INFLUENCE OF RATION GRAIN CONTENT ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS

By

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ABSTRACT

INFLUENCE OF RATION GRAIN CONTENT ON FEEDLOT PERFORMANCE AND CARCASS CHARACTERISTICS

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Corn Plot Studies

Two trials were conducted to determine the effect of ration grain content on feedlot performance and carcass characteristics of growing and finishing beef cattle. The percent grain in the corn silage dry matter was varied by planting corn at different plant populations. In trial 1, corn silage was harvested from plant populations of 24,709, 49,419 and 74,128 plants/hectare or from high oil or brown midrib corn. Grain percent was highest at the 24,709 plant population (48.9%) and was reduced to 27.4% when the population was increased to 74,128. The percent grain in the high oil and brown midrib plants were 8.7% and 15.0% lower than the normal population. Dry matter yield increased 11.3% between the 24,709 and 49,419 populations; no further increases were found at the 74,128 population.

In the second trial, corn silage was harvested from plant populations of 24,709, 49,419 or 123,548 plants/hectare. Grain percent was highest for the 24,709 (53.8%) and was reduced to 36.9% when the populations were increased to 123,548. Dry matter yield fell 5.3% between the 24,709 and 49,419 population; there was a 37.8% increase between 49,419 and 123,548 population.

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Feeding Studies

The effect of ration grain content on feedlot performance was studied when 160 steers were fed in a two-year feeding trial. Average daily gains increased and feed required per unit gain decreased as the percentage of grain in the ration increased ($P < .01$). Steers fed all silage rations increased in gain by 17.4% (.99 vs .82 kg) and feed efficiency was improved 12.3% (8.38 vs 9.55) as silage grain content was increased from 30% to 50%. Steers fed a high concentrate ration with 90% grain gained 6.6% faster (1.24 vs 1.16 kg) and required 16% less feed per unit gain (6.05 vs 7.22) than those fed 70% grain. Ration grain content influenced DE, NE_m and NE_g values ($P < .05$). Net energy for gain was 8.9% lower than predicted when the ration contained 70% grain.

Carcass characteristics were adjusted to an equal carcass weight and the percentage of grain in the ration influenced carcass fat, fat thickness and dressing percent ($P < .05$). Maturity, marbling, quality grade, yield grade, ribeye area and kidney, heart and pelvic fat were not influenced by ration grain content.

Steers fed on a two-phase system had similar gains (1.09 vs 1.10 kg) but improved in feed efficiency by 6.5% (6.80 vs 7.27) when compared to those receiving a constant percent grain ration. Steers fed on the two-phase system had a larger ribeye area and a lower yield grade ($P < .0005$).

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Economic Analysis

As the ration grain content was increased from 30% to 100%, cost of feeding, manure handling and storage were reduced by 5.9¢ per day (22.1¢ vs 16.2¢) but the manure credit increased by 1.19¢ per day (4.06¢ vs 2.87¢). The resultant net cost per day was 4.71¢ higher (18.09¢ vs 13.38¢) for the cattle receiving all silage.

Corn silage was priced such that it yields the same net return per acre as corn grain. At $2.00 per bushel corn, prices are $15.52 and $14.90 per ton for silage containing 47% and 30% grain, respectively.

Steers fed on the high concentrate system had a clear advantage at $2.00 per bushel corn over the all silage ration containing 50% grain. But, at $2.75 per bushel corn the all silage ration with 50% grain had an advantage. The two-phase system was competitive with the high concentrate ration at $2.00 corn and is competitive with the all silage system at $3.50 corn.

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INTRODUCTION

Corn silage is the principal source of forage in beef cattle rations in the midwest. Thirty-five to 40% more energy can be grown/acre when corn is harvested as silage than as grain. Corn varieties and plant population have a strong influence on the ear-stover ratio and energy production. Corn variety alone may alter the ear-stover ratio from 25% to 64% (Rossman *et al.*, 1975). Further, weather and plant population influence the ear to stover ratio. Currently only one energy value is listed in the NRC "Nutrient Requirements of Beef Cattle" (NRC, 1976). Studies are needed to identify the net energy value of corn silage as influenced by the ear-stover ratio.

Net energy value of a feed may vary due to the percent grain in the ration and the associative effects present in mixed rations. The associative effect of feedstuffs occur due to a change in digestion and metabolism of nutrients as a result of the incorporation of a feed ingredient into a ration containing one or more other ingredients. This effect occurs particularly when grains and roughages are mixed together in an animal's diet. Thus, the net energy value of an individual feedstuff is variable depending upon the ingredient proportion in the ration. Studies are needed to determine the net energy of rations with varying increments of corn grain added to beef cattle diets.

LITERATURE REVIEW

The Influence of Plant Population on Corn Plant Composition

Wurster (1972) reported that the approximate dry matter distribution of various components of the corn plant are grain, 46%; stalk, 23%; leaves, 11%; cob, 11% and husk, 9%. Average composition of the corn silage components were reported by Vetter (1973) and is described in Table 1. Alterations in the ear-stover ratio by plant population or harvesting at various stages of maturity levels will influence the crude protein, acid-detergent fiber, dry matter digestibility and subsequent net energy value of corn silage rations. The relative dry matter distribution of various plant components when harvested at various stages of maturity was reported by Ayres and Buchele (1971) and is summarized in Table 2. When corn silage was harvested at various stages of maturity or when stressed by increased plant populations, there is an alteration in the dry matter distribution of the various plant components.

As the corn population increases per hectare, the average grain yield of the individual plant significantly decreases (Duncan, 1958; Colville *et al.*, 1966; Lutz *et al.*, 1971; Stivers *et al.*, 1971). An increase in corn plant population from 9,884 to 59,303 plants/ha resulted in a reduction of ear weight from .32 to .13 kg. The average ear weight of .24 kg was secured at 29,652 plants/ha which corresponded

Table 1. Composition of Corn Silage Components (Vetter, 1973)[a]

Plant components	% Crude protein	% Acid-detergent fiber	*In vitro* digestible dry matter
Grain	10.2	--	91
Leaf	7.0	37.0	58
Husk	2.8	41.6	68
Cob	2.8	42.8	60
Stalk	3.7	48.2	51

[a]Average percentage composition.

Table 2. Relative Distribution of Total Dry Matter in the Corn Plant[a] (Ayres and Buchele, 1971)

	Kernel moisture %				
Plant part	40	35	30	25	20
Grain	38.4	42.4	46.4	50.5	54.5
Stalk	27.7	25.1	22.5	19.9	17.2
Leaf	15.1	13.2	11.3	9.4	7.5
Cob	11.0	11.1	11.3	11.5	11.7
Husk	7.8	8.1	8.5	8.5	9.1

[a]Predicted values by linear regression analysis.

to the highest dry matter yield (Lang et al., 1956; Lutz et al., 1971). Stivers et al. (1971) reported that average grain yields at 69,000 plants/hectare were 2.3% lower than that with 54,000 population. The amount of dry grain produced per plant and the ratio of dried shelled grain to total dry matter decreased as the plant population increased (Fairbourn et al., 1970 and Lutz et al., 1971).

In a number of studies, however, increases in corn plant population consistently increased dry matter production per hectare (Wasko and Kjelgaard, 1966; Rutger and Crowder, 1967; Lutz and Jones, 1969; Robinson and Murphy, 1972). In these studies corn silage dry matter yields increased linearly with increased population up to 98,839 plants/hectare. Alexander et al. (1963) found that increasing the plant population from 16,679 to 33,358 plants/ha increased yield of dry matter by 47.9%. Fairbourn et al. (1970) found similar increases in dry matter yield when corn plant populations were increased from 21,000 to 44,970 plants/hectare. Rutger and Crowder (1967) and Stivers et al. (1971) reported a 4.0% to 6.0% increase in total dry matter yield when plant populations increased from 49,419 to 86,485 plants/hectare.

Most studies have shown however that the percent grain in the dry matter is reduced when the plant population is increased. The energy value of corn silage likely varies due to varying grain content and ear-stover ratio. Duncan (1958), Rutger and Crowder (1967) and Fairbourn et al. (1970) reported a reduction in the amount of grain per plant as corn plant populations increased. As plant populations increased from 49,000 to 86,000 plants/ha ear content was reduced by 10% (Cummins and Dobson, 1973). In this study, there was also a 5% increase in stalk content. Bryant and Blaser (1968) however, noted only a slightly altered ratio of ear, stalk and leaves to whole plant weight when plant populations were increased from 39,000 to 98,000 plants/hectare. Similar results were reported by Robinson and Murphy (1972), who found no significant change in the ratio of forage to grain yield in populations ranging from 29,500 to 98,800 plants/ha.

Increasing plant populations and thus reducing the grain content results in lowering of the percentage of proximate constituents in corn silage. Lang et al. (1956) reported a significant decline in protein content of corn grain from 11.8% to 9.8% when plants/ha were increased from 9,880 to 59,300. Alexander et al. (1963) compared 41,215 to 82,430 plants/ha and found a reduction in protein content in the whole corn plant from 7.2% to 6.0%. Holter and Reid (1959) and Huber et al. (1965) reported that higher plant populations resulted in decreased protein digestibility, but results were not significant. High plant populations, however, increased levels of digestible energy, total digestible nutrients and crude protein by 40%, 42% and 27%, respectively.

Lodging and stalk barrenness also contributes to altered ear-stover ratios when plant populations were increased. There were also increases shown in plant height and stalk breakage with increases in plant population. Lang et al. (1956) reported a 2 to 3% stalk barrenness at 29,650 and up to 15% at 59,000 plants/hectare. Giesbrecht (1969) found that 3% of the stalks were barren at 29,650 plants and increased to 15% at 75,000 plants/hectare.

The Feeding Value of Brown Midrib and High Oil Corn Silage

The grain and the soluble non-cell wall fraction of the plant (Van Soest and Wine, 1967) is nearly 98% digestible. However, the lignin content within the plant cell walls inhibits the digestibility and utilization of cellulose and hemicellulose in microbial fermentation. Thus, the amount of lignin content of a feedstuff has a direct effect upon its digestibility, intake and energy utilization in the ruminant animal.

Investigations in the production of low lignin corn plant were first conducted by Kuc and Nelson (1964) and Gee *et al*. (1968). In these studies it was discovered that brown midrib mutant genotypes produced corn plants with lowered lignin content in the vegetative portion of the plant. Brown midrib mutants are identified by the brown pigment in the midrib of the leaf blade, stem tissue and cob. Muller *et al*. (1971, 1972) found a 40% reduction in lignin content in brown midrib corn plants as compared to normal inbred lines. Studies have shown that low lignin corn has a 7% to 9% increase in *in vitro* dry matter disappearance (Barnes *et al*., 1971; Muller *et al*., 1972). Lechtenberg et al. (1972; 1974) reported an increase in *in vitro* dry matter disappearance in the stem, leaf blade, leaf sheath, husk, tassel and cob of 10.4, 11.0, 7.0, 15,0, 17.7 and 12.7 percent, respectively, for brown midrib corn plants over normal corn (Table 3). There was also a 35 to 60% increase in the rate of cell wall and cellulose disappearance.

