 1956).

Results and Discussion

Agronomic Data. Agronomic performance data of the four hybrid grain sorghums are presented in table 3. There was a significant difference ($P < .05$)

TABLE 1. INGREDIENTS IN RATION

Item	% of ration
Sorghum grain[a]	98
Salt	1
Trace mineral premix[b]	.05
Urea[a]	.5
Limestone	.5
Chlorotetracycline	7.8 mg/kg
Vitamin A	1,653 IU/kg

[a] Grain varied with urea added to keep rations isonitrogenous at 12% protein (dry matter basis). Urea added as % of rations: Funk's G-766W, .57; Acco R-109, .62; DeKalb E-57, .70; Northrup King 222A, .23.

[b] Percentages of indicated elements in trace mineral premix: manganese 4.4%; iron 6.6%; copper 1.32%; cobalt .23%; iodine .30%; zinc 5%; magnesium 20%; sulfur 2.7%.

TABLE 2. PROXIMATE ANALYSIS OF FOUR HYBRID GRAIN SORGHUMS DRY MATTER BASIS

Item	Sorghum Hybrid			
	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
Dry matter %	84.20	84.84	84.49	84.11
Protein % (N x 6.25)	10.65	10.49	10.17	11.83
Ether extract %	3.26	3.18	2.92	3.20
Ash %	1.54	1.69	1.58	1.58
Crude fiber %	2.03	2.12	1.87	1.87
N-free extract %	82.77	82.52	83.43	81.52
Starch %	77.33	79.04	78.27	76.96
Gross energy Kcal/kg	4572.00	4520.00	4552.00	4585.00

TABLE 3. AGRONOMIC PERFORMANCE DATA OF FOUR HYBRID GRAIN SORGHUMS (SUMMER 1969) DRY MATTER BASIS

Item	Sorghum Hybrids			
	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
Ha/field	2.51	3.61	3.76	2.55
Kg/field	12,733	19,813	22,162	14,891
Dry matter %	85	84.8	85	85
Actual yield kg/ha*	5,073	6,270	5,894	5,839
Expected yield kg/ha*a	6,120	7,063	6,328	5,928
Field loss kg/ha**	1,046	793	434	65
Field loss %	17.1	11.2	6.9	1.1
Avg leaves/ mature plant	8 to 9	8 to 9	9 to 11	7 to 8
Mature plant height mm	1.37 to 1.47	1.32 to 1.35	1.32 to 1.40	1.24 to 1.32

* F-ratio indicates significance $P < .05$ between methods of harvesting

** Chi-square indicates significant field loss ($P < .01$)

a Expected yield = grain harvested by hand from 6.1 m of a .91 m row calculation of expected yield

10,000 sq m/ha, 555.1 sq m = .05551 of ha

1 ÷ .05551 = 18.015

18.015 X kg grain/6.1 m - expected kg/ha between methods of harvesting. Hand harvesting yielded significantly more grain than combine harvesting. Field loss was tested by chi-square and a significant loss ($P < .01$) was indicated. Some lodging of Funk's G-766W at harvest explains the higher field loss observed. No further statistical analysis was attempted because only one observation could be made of actual yield per hybrid. The yield potential of all four hybrids were about the same as shown by expected yield (table 3). Also the four hybrids were approximately the same in actual yield. Yield is the criteria used the most to compare hybrid sorghum grain.

Feedlot and Carcass Data. Feedlot and carcass data are presented in table 4. The data are based on the averages of 15 head (14 head for Acco R-109) per treatment, five head fed individually in sheltered pens (south side open), and 10 head fed in two groups of five in non-sheltered pens. There were no significant differences in average daily gain, feed intake, kg feed per kg gain or carcass traits (table 4). There was little variation in average daily gain due to hybrid, however, steers on DeKalb E-57 consumed slightly more feed. Steers receiving Funk's G-766W required .99 kg more feed to produce a kg of gain than the average of the three red hybrids. Acco R-109 was utilized most efficiently requiring 7.08 kg feed per kg gain; Northrup King 222A, DeKalb E-57, and Funk's G-766W required 7.47, 7.93, and 8.48 kg of feed per kg gain respectively. This trend is not in agreement with the findings of Drake et al. (1970), K. S. Eng (personal communication) or R. G. Hinders (personal communication) who all found the white grain to be more efficiently utilized. However, red sorghum grain of an unknown orgin listed as elevator-run or red sorghum grain was used in these trials.

When feedlot performance data were analysed seperately by analysis of

TABLE 4. PERFORMANCE AND CARCASS DATA OF STEERS FED ALL-CONCENTRATE RATIONS CONTAINING FOUR HYBRID GRAIN SORGHUMS (WINTER 1969-1970) DRY MATTER BASIS

Item	Sorghum Hybrids Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
				Feedlot data				
No. steers	15		14[a]		15		15	
Avg initial wt, kg	347	±4.64[b]	344	±4.09	350	±4.79	343	±3.9
Avg final wt, kg	472	±9.19	476	±9.14	480	±10.84	464	±10.57
Avg daily gain, kg	1.02	±0.06	1.06	±0.07	1.00	±0.05	.97	±0.08
Avg daily feed intake, kg	7.68	±0.51	7.62	±0.37	8.18	±0.37	7.39	±0.28
Avg kg feed/ kg of gain[c]	8.48	±0.37	7.08	±0.36	7.93	±0.37	7.47	±0.36
				Carcass data				
Avg hot carcass wt, kg	294	±5.55	274	±6.97	299	±7.35	285	±7.75
Avg rib-eye area cm^2	82.07	±1.61	79.42	±6.61	81.04	±1.29	80.26	±1.93
Avg fat over rib-eye mm	10.16	±0.76	10.16	±0.76	10.16	±0.76	9.04	±1.01
Avg carcass grade[d]	10.05	±0.30	10.16	±0.31	10.43	±0.25	10.26	±0.16
Avg yield grade[e]	2.43	±0.14	2.58	±0.14	2.46	±0.11	2.27	±0.16
Avg marbling score[f]	15.10	±0.71	15.02	±0.73	15.53	±0.58	15.31	±0.87

[a] One steer crippled in lot and had to be removed.
[b] Standard error.
[c] Figured by using 2 group fed lots at 2 observations plus 5 individually fed observations, a total of 7 observations.
[d] High good = 9; Low choice = 10.
[e] 1 = most desirable; 5 = least desirable.
[f] Small = 14; modest = 17.

variance for sheltered lots (individually fed) and non-sheltered lots (group fed) no significant differences were found in feedlot or carcass data. When average daily gain, average daily feed intake, and kg feed per kg gain were calculated seperately there was a trend for steers fed in sheltered lots to gain faster and require less feed per kg of gain (table 5). The sheltered steers gained 1.03 kg per day and the non-sheltered steers gained 1.00 kg per day. Kg feed per kg of gain was 8.48 for non-sheltered steers as compared to 7.20 for sheltered steers. In the sheltered pen it took 1.28 kg less feed to produce a kg of gain during the winter of 1969-70 on an all-concentrate ration.