Table 3. *In Vitro* Dry Matter Disappearance of Various Plant Components (Lechtenberg et al., 1972)

Genotype	Stem	Leaf blade	Leaf sheath	Husk	Tassel	Cob	Grain
BM_1, %	46.4	58.2	55.5	72.6	45.4	55.6	90.2
BM_2, %	52.1	60.4	53.9	73.2	48.5	55.1	91.5
BM_3, %	60.8	69.0	62.9	80.7	62.0	63.5	92.5
Normal, %	50.4	58.0	55.9	68.6	44.3	50.8	90.5

Muller et al. (1972) and Colenbrander et al. (1977) evaluated the digestibility, intake and feeding value of brown midrib corn silage. Lowered lignin content accounted for an increase of 15% digestibility of dry matter, total fiber, cellulose and hemicellulose. Similar results were shown in a feeding trial with cattle when Colenbrander et al. (1973, 1975) obtained significant improvement in average daily gains, feed efficiency and dry matter intake for brown midrib corn stover silage when compared to normal corn stover silage. The increase in performance appeared to be due to increased levels of energy through higher levels of intake and digestibility. These results are supported by the work of Stallings et al. (1977) who found an increase in dry matter digestibility of 9.1% (61.5 vs 56.5%) and 9.3% (70.9 vs 64.3%) in sheep digestion trials.

In another study, Colenbrander et al. (1977) fed 48 Hereford steers the following rations: (A) normal corn silage; (B) brown midrib corn silage; (C) normal silage plus 30% added corn; and (D) brown midrib silage plus 30% added corn. For the steers fed the all silage rations, those fed brown midrib gained 8.2% faster (.98 vs .90 kg) and required 12.7% less feed per unit of gain (5.36 vs 6.14) than those fed normal silage. Steers fed brown midrib plus added corn had similar gains and feed efficiency when compared to those fed normal silage plus corn. Thus, when brown midrib silage is fed without additional grain, performance is increased due to increased digestibility. When grain is added, the effect of the lower lignin content in brown midrib silage is reduced.

In another attempt to improve the nutritive value of corn silage, crop geneticists developed a high oil corn variety. The high oil corn improves the energy content by increasing the oil content in the grain portion of the plant. Several investigators have reported an increase of oil content in the kernel (Brunson et al., 1948; Leng, 1967). The oil content of 4.7% in normal corn may be increased to 7 to 13% by the result of selection (Schneider et al., 1952; Welch, 1969). Selection for high oil content also increased the proportion of germ in the kernel by 61%. Geneticists have shown improvements of oil content in the corn grain by increasing the ratio of germ weight to endosperm weight. Lang et al (1956) also reported that the percent oil in the grain increases as the corn plant population decreases. The grain in the normal corn variety contained 4.23% oil when corn population was 59,280 plants/hectare but increased to 4.58% at 9,9880 plants/hectare.

McCollough et al. (1972) fed steers in a 126 day feeding trial to determine the feedlot performance of different sorghum and corn varieties. Average daily gain and feed efficiency for the steers were: high oil corn (.78, 8.96) and regular corn (.95, 7.75). The steers fed the high oil corn had reduced gains (17.9%), poorer feed efficiency (13.5%) and reduced dry matter intake (2.1%). High oil fed steers had less fat thickness, reduced marbling and lower quality grades but had a more desirable yeild grade. Cost/cwt. gain was 13.5% higher for the high oil fed steers.

Prediction of Feedlot Performance from Laboratory Analysis of Feedstuffs

Accurate prediction of the energy value of feedstuffs is necessary for accurate formulation of feedlot rations. Studies have indicated that a decline in digestibility of fiberous components in feedstuffs is directly related to changes in cell wall digestibility. The cell wall includes cellulose, hemicellulose and lignin. The lignin within the cell wall is indigestible and protects the cellulose from digestion. It appears to be a major factor in reducing intake and digestibility of high forage rations.

As cell wall constitutents or crude fiber increases, the ratio of net energy to total digestible nutrients declines (Van Soest, 1973). "Associative effects" pose a problem in the estimation of net energy values through chemical analysis of feedstuffs. When various levels of concentrate are added to a forage ration there tends to be a decline in cell wall digestibility and net energy value.

Van Soest (1971) formulated a system for estimating the net energy value of a ration by determination of the digestible dry matter (DDM) and total digestible nutrients (TDN) from chemical analysis of feedstuffs, as follows:

$$TDN\ (\%) = DDM = Total\ Ash + Silica + 1.25\ Ether\ Extract + 1.9$$

$$NEm\ (Mcal/Kg) = .029\ TDN\ (\%) - 0.29$$

$$NEg\ (Mcal/Kg) = .029\ TDN\ (\%) - 1.01$$

This system more adequately estimates the net energy value of high roughage rations than does the TDN system. It was concluded, however, that a constant value of 70% TDN should be used for all corn silages.

In contrast, Schmid et al. (1975) reported that the digestibility of corn silage varied from 56 to 70% and sorghum silage from 45.1 to 65.8% when 23 various silages were fed to sheep. Regression equations were developed for predicting average daily gains from digestible dry matter intake (DDMI):

$$ADG\ (g) - 38.44 + .209\ DDMI\ (kg).$$

Agronomic characteristics of the corn silages were also correlated with quality measurements. The percent leaves were highly correlated with ADF (0.90) and average daily gain (-0.68). The percent ears were also correlated with ADF (-0.87) and gain (0.68). Dry matter yield had a relatively low correlation with dry matter intake (-0.15) and average daily gain (-0.26). Taller and higher yielding corn silage had a higher percent of leaf and stalk while early maturing, shorter corn had a higher percentage of ears and improved animal performance.

Marten et al. (1975) measured the quality of 25 corn and 26 sorghum silages in a sheep feeding trial. Correlations of chemical analysis of the silage indicate that ADF was highly correlated with crude fiber (r = 0.94) and cellulose digestion (r = 0.97). Due to the high correlation between fiber measurements, both ADF and crude fiber were useful in estimating similar parameters. However, ADF values were higher and more accurate measurements than those for crude fiber. Regression equations were formulated for the prediction of dry matter intake when sheep were fed corn silage or sorghum silage rations:

Corn Silage: DM Intake $(g/Wt_{kg}{}^{.75}) = 85.49 - .75$ ADF (%) $R^2 = 0.61$

Sorghum Silage: DM Intake $(g/Wt_{kg}{}^{.75}) = 82.87 - .78$ ADF (%) $R^2 = 0.81$

It was concluded in this study that the low cost and predictability of ADF determination makes it a useful procedure for predicting silage energy value.

In a later study, Marten et al. (1976) measured the digestibility of 23 corn and 26 sorghum silage varieties when fed to sheep. Correlations of acid detergent fiber with dry matter intake were 0.53 for corn silage and 0.77 for sorghum silage. Across all sorghum silages:

$$\text{DM Intake } (g/Wt_{kg}{}^{.75}) = 83.79 - 101 \text{ ADF } (\%) \qquad R^2 = 0.60.$$

Dry matter intake was correlated ($r = 0.66$) with the in vivo digestible dry matter of sorghum silage while intake and digestibility correlation was considerably lower for corn silage ($r = 0.40$). ADF was the most accurate predictor of digestibility as compared to alternative analysis (crude fiber, cellulose) and accounted for 80 percent of the variation, while crude fiber was the best predictor of intake, accounting for 72% of the variation.

Chandler and Walker (1972) developed a linear program for computerized ration formulation. The relationship between crude fiber and net energy for lactating cows was observed for 45 feedstuffs commonly used in dairy rations and varying from corn grain to alfalfa hay. When a number of feed ingredients were formulated into a ration, crude fiber was a good predictor of ration energy content. Regression equations were developed for predicting net energy value of feedstuffs from crude fiber analysis as follows:

$$\text{Net Energy (Mcal/Kg DM)} = 2.38 - 0.034 \text{ Crude Fiber } (\%)$$

There was a strong negative correlation between ration fiber level and ration energy level ($r^2 = 0.79$). Thus, the use of chemical analysis of feedstuffs in determining ration energy level is a useful method for predicting performance in cattle.

Galyean et al. (1978) studied the feasibility of predicting feedlot performance from laboratory analysis of grain. Data from 14 cattle feeding trials involving the evaluation of processed grain were utilized to study the relationship between laboratory analysis of grains and feed intake, average daily gain and feed efficiency. Laboratory analysis of the grains in the study included in vitro dry matter disappearance (IVDMD), in vitro gas production and degree of gelatinization. Correlations of intake with the various laboratory analysis were small (-0.22 to -0.36) and did not indicate a strong association. In contrast to these data, Albin et al. (1966) reported correlation values of 0.88 and 0.99 between IVDMD and feedlot gain and efficiency, respectively.

Brown and Radcliffe (1971) concluded that because of the loss of volatiles in oven drying of silage, in vitro DDM of silage was not satisfactory in predicting in vivo DDM in cattle. A correlation of 0.70 was found between in vivo DDM and in vitro DDM, in oven dried samples. When corrected for volatile losses, a correlation of 0.88 was obtained.

Van Soest (1965) studied the correlation of chemical analysis of forages and animal performance. Correlations between chemical analysis and performance varied and was reduced when several species were analyzed. Lignin, acid detergent fiber and cell wall digestibility were better predictors of digestibility than dry matter intake. Correlations were reported between digestible dry matter (DDM) and ADF (-0.86), DDM and cell wall constituents (-0.86), DDM and lignin (-0.79). Digestibility and intake were not related in forages that contained low cell wall contents. When cell wall contents were increased in forages, intake was highly correlated with chemical and digestible dry matter. It was concluded in this study that the relationship between digestible dry matter and dry matter intake was dependent on the proportion of digestible energy from cell wall constituents.

Ademosum _et al_. (1968) evaluated sorghum-sudan grass harvested at various stages of maturity on the basis of intake, digestibility and chemical composition. ADF was an adequate predictor of digestible dry matter (-0.90), digestible energy (-0.88) and dry matter intake (-0.86). The formulated regression equation for prediction of digestible energy (DE) from ADF and lignin analysis is as follows:

$$DE\ (Kcal/Wt_{kg}{}^{.75}) = 66.09 + .65\ ADF\ (\%) - 9.33\ Lignin\ (\%) \qquad R = 0.99$$

In this study, _in vitro_ DDM had no advantage over ADF, lignin and protein analysis as a predictor of the nutritive value of feeds.

The effect of fiber level on performance in young calves was reported by Jahn _et al_. (1970). Body weight gain declined as the fiber level in the ration increased. Dry matter intake was increased as fiber level increased in low fiber diets but intake was reduced in high fiber diets. Increased fiber levels increased the amount of content in the alimentary tract and can influence weight gain. Regression equations were developed relating fill, as a percentage of liveweight at slaughter and acid detergent fiber, as follows:

$$\text{Fill} = 8.33 + 0.41 \text{ ADF } (\%).$$

Increased fiber decreased soluble carbohydrates in the ration, reduced dry matter digestibility and increased crude fiber digestibility.

Due to the variation in digestibility of feedstuffs and subsequent alteration in performance, many studies have been completed in an attempt to more accurately predict performance (Van Soest, 1971; Chandler and Walker, 1972; Marten *et al*., 1975; Schmid *et al*., 1976). Many improvements have been shown in the evaluation of feedstuffs through chemical determination. But, further research is needed to accurately predict performance and net energy values for feedlot rations that vary in grain content and digestibility.

Influence of Ration Grain Content on Feedlot Performance and Carcass Characteristics

Research has shown that as ration grain level is increased, feedlot performance is improved (Pinney *et al*., 1966; Jesse *et al*., 1976a, 1976b; Hammes *et al*., 1964). When cattle are fed high silage *vs* high grain rations, average daily gain and feed efficiency is reduced, days on feed and non-feed costs are increased. Also, studies have reported a less desirable quality grade and eating quality of steers when fed high forage diets when compared to those fed grain (Black et al., 1940; Meyer et al., 1960). But most of these comparisons were made when cattle were slaughtered at different weights and thus resulting in a different carcass composition.

In examining the effect of ration energy level on feedlot performance and carcass characteristics, numerous studies have been conducted. In early studies, Richardson et al. (1961) fed heifers rations with a roughage-to-concentrate ratio of: (A) 1:1; (B) 1:3; and (C) 1:5. Heifers fed the 1:5 rations gained 13.6% faster (1.03 vs 0.89 kg) than those fed the 1:1 ration ($P < .05$). Carcass grade and marbling score was higher for the steers fed rations B and C, but the results were not significant.

Lofgreen and Adams (1976) fed 80 Hereford crossbred yearling steers various alfalfa-to-concentrate ratios of 100:0; 70:30; 40:60; or 10:90. The steers fed the rations containing the all alfalfa ration had reduced gains (0.98 vs 1.17, 1.22, 1.14 kg) and were less efficient (11.50 vs 9.12, 8.17, 8.00) than those fed the added concentrate rations. Steers fed the 60% concentrate ration had the highest rate of gain (1.22) but no significant difference was shown in efficiency when the concentrate level was increased to 90% of the ration. There was no difference in carcass characteristics among steers fed the concentrate rations. Steers fed the alfalfa ration had a lower percentage carcass fat and quality grade, but were slaughtered at lighter weights. The 30% and 60% concentrate rations were utilized 5% better than the 90% ration. These findings conflict with earlier studies that describe the presence of associative effects and a reduction in energy utilization when concentrate comprises 50 to 80% of the ration (Byers et al., 1975a, 1975b; Kromann, 1967).

Lancaster et al. (1972) compared the performance of 91 Angus steer calves fed a high concentrate finishing ration (78% milo) with steers fed a high roughage, growing ration (84% hay) prior to being fed a high concentrate ration. Steers were fed for 76 days on the growing ration and finished for 118 days on the finishing ration. For the first 76 days, steers fed the high concentrate ration gained 21.7% faster (1.29 vs 1.01 kg) and required 6.5% less feed per unit of gain (6.30 vs 6.74) when compared to those fed a high roughage ration. For the finishing ration, the steers started on the high roughage ration and switched to a high concentrate ration had 12.3% higher gains (1.46 vs 1.28 kg) but were similar in feed efficiency (6.49 vs 6.30). Steers started on the high roughage ration expressed compensatory gain when switched to the high concentrate ration. When the 194 day trial was summarized, average daily gains were the same, but the steers fed the high concentrate for the entire trial had an 8.7% improvement in feed efficiency (6.00 vs 6.57). There were no differences in carcass traits or body composition but steers fed high concentrate had more fat covering and a higher degree of marbling.

Theuninck (1977) studied the effects of a growing ration on the performance during the finishing period when 56 Angus crossbred steers were fed. During the 61 day growing period the rations fed included: (A) corn silage full fed, or (B) 1.36 kg of high moisture corn plus a full feed of corn silage. The rations fed during the 98 day finishing period included: (A) corn silage full fed, or (B) 3.6 kg of corn silage plus a full feed of corn. During the growing period, steers fed rations A and B had similar gains (0.96 vs 0.98 kg) and feed required per unit of gain (6.05 vs 5.90). During the finishing phase, steers fed ration B gained 12.1% faster (1.32 vs 1.16 kg) and improved in feed efficiency by 10.5% (6.11 vs 6.83) as compared to those fed ration A. The nutritional level fed during the growing phase did not affect total feedlot performance. Carcass characteristics were not influenced by energy level.

Pinney et al. (1966) fed 50 yearling Angus steers for 125 days on rations varying in proportions of ground corn and corn silage. The rations were: (A) corn silage plus ground shelled corn at 1.5% of body weight, (B) corn silage plus ground shelled corn at 1.0% of body weight, and (C) corn silage plus ground shelled corn at 0.5% of body weight. Average daily gain (kg) and feed efficiency for the rations were: (A) 1.06, 7.74; (B) 0.98, 8.93; and (C) 0.92, 9.83. The higher grain fed steers had slightly higher gains and were more efficient than those fed the higher roughage rations. Carcass grade was not influenced by ration energy level. Cost of gain was in favor of the steers fed high silage rations.

Perry and Beeson (1976) conducted five experiments with calves and yearling steers to study the extent corn silage energy could be substituted for shelled corn in finishing rations. The amount of corn added to corn silage ranged from 0.9 kg per head daily to 85.65% of the ration. In four of the five trials, steers fed the highest level of corn grain gained faster ($P < .01$) and were more efficient (air-dry basis) than those fed the high silage diets. Steer calves gained gained 16.7% faster (1.20 vs 1.00 kg) and were 19.8% more efficient (7.40 vs 9.00) when fed the high corn rations. Similarly, yearlings had a 12.0% improvement (1.42 vs 1.25 kg) in gains and 16.3% improvement in feed required per unit of gain (9.20 vs 7.70) when fed high grain rations. Calves or yearlings fed high silage rations had similar quality grades as those fed high corn rations.

Jesse et al. (1976a) studied the effects of feeding various corn-corn silage combinations on feedlot performance. The rations were fed in corn:corn silage combinations of: (A) 30:70; (B) 50:50; (C) 70:30; and (D) 80:20. Steers were slaughtered at 314, 454 and 545 kg. Steers fed the high silage ration (A) gained slower (0.90) than steers fed rations B (1.06), C (1.13) or D (1.11 kg). Dry matter intake, expressed as a percentage of empty body weight, was 2.25, 2.40, 2.52 and 2.37% for rations A, B, C and D. Carcass characteristics were similar; however, the steers fed the high concentrate rations were fatter and had a higher quality grade. The comparative slaughter technique was used to determine the net energy value of the various corn-corn silage rations (Jesse et al., 1976b). Regression analysis was used to estimate corn and corn silage net energy values for the rations. Net energy values were not affected by ration combination ($P < .05$). Net energy for gain for corn and corn silage were 1.17 and 1.05 Mcal/kg, respectively.

Peterson et al. (1973) fed rations with corn silage-to-high moisture corn at ratios of: (A) 100:0; (B) 67:33; (C) 33:67; and (D) 0:100, to 160 Angus crossbred steer calves. Average daily gain and feed required per unit of gain for steers fed the various rations were: (A) 1.18, 7.45; (B) 1.25, 7.11; (C) 1.39, 5.50; and (D) 1.48, 5.04. Average daily gain and feed efficiency improved linearly as the level of grain in the ration increased ($P < .01$). Energy level did not influence marbling, kidney, heart and pelvic fat or quality grade.

Miller et al. (1970) compared levels of forage and concentrate for growing and finishing Holstein steers. Ratios of corn silage-to-concentrate for the various rations were: (A) 3:1 from 181.4 kg to market; (B) 3:1 from 181.4 to 340.1 kg. followed by 1:1 to market weight; (C) 3:1 from 181.4 to 340.1 kg, followed by 1:2 to market; and (D) 1:1 from 181.4 kg to market. Average daily gains were: 1.10, 1.20, 1.24, and 1.20 kg and feed requirement per unit of gain was 6.49, 5.96, 5.81 and 6.00 for steers fed rations A, B, C and D. The steers fed ration D had the most rapid gains and were the most efficient. Carcass characteristics did not differ among treatments except the steers fed ration A had less marbling and a lower quality grade. Feed cost was highest for steers fed equal amounts of corn silage and concentrate (D), but, non-feed cost was highest for steers fed the high silage ration (A) for the entire trial due to lower gains and a longer time on feed.

The value of high silage rations for fattening beef cattle was studied by Hammes et al. (1964). During the two-year study, several combinations of silage and concentrate were fed, including: (A) 20% hay or haylage plus 80% corn silage plus 0.79 kg cottonseed meal, (B) corn silage plus 0.91 kg cottonseed meal, and (C) high concentrate ration. Steers fed ration A had lower gains as compared to those fed the high concentrate, fattening ration. But, feed efficiency, whether expressed as dry matter or TDN required per unit of gain, was in favor of the high silage fed steers when compared to those fed high concentrate. Ration energy level had no effect on carcass characteristics.

Workers from the Iowa station have reported on the influence of ration energy level on feedlot performance and carcass characteristics (Burroughs and Topel, 1969; Topel _et al_., 1973; Self and Hoffman, 1977). In a two-year feeding trial, Burroughs and Topel (1969) fed rations consisting of all silage or silage plus 38% grain to steers. For the first trial, steers fed the all silage ration gained 26.2% slower (1.10 _vs_ 1.49), were on feed 47 days longer, and required 19.4% more feed per unit of gain (8.82 _vs_ 7.11) than those fed added grain rations. In the second year, steers fed corn silage had 23.5% slower gains (1.08 _vs_ 1.41 kg) and were 11.5% less efficient (7.91 _vs_ 7.00) than those fed silage plus grain. In the two-year study, carcass characteristics were not affected by ration energy level. Net energy for maintenance and gain (Mcal/kg) were 0.79 and 1.29 for corn silage and 1.41 and 1.14 for silage plus added grain rations.

Topel _et al_. (1973) studied the influence of energy consumption during growth on carcass composition of 20 crossbred steers. The steers were slaughtered at 362.8 and 498.9 kg and were fed _ad libitum_ or restricted energy intake. During the growing phase, the steers fed the restricted energy intake gained slower (0.78 vs 1.22), were less efficient (7.13 vs 5.69) and required 71 more days on feed to reach 362.8 kg. When slaughtered at 498.9 kg, the full fed steers had 33.0% faster gains (0.77 vs 1.15), were 10.1% more efficient (7.37 vs 8.20), and required 132 fewer days on feed. The steers fed to the heavier weights required more feed per unit of gain than the lighter steers due to increased maintenance requirements. Carcass composition and characteristics were similar for the steers fed the two energy levels.

Self and Hoffman (1977) reported on the effect of silage level on feedlot performance of yearling steers. Steers were fed rations with various ratios of silage-to concentrate, as follows: (A) 25:75; (B) 45:55; and (C) 15:85. Steers fed the high silage ration had the lowest average daily gain (0.99) as compared to those fed rations B (1.13) and C (1.16). TDN required per unit of gain was lower for the high concentrate ration (5.87) than for the ration A (6.80) or B (6.17). Steers fed the high silage ration had similar dry matter intake (8.98 and 8.75 kg) but was reduced for the high concentrate (7.98).

Preston et al. (1975) studied the role of roughage in high concentrate rations for finishing steer calves. One hundred and twenty steer calves of various breed types were fed high concentrate rations containing various sources and levels of roughage. Rations containing low levels of pelleted cob, dried brewers grains and limestone treated corn silage were compared to all concentrate rations.