Lofgreen and Garrett's (1968) net energy tables were used to calculate expected gain for non-sheltered and sheltered steers (table 6). Non-sheltered cattle gained .29 kg less than expected, and the sheltered cattle gained .06 kg less than expected. Acco R-109 and Northrup King 222A fed in sheltered lots had higher average daily gains (+.05 and +.09 kg respectively) than would be expected of regular sorghum grain according to Lofgreen and Garrett's tables (1968). In non-sheltered lots steers on the same two hybrids gained closer to the expected values than did those on DeKalb E-57 or Funk's G-766W. Data in tables 5 and 6 indicates that steer's performance was best in sheltered lots. More energy was required for maintenance in the non-sheltered lots. In a review of feeding all-concentrate rations, Wise et al. (1968), made no mention of the effect the period of the year had on performance of all-concentrate rations. Ellis (1965) summarized the results of 27 trials involving approximately 3,300 cattle. The following figures for average daily gain, average daily feed intake and feed efficiency respectively were given: 1.20 kg, 8.67 kg and 7.24 kg. The average kg feed/kg gain of the four hybrids fed in sheltered lots was 7.20 which is in agreement with

TABLE 5. PERFORMANCE DATA OF NON-SHELTERED (GROUP FED) AND SHELTERED (INDIVIDUALLY FED) STEERS ON ALL-CONCENTRATE RATION (WINTER 1969-1970) DRY MATTER BASIS

Item	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
	Non-sheltered lots							
	Sorghum Hybrid							
No. steers	10		9[a]		10		10	
Avg initial wt, kg	348	±2.10	344	±1.69	350	±1.90	343	±1.67
Avg final wt, kg	479	±2.41	474	±1.51	475	±4.02	456	±3.87
Avg daily gain, kg	1.04	±0.06	1.02	±0.35	.99	±0.22	.89	±0.28
Avg daily feed intake, kg	9.38	[b]	8.00		8.27		7.70	
Avg kg feed/ kg gain	9.01		7.84		8.37		8.71	
	Sheltered lots							
No. steers	5		5		5		5	
Avg initial wt, kg	346	±3.30	347	±1.88	352	±1.40	346	±1.74
Avg final wt, kg	460	±5.94	485	±3.75	493	±3.12	483	±1.87
Avg daily gain, kg	.90	±0.32	1.10	±0.13	1.11	±0.34	1.08	±0.11
Avg daily feed intake, kg	7.02	±0.34	7.49	±0.45	8.18	±0.17	7.30	±0.22
Avg kg feed/ kg gain	7.96	±0.31	6.81	±0.06	7.32	±0.31	6.72	±0.28

[a] One crippled in lot and had to be removed.
[b] Standard error left off, only 2 observations.

TABLE 6. PREDICTION OF AVG DAILY GAIN OF SHELTERED AND NON-SHELTERED LOTS BY NET ENERGY[a,b]

	Sorghum Hybrids							
	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
Item	N-S[c]	S[c]	N-S	S	N-S	S	N-S	S
No. steers	10	5	9[d]	5	10	5	10	5
Mid wt, kg	432	403	409	416	412	422	381	414
Avg daily feed, kg	10.55	8.71	8.81	8.24	9.09	8.99	9.08	8.06
Kg grain for NE_m	3.71	3.65	3.68	3.75	3.72	3.77	3.65	3.72
Kg grain left for production	6.60	5.06	5.13	4.40	5.37	5.22	5.42	4.30
Megcal for production	8.43	6.46	6.55	5.74	6.86	6.66	6.92	5.49
Expected avg daily gain, kg	1.43	1.18	1.19	1.04	1.23	1.18	1.27	1.00
Observed avg daily gain, kg	1.04	.91	1.02	1.10	.99	1.12	.96	1.19
Difference in avg daily gain, kg	-.39	-.27	-.17	+.05	-.32	-.11	-.31	+.09

Avg of 4 treatment observed - Expected avg daily gain
Non-sheltered lots = -.29 kg
Sheltered lots = -.06 kg

[a] Lofgreen & Garrett's (1968) Net Energy Tables for Use in Fattening Beef Cattle.

[b] Sorghum grain NE_m = 1.92 megcal/kg
NE_p = 1.28 megcal/kg

[c] N-S = non-sheltered lots, S = sheltered lots.

[d] One steer crippled in pen and had to be removed.

[e] Observed avg daily gain - expected avg daily gain.

7.24 cited by Ellis (1965) for all-concentrate rations.

There were little differences among average daily gains of the steers receiving the four hybrids in sheltered lots. Average daily feed intake was slightly higher for DeKalb E-57. Steers receiving Acco R-109 and Northrup King 222A required less feed per kg of gain, 6.81 and 6.72 respectively, than DeKalb E-57 which required 7.32 and Funk's G-766W which required 7.96 kg to produce a kg of gain.

Based on the work presented in this study the four hybrid grain sorghums could be ranked as follows: Acco R-109, Northrup King 222A, DeKalb E-57, and Funk's G-766W. Although the differences were not significant, the majority of tests used to compare the four hybrids (table 3, 4, 5, 6) would indicate this rank. Generally Acco R-109 was utilized more efficiently than other hybrids and Funk's G-766W was utilized least efficiently. The first seven days of the trial steers receiving Acco R-109 did not consume as much grain, but after seven days consumption was essentially the same for all hybrids. This would indicate an initial palatability problem to which the cattle rapidly adapted.

Although not significant, data from the present study does indicate differences in nutritional value of different hybrid grain sorghums. Hale et al. (1964) and Riewe (1969) agree that there may be differences in the nutritional value of different hybrid grain sorghums.

Summary

This study was conducted to compare the agronomic characteristics and feedlot performance and carcass traits of steers fed four hybrid grain sorghums. There were significant differences ($P < .05$) in methods of harvesting. Hand harvesting yielded significantly more grain. When field loss was tested by chi-square a significant ($P < .01$) difference was observed between hybrids

which was probably due to Funk's G-766W lodging at harvest time. The four hybrid grains were dry rolled and incorporated into isonitrogenous all-concentrate rations. The rations contained approximately: sorghum grain, 98%; salt, 1%; trace mineral premix, .05%; urea, .5%; limestone, .5%; and 7.8 mg chlorotetracycline and 1,653 IU vitamin A per kg of ration. There were no significant differences in feedlot performance or carcass traits among hybrids when tested by analysis of variance either seperately as non-sheltered (group fed) or sheltered (individually fed) or when the two groups were pooled together. The steers in sheltered lots gained faster and utilized feed more efficiently for production than those in non-sheltered lots. More energy was required for maintenance of steers in non-sheltered lots. There were small differences in average daily gain among steers fed the four hybrids. Feed utilization (kg feed/kg gain) was more efficient for Acco R-109 (6.81) and Northrup King 222A (6.72) than for DeKalb E-57 (7.32) and Funk's G-766W (7.96) with steers in sheltered lots. In non-sheltered lots Acco R-109 was the most efficient (7.84 kg feed/kg gain) and Funk's G-766W was least efficient (9.01 kg feed/kg gain). DeKalb E-57 and Northrup King 222A were intermediate with 8.37 and 8.71 kg feed/kg gain respectively.