Feedlot performance was not affected by any of the roughage sources or levels, but feed efficiency was slightly reduced when roughage was added. Steers fed 2.27 or 6.80 kg of corn silage plus concentrate had 8.3% reduced gains (1.34, 1.32 vs 1.45 kg) and 14.0% poorer feed efficiency (5.17, 5.66 vs 4.66) as compared to the all concentrate ration. Carcass characteristics were not influenced by ration energy level.

Klosterman et al. (1965) conducted three experiments to determine the effect of corn silage or ground ear corn fed at various stages of growth and fattening upon carcass composition of beef cattle. In trial one, periods were on a time constant basis while a constant amount of gain was the basis used in the second trial. A third trial was conducted using the same rations for two time constant periods. Cattle fed the ear corn ration gained faster than those fed all silage, regardless if the ear corn was fed during the first, middle or last part of the feeding period ($P < .05$). Dressing percentage was increased when the ear corn was fed in the finishing stage. Ration energy level had no significant influence on carcass characteristics.

Newland (1976) finished 40 Angus and 40 Angus heifers on all corn silage or all concentrate rations. When fed corn silage, steers required 56 days longer (210 vs 154) and heifers 29 days (183 vs 154) longer to reach low choice as compared to those fed all concentrate. When fed all concentrate, steers gained 21.5% (1.30 vs 1.02 kg) and heifers 21.1% faster (1.09 vs 0.86) than those fed all silage. Those fed all concentrate required 28.5% less feed per unit of gain

(5.40 _vs_ 7.55). Ration energy level did not influence carcass characteristics. Cost per cwt. gain was reduced for the steers fed the all silage rations.

Gill _et al_. (1976) reported on the effect of feedlot rations containing various corn silage levels. The rations contained (A) 14%, (B) 30%, or (C) 75% of the ration dry matter from corn silage, the remainder from high-moisture corn. Average daily gain and feed efficiency for the steers fed the various rations were: (A) 1.41, 5.49; (B) 1.50, 5.69; and (C) 1.15, 7.40. Steers fed the high grain ration (A) had higher gains (18.4%) and improved feed efficiency (25.8%) than those fed the high silage ration (C). Steers fed the 75% silage ration had lighter carcass weights than those fed 14% silage (310 _vs_ 324 kg). The 75% silage fed steers had a lower dressing percentage, marbling score and kidney, heart and pelvic fat but had more backfat thickness ($P < .01$). The high silage fed cattle were fed 28 days longer but had a much lower quality grade. If steers had been fed to a similar weight, smaller differences would be expected in carcass characteristics between the high silage _vs_ high concentrate fed steers.

Utley _et al_. (1975) studied the feedlot performance and carcass characteristics when 68 crossbred steer calves and yearlings were fed all forage _vs_ high concentrate rations. Steers fed the high concentrate ration gained 21.5% faster (1.35 _vs_ 1.06 kg) than those fed the all forage ration ($P < .05$). Steer calves and yearlings had similar gains when fed the all forage rations. However, yearlings gained 7.9% faster (1.40 vs 1.29 kg) than calves when fed the high concentrate diet. When slaughtered at a similar weight, steers fed the high concentrate ration had more marbling, higher yield grade and more fat over the ribeye than steers fed the all forage rations ($P < .05$).

Oltjen et al. (1971) fed all forage diets to finishing beef cattle. Forty-eight Hereford steer calves were fed the following rations: (A) all concentrate; (B) pelleted, all-forage ration; (C) all concentrate followed by all forage, and (D) all forage followed by all concentrate. Average daily gains and feed efficiency for steers fed the various rations were: (A) 1.27, 5.71; (B) 1.05, 10.06; (C) 1.09, 7.98; and (D) 1.11, 8.14. Steers fed the all concentrate ration had 17.3% higher gains and 43.2% improvement in feed efficiency. Steers fed all forage during the growing phase and switched to all concentrate for the finishing phase had similar gains and feed efficiency as those fed all forage and switched to all forage. Carcass grade was higher for the steers fed all concentrate.

Embry and Fredrikson (1968) fed 100 steer calves various combinations of silage, ear corn and shelled corn. Rations fed were: (A) corn silage, 6.8 kg plus high moisture ear corn, full fed; and (B) corn silage full fed the entire trial. Steers fed ration A gained 28.2% faster (1.10 vs 0.79 kg) than those fed ration B. Steers fed the all silage ration had a lower marbling score and quality grade. But, the all silage steers were fed to a lighter weight (475 vs 523 kg); if these steers were fed to the same weight as the silage plus grain fed steers, differences in carcass parameters would likely be reduced.

Garrett (1971) determined the influence of rations varying in level of roughage and concentrate on feedlot performance and body composition when fed to yearling Hereford heifers. The roughage-to-concentrate ratios were: (A) 15:85; (B) 50:50; and (C) 85:15. The heifers were slaughtered following 70, 140 and 230 days of feeding the different rations. Gains were similar for rations A and B but gains were reduced for the steers fed the high roughage ration (C). Quality grade was increased by one-third of a grade for the steers fed the high concentrate ration when compared to those fed the high roughage rations. When fed to an equal body weight, final body composition was not greatly affected by the ratio of roughage-to-concentrate. The net energy value of the roughage or grain was constant and did not vary when fed at varous proportions in the ration.

Recently Michigan workers have studied the effect of ration energy level on feedlot performance (Newland and Henderson, 1965; Minish et al., 1966, 1967; Hawkins et al, 1967; Henderson and Britt, 1974; Danner and Fox, 1977; Crickenberger et al., 1977). Newland and Henderson (1965) fed steers rations varying in levels of concentrate-to-hay, including: (A) 50:50; (B) 61:39; (C) 71:29; and (D) 82:18. Average daily gain (kg) and feed efficiency (85% dry matter basis) for the rations were (A) 0.94, 10.89; (B) 1.00, 9.90; (C) 1.44, 7.34; and (D) 1.49, 6.51. Steers fed the high concentrate ration gained 36.9% faster and required 40.2% less feed per unit of gain. Carcass traits were not influenced by ration energy level.

Minish et al. (1966, 1967) conducted two feeding trials and reported on the effect of concentrate level on feedlot performance and carcass characteristics. Steers were fed rations containing: (A) all silage, or (B) 60% concentrate-40% silage. In trial 1 steers fed the high concentrate ration (B) gained 36.6% faster (1.09 vs 1.72 kg) than those fed all silage ($P < .05$). Steers fed the high concentrate ration had improved quality grades but no other carcass traits were influenced by ration energy level. In the second trial, steers fed the high concentrate ration gained 20.7% faster (0.92 vs 1.16) than those fed high silage ($P < .05$). Steers fed the high concentrate ration had improved quality grades.

Hawkins et al. (1967) fed 64 steers and heifers either all silage or silage plus a 1% added grain ration. Steers fed the added grain ration gained 7.7% faster (1.08 vs 1.17 kg) but were similar in feed efficiency when compared to steers fed all silage rations. The heifers fed all silage had 7.9% lower gains and required 8.2% more feed per unit of gain than those fed added grain rations. There was little difference in carcass grade due to ration energy level; but, those fed the high silage ration had lighter carcasses as compared to those fed rations containing various rations.

Henderson et al. (1974) fed rations containing various ratios of shelled corn-to-corn silage, including: (A) 40:60; (B) 60:40; and (C) 80:20. In conflict with previous studies, as grain level in the ration was increased, there were little change in gain or feed efficiency. Cattle were fed to a similar final weight and no difference was found in carcass characteristics.

In a more recent study, Danner and Fox (1977) conducted two trials to compare the influence of different feeding systems on efficiency of energy utilization and carcass characteristics when calves and yearlings were fed. The feeding programs included: (A) 85% concentrate-15% silage; (B) 40% concentrate-60% silage; (C) all silage, switched to 85% concentrate-15% silage one-half the way through the feeding period; (D) all silage, switched to 85% concentrate-15% silage two-thirds the way through the feeding period; and (E) all silage fed continuously. Yearling steers fed ration A had 35.7% faster gains and were more efficient than those fed all silage (E). When adjusted to an equal carcass weight, there were no differences in marbling or quality grade but steers fed all silage had a more desirable yield grade than steers fed the 85% concentrate ration. Little difference was found in metabolizable energy required per lb of retail beef, but those fed on the two-phase system and switched early were the most efficient. Calves fed ration A gained 22.8% faster and were more efficient than those fed all silage. Calves fed all silage had lower quality grade than those on the other systems, but no difference was found in yield grade. Steers switched earlier on the two-phase system (C) gained 8.6% faster than those fed ration D.

Two feeding trials involving 189 steer calves were conducted to compare performance and carcass traits when fed either corn silage or 60% corn-40% silage rations (Crickenberger et al., 1976). In both trials, ration energy level influenced average daily gain ($P < .05$). In trial 1, steers fed added grain rations gained 46% faster than those fed all silage. High grain fed steers had more external fat, kidney, heart and pelvic fat, higher quality grade but reduced yield grade. In trial 2, the high grain fed steers gained 27% more rapidly when compared to those fed all silage; but ration energy level did not influence carcass characteristics when adjusted to the same final carcass weight.

Goodrich et al. (1974) analyzed 17 university experiments that involved 878 steer calves to determine the influence of corn silage on performance. Average daily gain declined 23.7% (1.14 vs 0.87 kg) as corn silage level was increased from 10% to 80% of the ration. Examination of the data revealed that a 10 percentage unit increase in corn silage decreased gain to a greater extent when 70 to 80% corn silage was fed (0.063 kg) than when the ration contained 10 to 20% corn silage (0.014 kg). Feed required per unit gain increased linearly as corn silage level was increased. Maximum dry matter intake occurred when the ration contained 40 to 50% corn silage. The impact of corn silage on gain and feed efficiency when fed at various levels is useful for accurate prediction of feedlot performance.

To accurately compare the influence of ration grain content on feedlot performance and carcass characteristics, there are three adjustments that should be taken into consideration. First, performance data should be adjusted to an equal dressing percentage. Cattle fed a high roughage ration will typically have more fill than high concentrate fed cattle and thus, will influence the rate of gain (Burroughs et al., 1965; Utley et al., 1975; Peterson et al., 1973).

Second, adjustments should be made to correct for errors in dry matter determination. Due to the loss of energy containing volatiles, dry matter intake may be underestimated by 7% when determined by oven drying (Brown and Radcliffe, 1971; Jones and Larsen, 1974; Fox and Fenderson, 1976). Third, cattle should be slaughtered at the same final weight for accurate comparison of diet on performance and carcass characteristics. When slaughtered at various final weights, performance and carcass composition may be greatly influenced by differences in physiological maturity. Most studies reviewed have not taken these factors into consideration in measuring the effect on ration energy content on feedlot performance.

Numerous studies have been reported on the influence of ration energy level on feedlot performance and carcass characteristics. As ration grain content is increased, gain is increased but composition of gain was not influenced (Hammes et al., 1964; Minish et al., 1966; Pinney et al., 1966; Riley, 1969). In contrast, other workers have concluded that ration energy level may influence carcass composition (Oltjen et al., 1971; Utley et al., 1975; Jesse et al., 1976). In the review of literature, the effect of ration grain content on carcass composition is still in question. More research is needed to accurately assess the impact of high roughage vs high concentrate rations on body composition.

Effect of Feeding System on Efficiency of Roughage and Grain Utilization

The interactions of dietary ingredients was first reported by Armsby in 1917; digestibility was reduced 12% when feedstuffs containing carbohydrates were added to hay rations. Later, Forbes (1931) concluded that the energy value of feedstuffs cannot be evaluated individually in mixed rations. Kriss (1943) reported that the nutritive value of individual feeds depends on the combination with other ingredients when mixed rations containing alfalfa hay and corn were fed. Hamilton (1942) reported on the effect of corn sugar upon digestibility of the nutrients of a ration. As the level of corn sugar was increased in the ration, digestibility of crude fiber decreased. Swift and French (1954) reported a reduction in fiber digestibility when starch or other soluble carbohydrates were added to rations.

The conventional scheme of energy metabolism and variation in energy losses is shown in Figure 1 (NRC, 1966; Reid, 1962). From the gross energy ingested, 20 to 60% of the energy is lost as fecal energy which contains undigested feed, bacterial cell residue and digestible fluids. A portion of the digestible (DE) is excreted as urinary energy (3 to 5%) or lost as gas production (5 to 12%). From the metabolizable energy (ME), considerable energy is lost as heat increment (10 to 40%). The remaining energy is divided into net energy for maintenance (NE_m) and gain or production (NE_g), as described by Lofgreen and Garrett (1968). Alteration in digestion and metabolism of feedstuffs influence the net energy value of a diet.

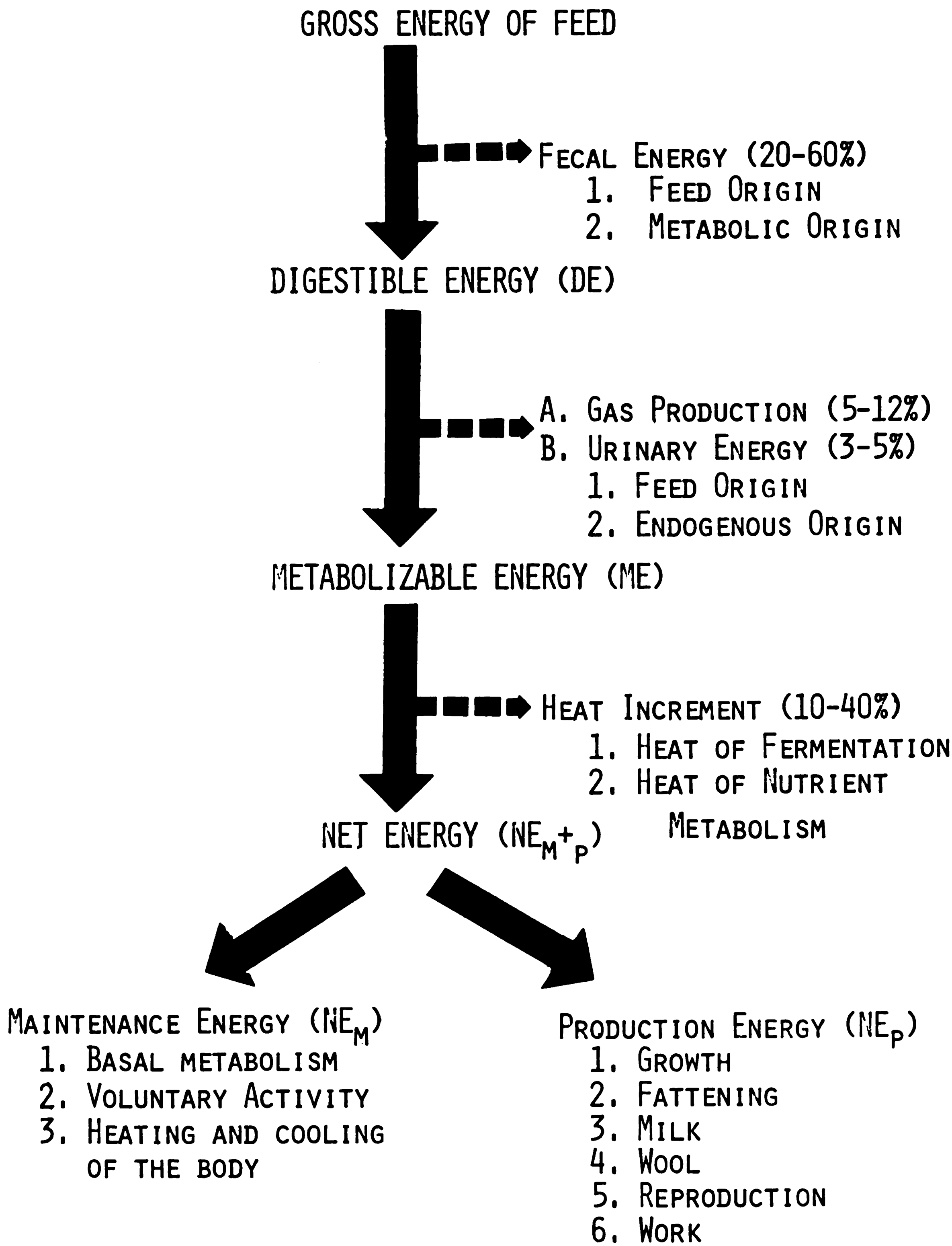


Figure 1. Scheme of energy metabolism (NRC, 1966) with expected losses (Reid, 1962).

Classical papers by Armstrong and Blaxter (1957a, 1957b), Armstrong et al. (1957) and Armstrong et al. (1958) have studied the effect of heat increment on nutrient metabolism in the ruminant. Heat increment (HI) represents the energy expended by the animal during the ingesting and fermentation of feedstuffs. Energy lost as heat is divided into heat of fermentation and heat of nutrient metabolism, but due to difficulty of calculation, these processes are summarized as heat increment. This loss of energy is considerable and influences the utilization of metabolizable energy and the net energy evaluation of feedstuffs.

Armstrong and Blaxter (1957a) concluded that the heat increment of mixed rations were variable and were not the sum of the individual feeds or volatile fatty acids (VFA) of the ration. Following the infusion of VFA's into the rumen, heat increment was measured in sheep. Heat increment for the VFA's were, acetic acid, 40.8; propionic acid, 13.5; and butyric acid, 15.9 Kcal/100 Kcal of metabolizable energy. A mixture of VFA's of 5:3:2 of acetic, propionic and butyric acid was projected to yield a heat increment of 27.0 Kcal/Kcal of ME, but only 17.0 was observed.

The heat increment of VFA's was determined when infused separately or in a mixture into fasting dairy cows (Holter et al., 1970, Table 4). Measured heat increments were, acetic acid, 40; propionic acid, 18.0; and butyric acid, 18.0 Kcal/100 Kcal of metabolizable energy. Mixed VFA's yielded a heat increment of 32.0, while 29.5 Kcal/100 Kcal of ME was projected. As a sole source of energy, acetic acid was considerably less efficient than propionic acid or butyric acid. The increase of observed heat increment when compared to projected losses suggest the presence of associative effects in mixed rations.

Table 4. Mean Heat Increments of Individual Volatile Fatty Acids and a Mixture of Acetate, Propionate and Butyrate Infused into the Rumen of Fasted Mature Cattle (Holter, Heald and Colovos, 1970)

	HI, Kcal/100 Kcal ME	
	Observed	Calculated
Acetate	40	--
Propionate	18	--
Butyrate	18	--
Mixture, 52:31:17[a]	32	29.5

[a]Molar ratio of acetate, propionate and butyrate.

Blaxter and Wainman (1964) fed varying levels of hay and corn grain to sheep and cattle in a metabolism study. As the percentage grain in the ration increased from 0 to 100%, fecal energy losses increased linearly. Methane losses increased linearly with increased levels of corn until the ration contained 60 to 80% grain, then declined markedly. There was a small effect of diet on urinary loss. Nitrogen digestibility increased with increasing levels of grain in the ration, but the increase was most marked when grain levels were greater than

60%. Metabolizable energy was linearly related to the grain level in the diet. When the percentage of grain in the ration was increased from 0 to 100%, efficiency of utilization of metabolizable energy for maintenance increased from 71 to 79% and from 29 to 61% for fattening. Results of this study suggests that high increments of heat and low efficiency of utilization with high roughage rations are due to the nature of the end products of fermentation and digestion process. There was an inverse relationship between ration fiber content and the efficiency of utilization for fattening.

Asplund and Harris (1971) studied the digestibility of energy and utilization of nitrogen in sheep fed varying proportions of alfalfa hay and beet pulp. Mixed rations containing alfalfa hay and dried molasses beet pulp in equal amounts had an increase in ether extract and nitrogen free extract digestibility and a decrease in biological value of nitrogen in comparison to the digestibility when feed ingredients were fed independently. The digestibility was significantly higher for gross energy, dry matter and nitrogen when the lowest level of energy was fed. It was concluded in this study that associative effects were present but at a lesser magnitude than previously predicted.

Byers, Matsushima and Johnson (1975a) used an indirect respiration calorimeter in determining the net energy value of corn silage with various increments of added grain. When corn grain was added at levels of 34 and 67% of the ration, the NE_m values decreased 4.7 and 14.8% below the predicted values (Figure 2). The NE_g values

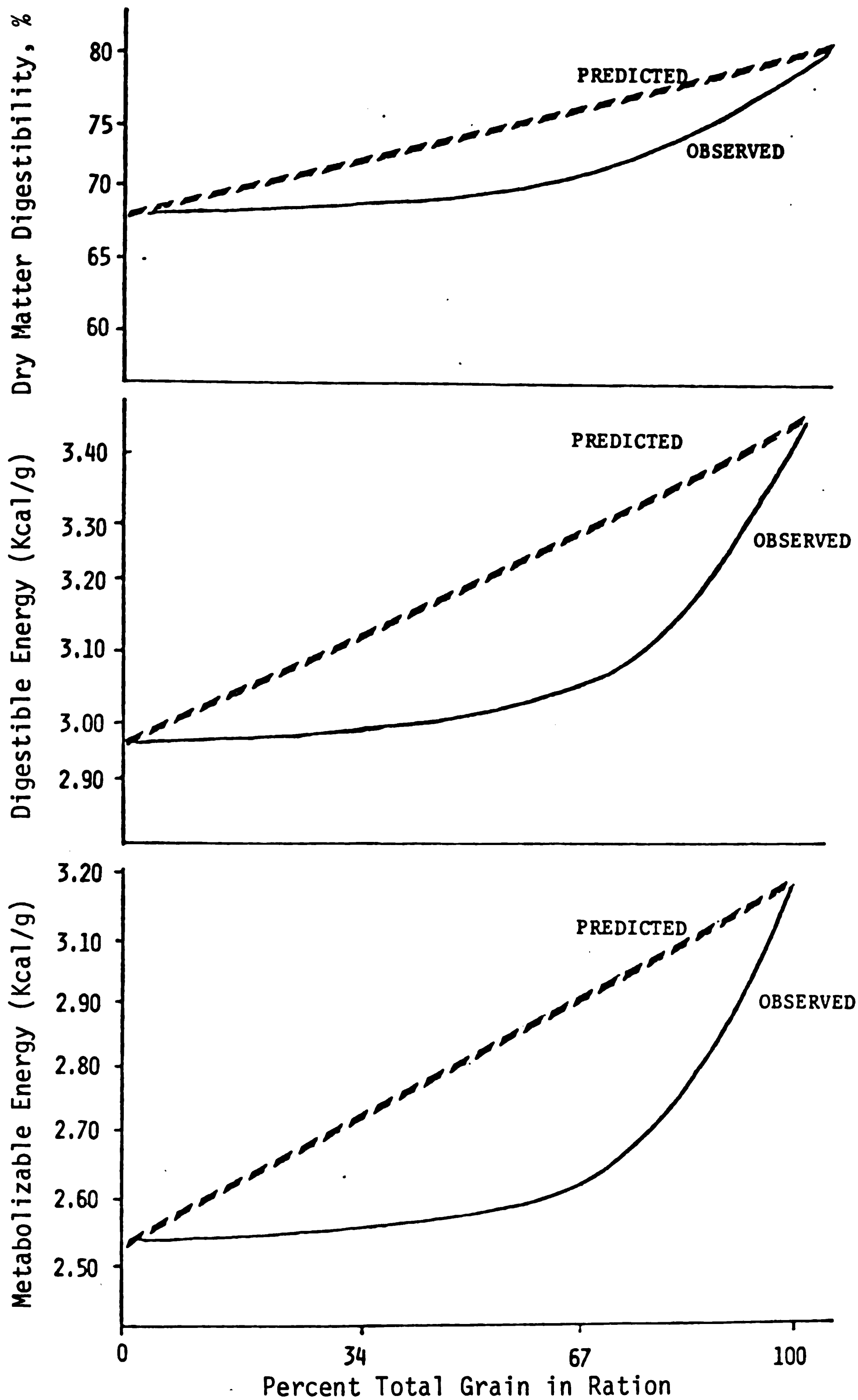


Figure 2. Influence of ration grain content on dry matter digestibility and digestible and metabolizable energy (Byers, Matsushima and Johnson, 1975a).