These results suggest there may be nutritional differences in hybrid grain sorghums for fattening cattle rations, although differences were not significant in this trial.

LITERATURE CITED

Drake, C. L., V. P. Carlson, P. H. Wilson and D. M. Allen. 1970. White sorghum grain (Funk's G-766W) and elevator-run red sorghum grain compared for fattening cattle. Kan. Agr. Exp. Sta. Bul. 536. p. 38.

Ellis, G. F. 1965. All-concentrate feeding research. Feedstuffs. 37:50.

Hale, W. H., B. Taylor, W. J. Saba, E. K. Keating and K. Palmer. 1964. The value of three varieties of milo compared with steam-rolled barley in a high-grain fattening ration. Ariz. Cattle Feeder's Day Rpt. p. 32.

Lofgreen, G. P. and W. N. Garrett. 1968. Net energy tables for use in feeding beef cattle. University of Calif. Davis, Calif.

Riewe, M. E. 1966. Utilization of several varieties of sorghum grain by sheep. Proc. 21st Ann. Tex. Nutr. Conf. p. 52.

Snedecor, G. W. 1956. Statistical Methods (5th ed.) Iowa State College Press. Ames, Iowa.

Wise, M. B., R. W. Harvey, B. R. Haskins and E. R. Barrick. 1968. Finishing beef cattle on all-concentrate rations. J. Anim. Sci. 27:1449.

Wilson, K. O. 1968. Comparison of the feeding value of Lindsey 765W and 744 sorghum varieties for dairy cows. West Texas State Univ. Agri. Res. Rpt.

Chapter IV

DIGESTIBILITY OF FOUR DIFFERENT HYBRID GRAIN SORGHUMS FOR STEERS

There is a lack of agreement in the literature concerning the effects of different parent varieties on coefficients of digestion (COD). Riewe (1966), Breuer (1966), Breuer _et al_. (1967) reported no significant differences among COD for sheep or cattle with different parent varieties of grain sorghums. McGinty and Riggs (1968) and McGinty (1969) reported significantly ($P < .05$) lower COD for brown seeded parent varieties. With the development of male-sterile types of sorghum in 1956, hybrid grain sorghum has become popular (Watson, 1959). Brewer _et al_. (1967) reported that if lower digestibility was found in parents the hybrid generally showed the same trend. Nishimuta, Sherrod, and Furr (1969) compared waxy and white grain sorghum to regular elevator-run (unknown orgin) and found a significant improvement ($P < .05$) in COD for waxy and white grain. Drake _et al_. (1970), K. S. Eng (personal communication) found an improvement in feed utilization in favor of the white grain in feedlot studies.

This trial was conducted to compare the COD, chemical composition, and mature kernel structure of four hybrid grain sorghums. Three red hybrids (Acco R-109, DeKalb E-57, Northrup King 222A) and one white hybrid (Funk's G-766W) were used. The red hybrids are popular in Kansas and the white hybrid is new but has shown superior feeding qualities in some trials.

Experimental Procedure

Trial 1. Four hybrid grain sorghums were purchased from local farmers in the fall of 1968. The grains were not grown under the same conditions. All were incorperated into isonitrogenous all-concentrate rations (13.02%

protein dry matter basis). The ration contained (table 1) approximately 98.45% sorghum grain, .5% limestone, .5% salt, .05% trace mineral premix, urea .45%, and 1,653 IU vitamin A and 7.8 mg of chlorotetracycline per kg of ration.

Trial 2. A second trial in 1969 was conducted using the same four hybrids. Each was exposed to the same conditions. They were grown under irrigation near Manhattan, Kansas. Planting rate was 7.85 kg/ha (7 lbs/A) on June 9, 1969 in .91 mm (36 in) rows. The field was rotary hoed, sprayed with 2, 4-D, cultivated twice and hilled for irrigation. One-hundred and sixty-eight kg N/ha (150 lbs/A) was applied preplant as anhydrous ammonia with 10 kg N (9 lbs/A), 24.6 kg P_2O_5 (22 lbs/A), 17.9 kg K_2O (16 lbs/A), and 5.6 kg Zn (5 lbs/A) supplied per hectare as starter fertilizer. All hybrids were harvested within three days and incorperated into an all-concentrate, isonitrogenous ration containing 12% protein dry matter basis (table 1). The rations were the same as trial 1 except 1% salt was used and urea levels were different due to different protein contents of the hybrid grains.

Chemical composition. The proximate analysis (A.O.A.C., 1960) of the four hybrid grain sorghums are given in table 2 and amino acid composition in table 3. Seventeen amino acids and ammonia were determined on acid hydrolysates by ion exchange chromatography using an amino acid autoanalyzer. The procedures of Spackman *et al.* (1958) and Moore *et al.* (1958) were used for analysis and samples were hydrolyzed by the procedure of Waggle *et al.* (1966).

Digestion trial procedure. Both digestion trial 1 (table 4) and trial 2 (table 5) were conducted in the same manner. Four Hereford steers that weighed approximately 372 kg for trial 1 and 338 kg for trial 2 were used. Animals and rations were arranged in a 4 X 4 Latin square design (Cochran

TABLE 1. ALL-CONCENTRATE RATIONS

Item	Trial 1	Trial 2
	% of Ration	% of Ration
Sorghum grain[a]	98.45	98.0
Salt	.5	1.0
Limestone	.5	.5
Urea[a]	.45[c]	.5[d]
Trace mineral[b]	.05	.05
Chlorotetracycline mg/kg	7.8	7.8
Vitamin A IU/kg	1653	1653

[a] Grain and urea varied to keep ration isonitrogenous.

[b] Percentages of indicated elements in trace mineral premix: Manganese 4.4%; iron 6.6%; copped 1.32%; cobalt .23%; iodine .30%; zinc 5%; magnesium 20 %; sulfur 2.70%.

[c] Trial 1 rations were made isonitrogenous to 13.02% protein (dry matter basis). Urea added as % of rations: Funk's G-766W, .4%; Acco R-109, .42%; DeKalb E-57, .75%; Northrup King 222A, 0%.

[d] Trial 2 rations were made isonitrogenous to 12% protein (dry matter basis). Urea added as % of rations: Funk's G-766W, .57%; Acco R-109, .62%; DeKalb E-57, .70%; Northrup King 222A, .23%.