expressed a similar decrease of 10.4 and 12.3%. The metabolic interactions due to varying grain levels influenced dry matter digestibility, digestible energy and metabolizable energy of the ration, as shown in Figure 3. When corn grain was added at 34% of the ration, dry matter digestibility, DE and ME were depressed by 4.8%, 4.8% and 7.4% and at the 67% added grain 6.2%, 7.4% and 12.1%, respectively. Observation of these parameters indicate that the net energy value for maintenance or gain for feedstuffs in a diet by assuming additive energy values is not an accurate procedure.

The greatest changes in digestion and metabolism of corn silage appears when corn grain is added at levels of 50 to 90% of the ration as shown in Figure 3 (Byers, Matsushima and Johnson, 1975b). The energy value of corn grain is considerably less when added to high silage rations as compared to its value in high grain rations. The NEg value of corn grain was 1.34 Kcal/g in a ration consisting of 10% grain-90% corn silage as compared to 2.09 Kcal/g in an all corn diet. Net energy values for maintenance for corn grain were 2.36 and 1.72 Kcal/g when added to all corn silage or all corn grain rations. The net energy values for corn silage were significantly lower when corn grain was added at various increments than when fed alone. The greatest changes in corn silage energy value occurred when the silage was less than 50% of the ration while corn grain NE changed the most rapidly when included at levels between 20 and 60% of the ration.

In a similar study, Preston (1975) summarized three trials and reported the net energy values for corn grain and corn silage when the

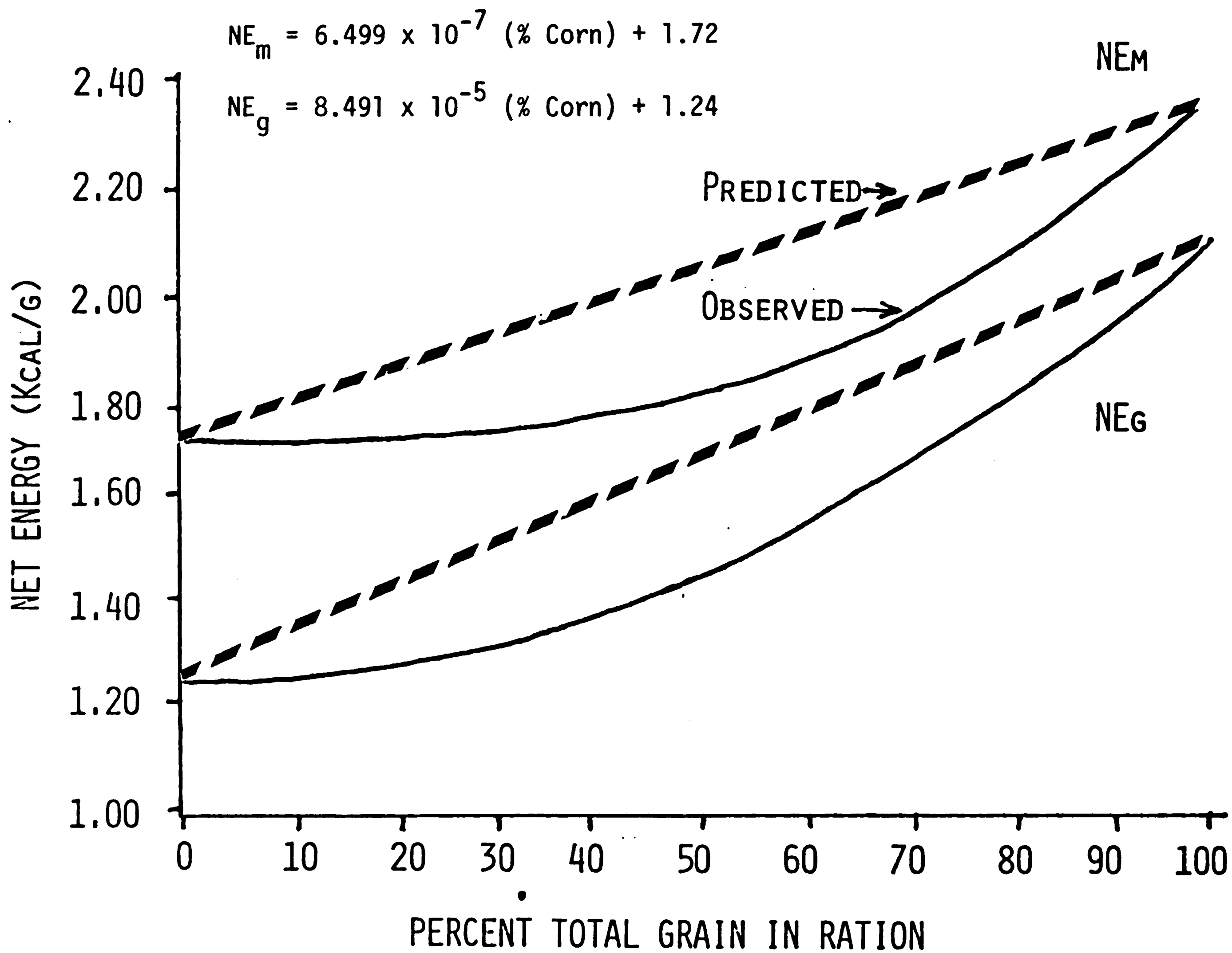


Figure 3. Net energy for maintenance and gain in relation to total gain in the ration (Byers, Matsushima and Johnson, 1975b).

proportion of grain added consisted of 40 and 100% of the ration. Steer calves were fed for 170 to 220 days and the net energy values were determined by the comparative slaughter technique. In this study there was a significant linear increase of NE_m and NE_g of the ration when varying levels of grain were added. The net energy value of the grain and silage were additive and no significant interaction with grain level was shown.

An experiment involving 21 diets consisting of varying increments of 0 to 100% of dehydrated alfalfa and corn were fed to lambs (Kromann et al., 1975). Digestible energy, metabolizable energy and net energy for maintenance and gain were determined on each of the rations. As the level of corn was increased in the ration, crude protein, ether extract and nitrogen free extract digestibility increased curvilinearly and crude fiber decreased curvilinearly. As grain increased in the diet, there was a linear relationship and no interaction between ration composition and digestible energy, metabolizable energy and net energy values for the rations.

Net energy value of a feedstuff is the result of the interaction of NE_m, NE_g, metabolizable and digestible energy. In rations in which associative effects or interactions occur, the net energy value of each ingredient may be more accurately determined by the use of simultaneous equations in contrast to the comparison method which assumes the energy value of an ingredient to be additive. This energy determination is a "two-way" dependency when two ingredients are in a ration and an "n-way" dependency when there are "n" ingredients, as described by Kromann

(1967). Consequently, individual feed net energy values are dependent on the combinations of feed used in a ration.

A simultaneous equation was applied to a study by Lofgreen and Otagaki (1960) when molasses was fed as 10, 25, and 40% of the ration. The energy value of the basal ration remained constant with increasing levels of molasses. When the simultaneous equation was applied, it was determined that the energy value for the basal ration was not constant and that associative effects were present. The energy value for molasses was lower than previously reported due to the decrease in the digestibility of the basal ration with increasing molasses levels.

Kromann and Ray (1967) added levels of 30, 60, and 90% milo to hay rations and reported the NE_m and NE_g values for these rations and their ingredients. When summarizing the results using the simultaneous equation, the energy value of hay decreased and energy for milo increased as milo was added at various levels to the ration.

The comparative slaughter technique was used to measure the net energy value of feedlot rations containing corn silage and varying proportions of corn grain (Vance et al., 1971a). Net energy value of the rations increased as the percentage of grain in the ration was increased from 36 to 97%. In this study a relatively constant NE_m value for both corn grain and corn silage was obtained. Regression analysis showed that 97% of the variation in NE_m of the ration was associated with the percentage of corn grain in the ration. When corn grain was added in the ration at varying increments, NE_g increased curvilinearly with a greater increase at levels of 85 to 97%. The

NE_g of the corn grain increased while that of corn silage decreased as additional increments of corn grain was added to the ration. The greatest change in digestion appeared when 61 to 83% corn grain was fed. These data suggest that to obtain maximum energy utilization, beef cattle rations should be either high in roughage or contain 80% grain or greater.

Fox and Black (1975) suggested three factors responsible for improved efficiency when cattle are fed on a "two-phase" feeding system (high roughage ration fed during the growing phase followed by high concentrate ration during the finishing phase) in comparison to steers fed a constant amount of added grain throughout the entire feeding period. First, the interaction between fiber and grain level in the ration alters digestion and metabolism of nutrients in individual feeds. This concept has been well established by Kriss (1943), Byers et al. (1975a, 1975b) and Kromann (1967). Secondly, when cattle are switched from a high roughage ration fed during the growing phase to a high concentrate ration, there is compensatory performance, which results in more efficient use of dietary energy during the finishing phase (Fox et al., 1972). Thirdly, cattle are fed for slower rates of gain during the growing phase when they are of lighter weight and their maintenance requirements are lower. During the finishing phase the cattle are heavier which results in higher maintenance costs. When fed a high grain ration during this period they have a higher rate of gain and spend less time in this phase. Thus, a lower percentage of feed is used for maintenance requirements and more is available for gain for the two-phase system.

Dexheimer et al. (1971) studied the influence of corn silage in four different systems when fed to finishing steer calves. Steers were fed corn silage as: (A) constant amount daily, (B) two-phase feeding system, (C) gradually decreasing silage, and (D) gradually increasing silage. Corn silage was fed to total 1,619 kg/steer in all programs. Feed efficiency was improved for the cattle fed on the two-phase system (688) vs ration A (738), C (710), or D (733), as reported in Table 5. But, cattle fed on the gradually increasing amount of silage (D) had higher marbling scores than the other systems. Cattle fed on the two-phase system also had lower feed cost per gain and greater return per head than steers fed on the other feeding systems.