TABLE 2. PROXIMATE ANALYSIS OF FOUR HYBRID GRAIN SORGHUMS
DRY MATTER BASIS

Item	Sorghum Hybrid Funk's G-766W	 Acco R-109	 DeKalb E-57	 Northrup King 222A
Dry matter %	84.20	84.84	84.49	84.11
Protein % (Nx6.25)	10.65	10.49	10.17	11.83
Ether extract %	3.26	3.18	2.92	3.20
Ash %	1.54	1.69	1.58	1.58
Crude fiber %	2.03	2.12	1.87	1.87
N-free extract %	82.77	82.52	83.43	81.52
Starch %	77.33	79.04	78.27	76.96
Gross enery Kcal/kg	4572.00	4520.00	4552.00	4585.00

TABLE 3. THE AMINO ACID COMPOSITION OF FOUR HYBRID GRAIN SORGHUMS[a]
DRY MATTER BASIS

	Sorghum Hybrid							
	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
Amino Acid	% of Sam[b]	% of Prot[c]	% of Sam	% of Prot	% of Sam	% of Prot	% of Sam	% of Prot
Lysine	.223	2.10	.230	2.19	.254	2.50	.231	1.96
Histidine	.190	1.79	.227	2.16	.250	2.46	.252	2.13
Arginine	.419	3.93	.393	3.75	.432	4.25	.400	3.38
Aspartic acid	.725	6.81	.743	7.08	.805	7.92	.805	6.81
Threonine	.353	3.32	.360	3.43	.368	3.62	.386	3.25
Serine	.494	4.63	.491	4.68	.511	5.02	.552	4.67
Glutamic acid	2.319	21.77	2.250	21.45	2.263	22.25	2.581	21.82
Proline	.900	8.13	.894	8.53	.863	8.49	1.000	8.45
Glycine	.340	3.19	.344	3.28	.360	3.54	.369	3.12
Alanine	.997	9.36	.971	9.26	.973	9.58	1.114	9.42
Valine	.555	5.21	.508	4.84	.553	5.44	.422	3.57
Methionine	.141	1.33	.145	1.38	.104	1.03	.105	.89
Half cystine	.086	.81	.214	2.04	.119	1.17	.129	1.09
Isoleucine	.390	3.66	.411	3.92	.393	3.86	.458	3.87
Leucine	1.420	13.27	1.383	13.19	1.368	13.46	1.578	13.34
Tryosine	.425	3.99	.419	3.99	.399	3.92	.394	3.33
Phenylalanine	.494	4.63	.550	5.24	.516	5.07	.603	5.10
Ammonia	.229	2.15	.249	2.37	.268	2.64	.295	2.49

[a] Determined by ion exchange chromatography using an amino acid autoanalyzer.

[b] Gm of amino acid per 100 gms of sample.

[c] Gm of amino acid per 100 gms of protein.

TABLE 4. MEANS AND STANDARD ERRORS OF APPARENT COEFFICIENT OF DIGESTION AND NITROGEN BALLANCE OF STEERS FED ALL-CONCENTRATE RATIONS CONTAINING FOUR HYBRID GRAIN SORGHUMS (TRIAL I)

	Sorghum Hybrid							
Item	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
No. steers	4		4		4		4	
Daily dry matter intake kg/day	4.9		4.5		4.6		4.8	
Digestibility[a]								
Protein	62.8	±2.8[b]	62.9	±1.5	66.9	±1.7	60.2	±2.4
Crude fiber	51.1	±4.2	49.8	±2.4	48.2	±4.4	46.9	±2.4
Ether extract	58.2	±4.0	52.8	±6.4	60.3	±2.4	61.3	±6.0
Nitrogen free extract	78.9	±3.6	80.5	±3.1	79.9	±3.0	79.2	±2.8
Dry matter	74.9	±3.4	76.1	±2.6	76.4	±2.8	75.0	±2.6
Total digestible nutrients	75.7	±3.6	76.5	±2.3	76.9	±2.8	75.7	±2.5
Gross energy	73.2	±3.1	73.8	±3.5	69.8	±3.9	71.8	±1.1
Digestible energy Kcal/kg	3378	±37.6	3360	±16.5	3143	±17.3	3273	±10.6
Nitrogen balance[c]								
Fecal	37.3	±2.7	37.1	±1.5	32.8	±1.5	39.8	±3.0
Urinary*	47.8[d]	±4.7	57.9[e]	±6.0	43.0[d]	±2.6	47.5[d]	±4.6
Retention*	15.0[d]	±5.7	5.1[e]	±5.3	21.3[d]	±4.1	12.5[d]	±6.1
Nitrogen retained* gm/day	15.6[d]	±5.9	5.9[e]	±5.8	21.8[d]	±3.2	12.8[d]	±6.5

[a] Percent of intake, coefficient of digestion (COD) as cited in text.
[b] Standard error.
[c] Percent of intake.
[d,e] Any means in the same row with different subscripts is significantly different ($P < .05$).
* F-ratio from analysis of variance indicates significance at $P < .05$.

TABLE 5. MEANS AND STANDARD ERRORS OF APPARENT COEFFICIENT OF DIGESTION AND NITROGEN BALANCE OF STEERS FED ALL-CONCENTRATE RATIONS CONTAINING FOUR HYBRID GRAIN SORGHUMS (TRIAL 2)

	Sorghum Hybrid			
Item	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
No. steers	4	4	4	4
Dry matter intake kg/day	4.7	4.6	4.8	4.8
Digestibility[a]				
Protein	67.8 ±0.9	66.0 ±1.3	65.4 ±2.3	64.4 ±1.6
Crude fiber	46.8 ±5.0	45.4 ±4.9	45.5 ±6.4	41.6 ±9.2
Ether extract	65.2 ±1.6	65.7 ±4.3	67.5 ±2.8	64.3 ±2.0
Nitrogen free extract	81.5 ±2.4	79.8 ±1.9	80.6 ±2.3	82.5 ±1.7
Dry matter	78.3 ±2.0	76.7 ±1.8	77.3 ±2.1	78.7 ±1.5
Total digestible nutrients	78.7 ±2.0	76.9 ±1.9	77.5 ±2.2	78.7 ±1.5
Gross energy	75.5 ±2.1	75.2 ±1.4	75.6 ±2.0	75.8 ±1.5
Starch	87.5 ±2.6	86.8 ±1.0	86.9 ±2.2	88.7 ±2.2
Digestible energy Kcal/kg	3224 ±27.2	3338 ±22.3	3312 ±16.4	3406 ±19.0
Nitrogen balance[b]				
Fecal	32.3 ±1.1	33.9 ±1.4	34.5 ±2.3	35.5 ±1.7
Urinary	39.6 ±3.2	46.1 ±9.4	34.8 ±2.4	37.5 ±5.1
Retention	28.1 ±3.0	20.0 ±1.0	30.7 ±2.2	26.9 ±4.0
Nitrogen retained gm/day	26.7 ±4.0	21.9 ±9.5	30.1 ±4.6	27.2 ±5.6

[a] Percent of intake, coefficient of digestion (COD) as cited in text.
[b] Percent of intake.

and Cox, 1957) for each trial. Over a four week period the steers were adjusted to an all-concentrate ration by gradually removing sorghum silage. Steers were placed in digestion stalls for a 7 day preliminary adjustment period. After the preliminary period the rations were assigned randonly and COD were determined by using a 7 day adjustment period to the ration followed by a 7 day total collection period. Feed intake was held constant at the consumption of the lowest steer, approximately 1.6% of body weight. Excreta were collected daily and a five percent aliquot of feces and urine were obtained for chemical analysis. Fifteen milliliters of toluene were added to each urine collection container daily and 20 milliliters of 50% sulfuric acid were added weekly to urine sample containers to reduce ammonia loss. Fecal samples were frozen daily and each weekly collection was dried to a constant weight at 60° C. Feed and fecal samples were ground in a Wiley mill and the 7 samples per week per ration were mixed thoroughly and subjected to proximate analysis (A.O.A.C. 1960) and oxygen bomb calorimetry. Urine nitrogen was determined by Kjeldahl method (A.O.A.C. 1960).

Starch procedure. The starch determination used in trial 2 (Earle and Milner, 1944) has been used for determination of sorghum grain starch by Jones and Beckwith (1970) and Hubbard, Earle and Curtis (1964). The feces samples were very difficult to filter and the filtrates were turbid so accurate readings through a polarimeter could not be made. The procedure was modified and 98.5% recovery of starch was obtained. Modification involved extracting the fecal samples in absolute ethanol for 48 hours using a soxlet apparatus. This removed the pigments that caused turbidity. The samples were then centrifuged 10 min at 17,500 RPM and the supernatant was filtered. This eliminated the difficult filtering of feces samples. A detailed procedure for starch analysis is presented in appendix table G.

Starch granule size and uniformity (table 6) were determined by wet milling 500 gm samples steeped in .15% SO_2 for 48 hours. Following steeping, samples were wet milled in a Horbart attrition mill with one stationary and one moving plate. Bran and starch were seperated using a silk screen. Kafirin (zein like sorghum protein) was removed after centrifugation and the starch was dried in a forced air oven at 50° C. Starch was dispersed in cold water and measured by using a microscope fitted with a micrometer.

Sectioning. The sorghum grain kernels were steeped 48 to 72 hours at room temperature in .15% SO_2 solution. The kernels were frozen in water and sectioned to 8 microns on a cryostat, stained with dilute iodine solution, and mounted in glycerol (table 7). Photographs were taken with a 35 mm camera mounted on a microscope (plate 1). Data were analyzed by analysis of variance for Latin square design (Snedecor, 1956). Subclass means were tested for significance by Duncan's multiple range test (Kramer, 1956).

Results and Discussion

Trial 1. The apparent COD for Trial 1 are given in table 4. There were no significant differences among COD for protein, crude fiber, ether extract, nitrogen free extract, dry matter, total digestible nutrients, gross energy or digestible energy. Grams of nitrogen retained per day were significantly ($P < .05$) lower for Acco R-109. When expressed as percent of intake, urinary nitrogen loss was higher and nitrogen retention was lower ($P < .05$) for Acco R-109. The last two weeks the steers receiving Acco R-109 were in negative nitrogen balance. These steers lost an average of 11.3 kg weight per week. Tissue breakdown was indicated by a higher percent of urinary nitrogen (57.9).

TABLE 6. MEANS, STANDARD DEVIATION, AND VARIANCE OF SIZE OF STARCH GRANULES WET MILLED FROM FOUR HYBRID GRAIN SORGHUMS

	Sorghum Hybrid			
Item	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
No. starch granules measured	55	55	55	55
Starch granule size, microns	18.23 ±.69	18.25 ±.57	17.65 ±.55	16.70 ±.59
Variance	26.55	18.15	16.44	19.20
Standard deviation	5.15	4.26	4.05	4.38

TABLE 7. APPROXIMATE MEASUREMENT OF THE STRUCTURES OF FOUR HYBRID GRAIN SORGHUMS

	Sorghum Hybrid			
Item	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
Thickness, microns cuticle to epidermis	10	11	11	14
Hypodermis	21	15	14	11
Mesocarp	57	31	9	20
Seed coat	6	8	15	9
Aleurone	10	11	13	8

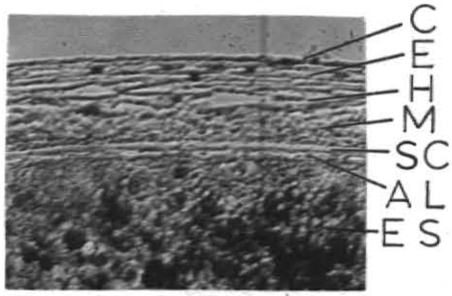
Explanation of Plate I

Hybrid grain sorghum sectioned eight microns thick and stained approximately one minute in dilute iodine solution.

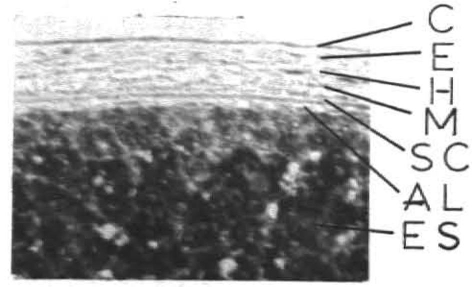
C - Cuticle
E - Epidermis
H - Hypoderm
M - Mesocarp
SC - Seed coat
AL - Aleurone layer
ES - Endosperm