Table 5. Two-Year Summary of Performance Data of Finishing Steers Fed Rations Containing Corn Silage in Four Different Feeding Programs (Dexheimer et al., 1971)

	Silage feeding programs			
	Constant amount	Two-phase	Gradually decreasing	Gradually increasing
Avg. daily gain (kg)	1.10	1.11	1.09	1.04
DM intake	8.13	7.61	7.71	8.02
Feed/100 kg gain	738	688	710	773
Total feed cost ($)	86.30	80.59	81.82	85.07
Return/head ($)	29.70	40.94	27.89	23.18

Newland et al. (1975) studied methods of feeding corn silage or shelled corn to finishing steers. Forty Hereford and Charolais Hereford crossbred steer calves were backgrounded on urea-treated silage for 126 days and finished on an all concentrate ration for 100 days or full fed whole shelled corn for the entire feeding period of 203 days. During the backgrounding phase, steers fed the all concentrate ration gained 33.3% faster (1.17 vs 0.78 kg) than steers fed all silage rations. But, when steers were switched from the all silage ration to an all concentrate ration during the finishing phase they gained 20.1% faster (1.44 vs 1.15 kg) when compared to steers receiving the all concentrate ration for the entire feeding period. In this study, backgrounding steers on all silage gained considerably less during the growing phase but had significant compensatory gain during the finishing phase as compared to steers fed all concentrate.

Newland et al. (1974) studied different methods of feeding corn silage and shelled corn to 40 Hereford steer calves. Rations were: (A) full feed of whole shelled corn for the entire feeding period of 243 days, (B) full feed of whole shelled corn plus 4.54 kg of corn silage the entire feeding period, (C) backgrounded on corn silage for 127 days and finished on whole shelled corn for 132 days, and (D) backgrounded on corn silage and finished on whole shelled corn plus 4.54 kg of corn silage. Cattle fed whole shelled corn for the entire feeding period (A) gained faster than those backgrounded with corn silage. For the entire period, average daily gain and feed efficiency for steers fed the various rations were: (A) 1.16, 5.07;

(B) 1.12, 5.80; (C) 1.00, 6.29, and (D) 0.93, 6.78. When the calves were switched from high silage during the backgrounding phase to high concentrate, no compensatory gain was found. There were no differences in carcass characteristics between steers fed the various rations.

Young et al. (1962) fed steer and heifer calves similar amounts of ground shelled corn in two different feeding programs. Rations fed were: (A) ground shelled corn fed at the rate of 0.57 kg/cwt of body weight for the entire feeding period, or (B) fed corn silage for 98 days followed by full feeding of ground shelled corn for the remainder of the feeding period. Average daily gain and feed efficiency for the steers was (A) 1.0, 6,08; (B) 0.95, 5.84; and heifers (A) 0.95, 4.82; (B) 0.91, 5.06. Over both trials, the two-phase system was 4.5% more efficient. There was no difference in yield grade, quality grade or carcass fat analyzed from the 9-10-11 rib section between the two treatments.

OBJECTIVES

1. To determine the net energy value of corn silage varying in grain content.
2. To determine the net energy value of rations with varying proportions of corn silage to corn grain.
3. To determine the influence of ration grain content on feedlot performance and carcass characteristics.
4. To compare the performance of steers fed on a two-phase to rations containing a constant percentage of grain.
5. To determine the net energy value of brown midrib and high oil corn silage.
6. To develop equations for predicting feedlot performance and net energy value of rations.

MATERIALS AND METHODS

Corn Silage Harvested From Three Plant Populations

Experimental Design

Corn varieties representative of those commonly grown in Michigan were planted for two consecutive years to study the influence of corn plant population with varying grain content on subsequent feedlot performance and carcass characterisitcs. In an attempt to vary the percentage of grain in the corn silage, various plant populations were grown. In the first year, Michigan 396, a three-way cross variety, was planted in 8.1-hectare plots to yield approximate plant populations of 24,709, 49,419 and 74,128 plants/hectare. Brown midrib and high oil corn varieties were also planted in 4.1-hectare plots with a plant population of 49,419/hectare. At time of planting, 36.7 kg of 12-24-24 granulated fertilizer was added per hectare. Anhydrous ammonia fertilizer was applied approximately three weeks post-planting at the rate of 18.38 kg of actual nitrogen per hectare. Following a growing period of 108 days for the three plant populations and 117 days for the high oil and brown midrib varieties, corn silage was harvested at 30% dry matter to insure physiological maturity and ensiled in upright concrete silos.

In the second year, Michigan 407, a two-way cross variety, was planted in 8.1-hectare plots to yield approximate plant populations of 24,700, 49,419 and 123,548 plants/hectare. At the time of planting, 36.7 kg of 10-20-20 granulated fertilizer was added per hectare. Approximately three weeks post-planting anhydrous ammonia fertilizer was applied at the rate of 18.38 kg of actual nitrogen per hectare. Following a 118 day growing period, corn was harvested as silage at 35% dry matter to insure physiological maturity and was ensiled in upright concrete silos.

Laboratory Analysis and Plant Component Determinations

Prior to harvest, four subsamples consisting of 10 corn plants each were randomly selected from each corn plot. The samples were dissected and the distribution of stalk, leaf, husk, cob and grain were determined. Dry matter distribution for each component was determined following a period of drying for 24 hours in a forced air oven at 60°C. Grain and forage yields per hectare were determined from the total dry matter and the ear to stover ratio of the dissected corn plants.

Crude protein (N x 6.25) for each plant component was determined from a dry sample using the Technicon Auto-Kjeldahl system. Acid detergent fiber of the dried feed samples were determined by the standard Van Soest procedure (Van Soest, 1963; Van Soest and Wine, 1967).

Feedlot Study

Experimental Design and Rations

In trial 1, 80 Charolais crossbred steers weighing 226.8 kg were fed to determine the net energy value of rations containing corn silage varying in grain content and the impact of added grain on corn silage net energy value. The calves were purchased in November at a feeder calf sale at Gaylord, Michigan, and were transported by truck 402 km to the MSU Beef Cattle Research Center. Upon arrival the steer calves were fed an experimental starting on feed ration for a period of 28 days prior to the beginning of the experiment.

As shown in the following experimental design, the steers were randomly allotted by weight groups to their respective treatment (Table 6). Each of the three silages grown at different plant populations with varying grain content (27% to 49%) were fed to two pens of eight steers each with one of the two pens receiving the respective silage plus added grain in the ration. In addition, one pen of steers each were fed a 91% or 96% concentrate ration. Brown midrib and high oil silage were each fed to one pen of eight steers. Ingredients fed in trial 1 and the nutrient composition of each ingredient is described in Table 8.

In trial 2, 80 Hereford steers weighing 272.1 kg were fed. The calves were purchased in October from the Arthur King Ranches in Channing, Texas, and were transported 1,931 km by truck to the MSU Beef Cattle Research Center. Upon arrival the steers were fed an experimental starting on feed ration for a period of 28 days prior to the beginning of the experiment.

Table 6. Experimental Design (Trial 1)[a]

	Corn silage			Silage plus added grain			High concentrate		Brown midrib	High oil
No. steers/ treatment	8	8	8	8	8	8	8	8	8	8
% grain in silage	27	43	49	27	43	49	43	--	36	39
% added grain[b]	4	4	4	39	39	39	86	96	4	4
Total grain in ration	29	40	50	55	64	68	91	96	38	41

[a]Average initial shrunk weight of 226.8 kg.

[b]Includes corn in supplement.

As described in the following experimental design, the steers were randomly allotted by weight groups to their respective treatments (Table 7). Each of three corn silages grown at different plant populations and with varying grain content (36% to 53%) were fed to two pens of eight steers each with one of the two pens of eight steers receiving the respective silage plus added corn grain. One pen of steers was fed a 90% or 96% concentrate ration. In addition, two pens of steers were fed on a two-phase system in which they received all silage rations containing low (36%) or high (53%) grain content silage. Steers on the two-phase system were switched from their respective silage ration to all concentrate at 415 kg. At this time it was predicted that they would consume approximately the same amount of

Table 7. Experimental Design (Trial 2)[a]

	Corn silage			Silage plus added grain			High concentrate		Two-phase system[b]: Low grain silage	Two-phase system[b]: High grain silage
No. steers/ treatment	8	8	8	8	8	8	8	8	8	8
% grain in silage	36	50	53	36	50	53	50	--	36	53
% added grain[c]	5	5	5	48	51	53	59	96	31	31
total grain in ration	38	51	54	59	67	69	90	96	57	68

[a]Average initial shrunk weight of 272.1 kg.

[b]Steers were switched from all silage to all concentrate at 415 kg.

[c]Includes grain in supplement.

total grain throughout the feeding period as the respective silage plus added grain group. The ration ingredients fed in trial 2 and the nutrient composition of each ingredient is shown in Table 9.

Composition of the urea-mineral protein supplements fed in the two-year feeding study is described in Table 10. At the beginning of the experiments, rations were supplemented to a 13% crude protein level. When the steers reached 408 kg, the protein level in the ration was reduced to 12.0%.

Table 8. Nutrient Composition of Ration Ingredients (Trial 1)

Ingredient	Int. ref. no.	Nutrient content, % of dry matter Dry matter[a]	Crude protein[a]	Ca.	P	K
Corn, aerial pt, w-ears, w-husks, ensiled						
27% grain	--	27.70	8.65	0.28	0.21	0.95
43% grain	--	30.60	8.66	0.28	0.21	0.95
49% grain	--	32.90	9.74	0.28	0.21	0.95
High oil	--	27.90	9.47	0.28	0.21	0.95
Brown midrib	--	30.40	7.90	0.28	0.21	0.95
Corn, dent, yellow, grain gr. 2 US	4-02-931	70.000	10.50	0.03	0.35	0.46
Urea, 45% N		100.00	281.00	--	--	--
Limestone, grnd.	6-02-632	100.00	--	33.80	--	--
Phosphate, def. grnd.	6-01-780	100.00	--	33.10	18.00	--
Calcium sulfate	--	100.00	--	20.30	--	--
Potassium chloride	--	100.00	--	--	--	52.30
Trace mineral salt	--	100.00	--	--	--	--
Vitamin A[b]	--					
Vitamin D[c]	--					

[a]Determined by actual laboratory analysis.

[b]Vitamin A, 30,000 IU per g.

[c]Vitamin D_3, 3,000 IU per g.

Table 9. Nutrient Composition of Ration Ingredients (Trial 2)

Ingredient	Int. ref. no.	Dry matter[a]	Crude protein[a]	Ca	P	K
	Nutrient content, % of dry matter					
Corn, aerial pt, w-ears, w-husks, ensiled						
36% grain	--	37.20	8.10	0.28	0.21	0.95
50% grain	--	42.80	8.40	0.28	0.21	0.95
53% grain	--	41.40	8.70	0.28	0.21	0.95
Corn, dent, yellow, grain gr 2 US	4-02-931	70.00	10.50	0.03	0.35	0.46
Urea, 45% N	--	100.00	281.00	--	--	--
Limestone, grnd.	6-02-632	100.00	--	33.80	--	--
Phosphate, def. grnd	6-01-780	100.00	--	33.10	18.00	--
Calcium sulfate	--	100.00	--	20.30	--	--
Potassium chloride	--	100.00	--	--	--	52.30
Trace mineral salt	--	100.00	--	--	--	--
Vitamin A[b]						
Vitamin D[c]						

[a]Determined by actual laboratory analysis.