First four small pictures 100X
Large picture 400X

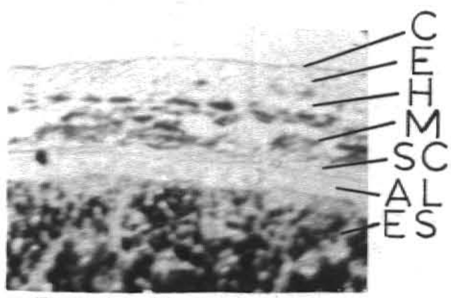
PLATE 1



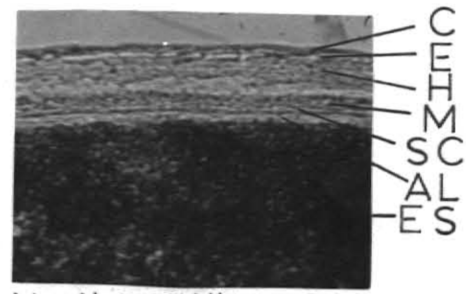
Funk's G-766W



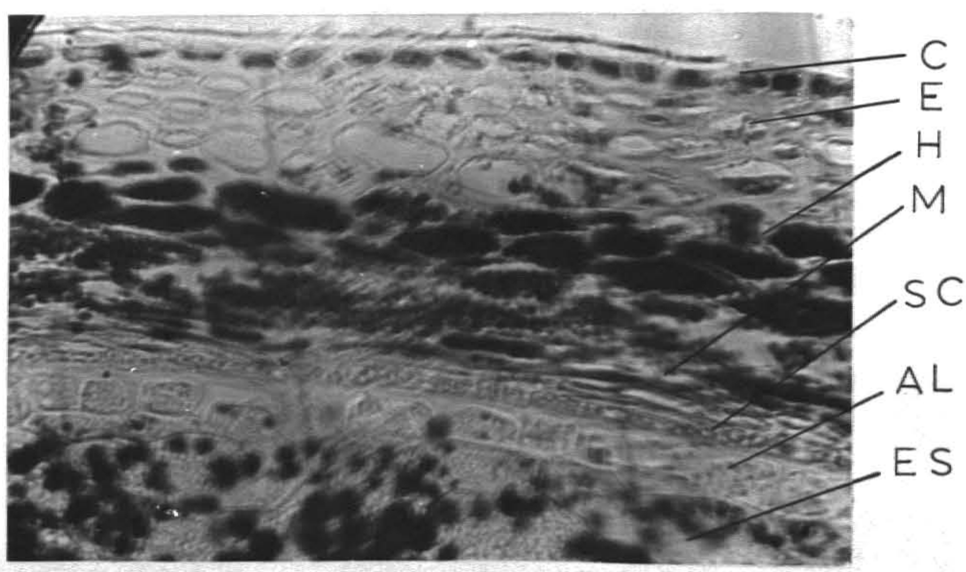
Acco R-109



DeKalb E-57



Northrup King 222A



DeKalb E-57

Differences in protein COD approached significance ($P < .10$). Northrup King 222A had the lowest (60.2) and DeKalb E-57 the highest (66.9) protein COD. This probably occurred because urea was not added to Northrup King 222A and DeKalb E-57 contained .75% urea. In the rumen urea was readily hydrolized to ammonia while sorghum protein was degraded more slowly and was found undigested in the feces. Greathouse (1970) reported 1% urea in an all-sorghum grain diet significantly ($P < .001$) increased protein digestion over an all-sorghum grain diet with no other source of protein added.

Trial 2. COD are reported in table 5. There were no significant differences among COD for proximate analysis fractions, energy, starch or nitrogen balance.

When comparing trial 1 (table 4) and trial 2 (table 5) the results were essentially the same except for nitrogen balance. Older and heavier steers were used in trial 1 and they tended to loose more weight during the collection period than did steers in trial 2. The younger steers used in trial 2 had a higher nitrogen retention indicating more tissue building. Both trials indicated there were no differences in COD between these four hybrid grain sorghums.

Starch size and uniformity. There were no significant differences in the size of the starch granules among the four hybrid grain sorghums (table 6). Hartely's F-max test (Fryer, 1960) indicates no significant difference among variance in size of starch granules. R. G. Hinders (personal communication) states the starch of Funk's G-766W is visibly more uniform than the starch of regular red sorghum grain. This work (table 6) is in disagreement with Hinder's work since Funk's G-766W had the highest variation in starch granule size. Nishimuta et al. (1969) found a significant ($P < .10$) increase in COD for gross energy and nitrogen free extract for the white grain (Funk's G-766W) over the regular red grain sorghum and indicated this increase in digestion may be due to type and uniformity of starch granules.

Mature structure. The structure of the mature kernel of each hybrid was studied and small differences were found (table 7). All hybrids had the same structure present but were different in cell size and thickness. Swanson (1928) states the color of sorghum grain is due to pigments in the nucellar layer (seed coat) and in epidermis and hypodermal cells, the outer two layers of the pericarp. The coloring pigments of seed coat may be covered up by a thick mesocarp which contains starch. The outer two layers may or may not contain coloring pigments. He also states that some varieties may have a very thin mesocarp and the coloring of the mature kernel is due to the red-brown pigments in the seed coat (nucellar) layer. This is indicated with DeKalb E-57 whose kernels were the darkest red-brown in color of all hybrids. The mesocarp was 9 microns thick and seed coat 15 microns. Funk's G-766W which is a chalky white in color had the thickest mesocarp, 57 microns. The chalky white color was probably due to starchy material in the mesocarp.

Amino acids. The amino acid data (table 3) indicates there were no large difference in composition among hybrid grain sorghums except for half cystine. Acco R-109 contained almost twice as much half cystine as the other three hybrids. Acco R-109 was not consumed as readily as the other three hybrids at the beginning of the digestion trials or the feeding trials.

Summary

This study was conducted to compare the coefficients of digestion (COD), chemical composition and mature kernel structure of four hybrid grain sorghums. The grains were incorperated into all-concentrate, isonitrogenous rations

for trial 1 (13.02% protein dry matter basis) and for trial 2 (12% protein dry matter basis). The rations contained approximately 98.45% sorghum grain, .5% limestone, .05% trace minerals premix, .5% salt and 1653 IU vitamin A and 7.8 mg of chlorotetracyline per kg ration.

COD were determined using a 4 X 4 Latin square design with a 7 day total collection method used for both trials. The kernels were sectioned 8 microns thick and examined with a microscope. The starch was wet milled and measured with a microscope fixed with a micrometer.

For trial 1 and 2 there were no significant differences among COD for proximate analysis fractions, energy or starch. In trial 1 Acco R-109 had a significantly higher ($P < .05$) urinary nitrogen loss expressed as percent of intake. Nitrogen retained (gm/day) and nitrogen retained (% of intake) were significantly ($P < .05$) less for Acco R-109. The steers receiving Acco R-109 lost 11.3 kg weight per week, and were in negative nitrogen balance the last two weeks of trial 1. There were only small differences among hybrids in amino acid composition, except for half cystine. Acco R-109 was twice as high in half cystine content as other hybrids. Acco R-109 was not consumed as readily the first seven days of the trial as the other hybrids.

The average starch granule size of the four hybrids was essentially the same and not significantly different. The variation in size of the starch granules were not significantly different. Funk's G-766W (white) had the thickest mesocarp 57 microns and DeKalb E-57 had the thinest 9 microns. There were other small differences in makeup among hybrids.

These results indicate there were no differences in COD of the proximate analysis fractions, energy, or starch among the four hybrid grain sorghums when fed as an all-concentrate ration under these conditions.

LITERATURE CITED

A.O.A.C. 1960. Official methods of Analysis (9th Ed.). Association of Official Agricultural Chemists. Washington, D.C.

Breuer, L. H. 1966. Utilization of several varieties of grain sorghum by cattle and rats. Proc. 21st Ann. Tex. Nutr. Conf. p. 94.

Breuer, L. H., M. C. Riewe, J. K. Smith, C. K. Dohme, T. M. Taylor, and J. C. Harper. 1967. Sorghum grain utilization research. Proc. 22nd Ann. Tex. Nutr. Conf. p. 215.

Cochran, W. G. and G. M. Cox. 1967. Experimental Designs. John Wiley and Sons. New York.

Drake, C. L., V. P. Carlson, P. H. Wilson and D. M. Allen. 1970. White sorhum grain (Funk's G-766W) and elevator-run red sorghum grain compared for fattening cattle. Kan. Agr. Exp. Sta. Bul. 536. p. 38.

Earle, F. R. and R. T. Milner. 1944. Improvements in determination of starch in corn and wheat. Cereal Chem. 21:567.

Fryer, H. C. 1960. Concepts and Methods of Experimental Statistics. Allyn and Bacon, Inc., Boston.

Greathouse, G. A. 1970. Effects of levels and sources of protein on preformance and carcass characteristics of steers fed all-concentrate rations. M.S. Thesis. Kansas State University, Manhattan, Kansas.

Hubbard, J. E., F. R. Earle and J. J. Curtis. 1964. Composition of commercial grades of corn, oats and grain sorghum. Agri. Res. Services USDA Pub. ARS-71-32. Northern Util. Res. Lab.

Jones, R. W. and A. C. Beckwith. 1970. Proximate composition and proteins of three grain sorghum hybrids and their dry-mill fractions. Agri. and Food Chem. 18:33.

Kramer, C. Y. 1956. Extension of multiple range tests to group means with unequal number of replication. Biometrics 12:307.

McGinty, D. D. 1969. Variation in digestibility of sorghum varieties. Proc. Grain Sorghum Res. and Util. Conf. p.20.

McGinty, D. D. and J. K. Riggs. 1968. Variation in digestibility of sorghum grain varieties. J. Anim. Sci. 27:1170 (Abstr.).

Moore, S. D., Spackman and W. H. Stein. 1958. Chromatography of amino acids on sulfonated polystyrene resins (an improved system). Anal. Chem. 30:1185.

Nishimuta, J. F., L. B. Sherrod and R. D. Furr. 1969. Digestibility of regular, waxy and white sorghum grain rations by sheep. Proc. Western Sect. Am. Soc. Anim. Sci. 20:259.

Riewe, M. E. 1966. Utilization of several varieties of sorghum grain by sheep. Proc. 21st Ann. Tex. Nutr. Conf. p.89.

Snedecor, G. W. 1956. Statistical Methods. (5th Ed.). Iowa State College Press, Ames, Iowa.

Spackman, K. H., W. H. Stine and S. Moore. 1958. Automatic recording apparatus for use in the chromatography of amino acids. Anal. Chem. 30:1190.

Swanson, A. F. 1928. Seed coat structure and inheritance of seed color in sorghums. J. Agr. Res. 37:577.

Waggle, D. H., D. B. Parrish and C. W. Deyoe. 1966. Nutritive value of protein in high and low protein content sorghum grain as measured by rat performance and amino acid assay. J. Nutr. 88:370.

Watson, S. A. 1959. The present importance and bright future of grain sorghum. Cereal Sci. Today 4:231.

APPENDIX

APPENDIX TABLE A

AGRONOMIC PERFORMANCE DATA OF FOUR HYBRID GRAIN SORGHUMS (SUMMER 1969) DRY MATTER BASIS

Item	Sorghum Hybrids Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
Acres/field	6.2	7.8	9.3	6.3
Lbs/field	32,835.	43,689.	48,866.	32,835.
Test wt, lbs/bu (moisture basis)	59.5	59.5	60.5	59.5
Actual yield, bu/A* 56 lbs/bu	80.9	99.2	93.2	92.5
Dry matter %	85.0	84.8	85.0	85.0
Expected yield, bu/A[a*] 56 lbs/bu	99.9	114.8	102.9	96.2
Field loss, bu/A**	19.1	15.6	9.6	3.6
Field loss %	19.1	13.6	9.3	3.7
Avg leaves/plant	8 to 9	8 to 10	9 to 11	7 to 8
Mature plant height, in	54 to 58	51 to 53	52 to 55	49 to 52

* F-ratio of analysis of variance indicates significance ($P < .05$) between methods of harvesting.

** Chi-square indicates significance ($P < .01$) between field loss.

[a] Expected yield = grain harvested by hand from 20 ft of 36 in row
Calculation = expected yield
43.56 sq ft/A, 60 sq ft or .00138 of an acre
1 ÷ .00138 = 726.005
726.005 ÷ 56 lbs/bu = 12.964
12.964 X lbs of grain/20 ft = expected bu/A

APPENDIX TABLE B

ALL-CONCENTRATE RATIONS
FOR DIGESTION TRIALS

Item	Trial 1 Lbs/ton	Trial 2 Lbs/ton
Sorghum grain [a]	1970.44	1959.5
Limestone	8.44	8.5
Trace mineral premix[b]	1.00	1.0
Salt	10.00	20.00
Chlorotetracycline premix (10 gm/lb)	.8 (363.2 gm)	.71 (322.8 gm)
Vitamin A premix (10,000 IU/gm)	.32 (151 gm)	.33 (150 gm)
Urea[a]	9.00[c]	10.00[d]

[a] Grain and urea varied to keep ration isonitrogenous.

[b] Percentages of indicated elements in trace mineral premix: Manganese 4.4%; iron 6.6%; copper 1.32%; cobalt .23%; iodine .30% zinc 5%; magnesium 20%; sulfur 2.70%.

[c] Trial 1 rations were made isonitrogenous to 13.02% protein (dry matter basis). Urea added as % of rations: Funk's G-766W, .4%; Acco R-109, .42%; DeKalb E-57, .75%; Northrup King 222A, 0%.

[d] Trial 2 rations were made isonitrogenous to 12% protein (dry matter basis). Urea added as % of rations: Funk's G-766W, .57%; Acco R-109, .62%; DeKalb E-57, .70%; Northrup King 222A, .23%.

APPENDIX TABLE C

PERFORMANCE AND CARCASS DATA OF STEERS FED ALL-CONCENTRATE RATIONS CONTAINING FOUR HYBRID GRAIN SORGHUMS (WINTER 1969-1970) DRY MATTER BASIS

Item	Sorghum Hybrids							
	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
Feedlot data								
No. steers	15		14[a]		15		15	
Avg initial wt, lbs	765	±10.25[b]	760	±9.02	772	±10.56	758	±8.60
Avg final wt, lbs	1042	±20.26	1051	±20.16	1059	±23.90	1024	±23.30
Avg daily gain, lbs	2.25	±0.14	2.34	±0.15	2.21	±0.12	2.15	±0.17
Avg daily feed intake, lbs	16.96	±1.12	16.82	±0.82	18.06	±0.82	16.32	±0.61
Avg lbs feed/ lb gain[c]	8.48	±0.81	7.08	±0.80	7.93	±0.81	7.47	±0.80
Carcass data								
Avg hot carcass wt, lbs	648	±12.24	605	±15.37	660	±16.21	629	±17.08
Avg rib-eye area, sq in	12.72	±0.25	12.31	±0.25	12.56	±0.20	12.44	±0.30
Avg fat over rib-eye, in	.40	±0.03	.40	±0.03	.40	±0.03	.37	±0.04
Avg carcass grade[d]	10.05	±0.30	10.16	±0.31	10.34	±0.25	10.26	±0.37
Avg yield grade[e]	2.43	±0.14	2.58	±0.14	2.46	±0.11	2.27	±0.16
Avg marbling score[f]	15.10	±0.71	15.02	±0.73	15.53	±0.58	15.31	±0.87

[a] One steer crippled in lot and had to be removed.
[b] Standard error.
[c] Figured by using 2 group fed lots as 2 observations plus 5 individually fed observations, a total of 7 observations.
[d] High good = 9; low choice = 10.
[e] 1 = most desirable; 5 = least desirable.
[f] Small = 14; modest = 17.

APPENDIX TABLE D

PERFORMANCE DATA OF NON-SHELTERED (GROUP FED) AND SHELTERED (INDIVIDUALLY FED) STEERS ON ALL-CONCENTRATE RATION (WINTER 1969-1970) DRY MATTER BASIS

Item	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
Non-sheltered lots (Sorghum Hybrid)								
No. steers	10		9[a]		10		10	
Avg initial wt, lbs	767	±4.63	759	±3.68	771	±4.18	756	±3.68
Avg final wt, lbs	1055	±5.32	1044	±3.34	1046	±8.87	1004	±8.54
Avg daily gain, lbs	2.29	±0.14	2.25	±0.78	2.19	±0.48	1.97	±0.61
Avg daily feed intake, lbs	20.67	b	17.64		18.21		16.95	
Avg lb feed/ lb gain	9.01		7.84		8.37		8.71	
Sheltered lots								
No. steers	5		5		5		5	
Avg initial wt, lbs	762	±7.28	764	±4.14	775	±3.08	762	±3.83
Avg final wt, lbs	1014	±13.09	1069	±8.28	1085	±6.37	1063	±4.13
Avg daily gain, lbs	2.00	±0.71	2.42	±0.28	2.46	±0.75	2.39	±0.24
Avg daily feed intake, lbs	15.48	±0.76	16.49	±1.05	18.01	±0.38	16.07	±0.48
Avg lb feed/ lb gain	7.96	±0.69	6.81	±0.14	7.32	±0.68	6.72	±0.61

[a] One crippled in lot and had to be removed.
[b] Standard error left off, only 2 observations.

APPENDIX TABLE E

PREDICTION OF AVG DAILY GAIN OF SHELTERED AND NON-SHELTERED LOTS BY NET ENERGY[ab]

Item	Sorghum Hybrids							
	Funk's G-766W		Acco R-109		DeKalb E-57		Northrup King 222A	
	N-S[c]	S[c]	N-S	S	N-S	S	N-S	S
No. steers	10	5	9[d]	5	10	5	10	5
Mid wt lbs	911	888	901	917	908	930	893	913
Avg daily feed, lbs	23.23	19.19	19.40	18.14	20.03	19.81	19.99	17.67
Lbs grain for NE_m	8.19	8.04	8.11	8.25	8.20	8.32	8.05	8.20
Lbs grain left for production	14.54	11.15	11.29	9.89	11.83	11.49	11.94	9.47
Megcal for production	8.43	6.46	6.55	5.74	6.86	6.66	6.92	5.49
Expected avg daily gain, lbs	3.15	2.60	2.62	2.30	2.70	2.60	2.80	2.20
Observed avg daily gain, lbs	2.29	2.00	2.25	2.42	2.19	2.46	2.12	2.39
Differences in avg daily gain, lbs	-.86	-.60	-.37	+.12	-.71	-.24	-.68	+.19

Avg of four treatment observed - expected avg daily gain
non-sheltered lots = -.65 lbs
sheltered lots = -.13 lbs

[a] Lofgreen and Garrett's (1968) Net Energy Tables For Use In Fattening Beef Cattle.

[b] Sorghum grain NE_m = .87 megcal/lb
NE_p = .58 megcal/lb

[c] N-S = non-sheltered lots, S = sheltered lots.

[d] One steer crippled in pen and had to be removed.

[e] Observed avg daily gain - expected avg daily gain.

APPENDIX TABLE F

TEST WEIGHT POUNDS PER BUSHEL OF WHOLE AND DRY ROLLED GRAIN FROM STORAGE BINS AS IS MOISTURE

Item	Sorghum Hybrids			
	Funk's G-766W	Acco R-109	DeKalb E-57	Northrup King 222A
Whole grain lbs/bu	58.75	61.25	60.00	59.50
Dry rolled rations lbs/bu	50.50	52.50	52.00	53.00

APPENDIX TABLE G

STARCH PROCEDURE IN DETAIL

All solutions were made as described by Earle and Milner (1944).

1. Samples finely ground
2. 1.3 to 1.5 gm put in filter paper and placed in paper thimble
3. Extracted in soxlet apparatus for 48 hrs
4. Dry sample put in tared 250 ml beaker
5. 10 ml distilled H_2O added to wet the sample
6. 70 ml $CaCl_2$ solution added
7. Bring to boil in 10 min
8. Boil 20 min
9. $CaCl_2$ solution was added to keep volume constant while boiling
10. Cool to room temperature
11. 5 ml uranyl acetate solution added
12. Brought to 100 ml volume by weight with $CaCl_2$ on analytical balance
13. Centrifuged 10 min at 17,500 RPM
14. Filtered into fluted No. 4 Whatman filter paper
15. First 15 ml discarded, remainder filtered into clean flask
16. Optical rotation determined by polarimeter and a Na light source
    1 dcm tube
17. Percent starch dry matter basis = $\frac{\text{observation rotation} \times 100 \times 100 \times 100}{1 \times 203 \times \text{sample wt} \times \text{\% dry matter}}$

    1 dcm is tube length
    203 specfic rotation for corn and sorghum starch

Note: The procedure was followed as outlined for both grain and feces, except grain samples were not subjected to steps 3 and 13.

FEEDLOT COMPARISONS AND DIGESTIBILITY OF FOUR HYBRID GRAIN SORGHUMS FOR BEEF CATTLE FED ALL-CONCENTRATE RATIONS

by

RICHARD LEE MCCOLLOUGH

B. S., Kansas State University, 1968

AN ABSTRACT OF A MASTER'S THESIS

Submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Animal Science and Industry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1970

Two digestibility trials and one fattening trial were conducted to determine the effect four different hybrid grain sorghums had on digestibility, feedlot performance and carcass characteristics when fed an isonitrogenous all-concentrate ration. The four hybrids were Funk's G-766W(white over yellow endosperm), Acco R-109(red over yellow endosperm), DeKalb E-57(red) and Northrup King 222A(red over yellow endosperm).

The two digestibility trials were conducted in the same manner. Four Hereford steers (350 kg) were used in a 4 X 4 Latin square design and a seven day total collection method was used. Results showed there were no significant differences in coefficients of digestion (COD) for proximate analysis fractions, energy or starch among the four hybrids. In trial 1 Acco R-109 had a higher urinary nitrogen loss ($P < .05$) and less nitrogen retained ($P < .05$) than the other hybrids. In trial 2 there were no differences in nitrogen balance among hybrids. The mature kernel structure was examined by microscope. Only small structural differences were found among the four hybrids. DeKalb E-57 had the thinnest mesocarp (9 microns) and Funk's G-766W had the thickest (57 microns).

In trial 2 the same four hybrids were grown under similiar conditions, dry rolled and incorperated into isonitrogenous, all-concentrate rations used to conduct a 126 day fattening trial. During the winter of 1969-1970 sixty Hereford steers (346 kg) were randomly alloted by weight into four treatments. Ten head were group fed (non-sheltered) and five head individually fed (sheltered) for each hybrid. There were no significant differences in feedlot performance or carcass traits of steers due to hybrids. Steers in sheltered lots gained faster and utilized feed more efficiently for production than those in non-sheltered lots.

Although the differences were not significant, a trend was noticed among hybrids. Feed utilization (kg feed/kg of gain) was better for Acco R-109 (7.08) and Northrup King 222A (7.47) than for DeKalb E-57 (7.93) or Funk's G-766W (8.48). Average daily gain was variable among hybrids but differences were not significant.