[b]Vitamin A, 30,000 IU per g.

[c]Vitamin D_3, 3,000 IU per g.

Table 10. Composition of the Protein Supplements

Ingredient[a]	Ration: Low grain corn silage	High grain corn silage	Corn silage +40% corn grain	High concentrate rations
	-------- (% content of supplement) ---------			
Gd. sh. corn, dent yellow, gr. 2 US	63.78	66.66	66.32	56.24
Urea (45% N)	19.77	15.33	15.25	13.50
Trace mineral salt	3.19	3.32	3.32	2.80
Vitamin A[b]	0.13	0.13	0.13	0.13
Vitamin D[c]	0.13	0.13	0.13	0.13
Calcium sulfate	3.95	4.13	4.11	4.05
Defluorinated phosphate	9.06	10.27	6.50	--
Limestone, grnd.	--	--	4.24	13.27
Potassium chloride	--	--	--	9.90

[a]Average nutrient composition (NRC, 1976).

[b]Vitamin A, 30,000 IU per g.

[c]Vitamin D_3, 3,000 IU per g.

Feeding, Weighing and Management Practices

The corn silage fed in this experiment was stored in upright concrete silo while the high moisture corn was stored in a Harvestore silo. Immediately prior to feeding, corn silage, high-moisture corn and the urea-mineral supplement were mixed in a horizontal batch feed mixer. The complete rations were fed once daily. Feed intake was recorded daily and the unconsumed feed removed and weighed periodically. Protein content (N x 6.25) and dry matter of the corn silage, high-moisture corn and urea-supplement was determined bi-weekly. Crude protein of the ration ingredients was determined from a wet sample using the Technicon Auto-Kjeldahl system. Moisture was determined from drying for 24 hours in a forced air oven at 60°C. Corn and corn silage intakes were adjusted for errors in dry matter determination by factors of 1.03 and 1.068, respectively (Fox and Fenderson, 1977).

Initial and final shrunk weights for all cattle were obtained after a 16 hour shrink without feed and water. Intermediate weights were obtained every 28 days following a 16 hour shrink without water.

Within 12 hours of arrival, steers were vaccinated for pasteurella and a 3-way vaccine containing infectious bovine rhinotracheitis (IBR), bovine virus diarrhea (BVD) and parainfluenza (PI_3). Steers were injected with 2 million international units of vitamin A and a pour-on for grubs and lice was administered. A pasteurella booster was given at two to four weeks following the initial injection.

In trial 1, all steers were implanted initially and every 112 days with Synovex S. In trial 2, steers were implanted initially and at 112 intervals with Ralgro.

All steers (8/pen) were housed in concrete, fully covered, straw bedded pens.

Slaughter, Carcass Evaluation and Collection of Data for Estimation of Carcass Composition

In trial 1, steers fed high grain rations were slaughtered when 80% were estimated to grade low choice; the remaining pens were slaughtered when they reached approximately the same shrunk weight (512.5 kg). When steers were removed from the experiment they were held off feed and water for 16 hours, the twelfth rib fat was estimated by an Ithaco Ultrasonic Scanoprobe and individual shrunk weights were taken. Cattle were then transported by truck 105 km to Walter Packing Plant in Coldwater, Michigan, where they were slaughtered. Warm carcass weights were obtained and the carcasses chilled for 24 hours prior to evaluation by a federal USDA grader. Following carcass evaluation, the 9-10-11 rib cut was removed from one side of each carcass according to procedures described by Hankins and Howe (1946). Rib samples were transported to the MSU meats laboratory for further processing.

In trial 2, cattle were removed from the experiment with an average shrunk weight of 497.5 kg and were processed in a similar procedure as in trial 1. Cattle were transported 177 km to the Dinner Bell Packing Plant in Archbold, Ohio, where they were slaughtered. Warm carcass weights were obtained and the carcasses were chilled for 24 hours prior to evaluation by a federal USDA grader. Following carcass evaluation, the carcass composition was determined by the specific gravity technique (Kraybill, 1952). In this procedure the left side of each carcass was split between the 12th and 13th rib and each quarter was weighed in air and then submerged under water into a stainless steel tank (238.9 cm wide by 464.5 cm in height) and weighed under water with a 5 kg Toledo Pan Balance scale (Toledo Scale Company, Toledo, Ohio). Carcass and water temperature (centigrade) were measured periodically. Carcass composition was estimated from specific gravity using previously developed equations, as described in Table 11.

Procedures for Estimation of Carcass Composition

In trial 1, six Charolais crossbred steers (226.8 kg) were selected at random by weight groups and slaughtered to determine initial body composition. Steers fed high grain rations were slaughtered when 80% were estimated to grade low choice and then the remaining pens were slaughtered when they reached approximately the same shrunk weight (512.5 kg). At the time of slaughter, the 9-10-11 rib section was removed for chemical analysis. The rib cut samples were separated into soft tissue and bone. The soft tissue was ground and mixed five times with a Hobart meat grinder using a 0.47 cm plate. Approximately 500 g of sample was frozen for storage. Prior to analysis, samples were thawed for 24 hours. Chemical analysis of each rib sample included crude protein (N x 6.25), ether extract, ash and moisture content. Protein content was analyzed using wet samples by the Technicon Auto-Kjeldahl system. Ether extraction was determined from dried samples using the Goldfisch procedure. Moisture was determined from drying in a forced air oven at 100°C for 24 hours. Fat and protein determination of the 9-10-11 rib section from chemical analysis was used to estimate initial and final body composition (Hankins and Howe, 1946). Empty body composition was estimated from carcass composition using the equations developed by Garrett and Hinman (1969).

In trial 2, four Hereford steers (274.4 kg) were selected at random by weight groups and were slaughtered to determine the initial body composition. The procedure for removing the steers for slaughter was the same as trial 1. To estimate initial body composition, the 9-10-11 rib section was removed for chemical analysis (Hankins and Howe, 1946). Chemical analysis included crude protein, ether extract, ash and moisture determination, as described in the first trial. At the termination of the feeding trial, final body composition was determined by the specific gravity technique (Kraybill et al., 1952). Empty body composition was estimated from carcass composition using the equations developed by Garrett and Hinman (1969). The determination of net energy values of the rations from previously established equations is described in Table 11.

Table 11. Determination of Net Energy Value of Rations

Net energy value of each of the rations were determined from previously established equations, as follows:

1. Total carcass composition is determined by:

   a. Analysis of the 9-10-11 rib section (Hankins and Howe, 1946).
      Carcass protein, % = .66X + 5.98
        where X = 9-10-11 rib cut protein, %.
      Carcass fat, % = .77X + 2.82 where X = 9-10-11 rib cut fat, %.

   b. Specific gravity technique (Kraybill, 1952).
      SG = (carcass wt. in air)/(carcass wt. in air minus carcass wt. in water) (correction for water and carcass temperature).
      Carcass fat, % = 587.86 - 530.45X
        where X = carcass specific gravity (Garrett and Hinman, 1969).
      Carcass protein, % = (20.0X - 18.57) times 6.25
        where X = carcass specific gravity (Garrett and Hinman, 1969).

2. Empty body weight is calculated from the regression equation of Garrett *et al*. (1978)

   Y = 1.316X + 32.29 where Y = empty body weight; and
   X = chilled carcass weight.

3. Empty body composition is calculated from carcass composition (Garrett and Hinman, 1969).

   Empty body protein, % = .7772X + 4.456
     where X = carcass protein, %.
   Empty body fat, % = .9246X - .647 where X = carcass fat, %.

4. Energy retained is determined from the difference in body protein and fat between initial and final slaughter groups of cattle.

   Energy retained (Kcal) = FG x 9367 + PG x 5686 where
     FG = kg fat gain (Blaxter and Rook, 1953); and
     PG = kg protein gain (Garrett *et al*., 1958).

5. Metabolizable energy (ME) value of the rations is determined in a metabolic trial.

Table 11--Continued

6. Relationship between heat production (HP) and metabolizable energy intake (ME) is used to determine the feed needed for maintenance (Lofgreen and Garrett, 1968).

   a. HP = ME intake - energy retained.

   b. A regression of heat production (log HP) on metabolizable energy intake is established between total heat produced for the ration at *ad libitum* intake and basal heat production.

   c. $$\text{NEm} = \frac{77 \text{ Kcal}}{\text{DM intake/wt}^{.75} \text{ where ME} = \text{HP}}.$$

7. $$\text{NEg} = \frac{\text{Energy retained}}{\text{Total DM intake - DM needed for maintenance}}.$$

Metabolism Study

Experimental Design

The rations previously described were fed in metabolic trials to determine the metabolizable energy value of the various rations. In trial 1, 10 Charolais crossbred steer calves weighing 284.1 kg were utilized. The study consisted of 10 treatments fed to 10 steers for four periods. Each steer was fed for 15 days for adaptation to the respective ration, followed by a 5 day collection period. At the end of each period, each steer was randomly reassigned to a different treatment, with the restriction of never receiving the same ration twice. In trial 1, rations fed were the same as those in the feedlot study (Table 8). Each of three silages with varying grain content (27% to 49%) were fed to two steers each with one of the steers receiving the respective silage plus added grain in the ration. In addition, one steer was fed a 91% or 96% concentrate ration. Brown midrib and high oil silage was also fed to one steer.

In trial 2, 8 Hereford steer calves weighing 209.5 kg were utilized. The second study consisted of 8 treatments fed to 8 steers over four periods. As in trial 1, each steer was fed for 14 days for adjustment to the ration and was followed by a 5 day collection period. Rations corresponded with those fed in the feedlot study (Table 9). Each of three silages with varying grain content (36% to 53%) were fed to two steers each with one of the steers receiving the respective silage plus added grain in the ration. One steer each was fed a 90% or 96% concentrate ration.

In both years, ration crude protein was supplemented to 12.5%. Calcium, phosphorous, trace mineral salt and vitamins A and D were supplemented according to NRC (1976) recommendations.

Rations were mixed and fed _ad libitum_ once daily. The unconsumed feed was weighed and recorded daily. All animals were housed in an environmentally controlled room and were maintained in 91 cm x 244 cm individual collection stalls. All steers had free access to water.

Sample Collection

Ration samples were obtained daily for each steer during the collection period. A sample of mixed ration for each steer was frozen for the duration of the collection period. At the end of each period the composite samples were thawed, finely chopped in a Hobart food chopper, mixed and 1 kg was refrozen for further determinations.

In each period, total feces excreted for each steer was collected in a steel trough lined with plastic bags. At least every two days, the feces was collected, weighed, thoroughly mixed and a 10% subsample retained and frozen. At the end of the period, composited feces samples for each steer were thawed, mixed and approximately 1 kg was retained and frozen for dry matter, nitrogen and fecal energy determinations.

The total urine excreted during each period was collected for each steer. A plastic carboy, placed under each collection stall which contained 200 ml of 18 N sulfuric acid to prevent ammonia loss, was used for collection. At least every two days, urine was collected, measured and diluted to 10 liters of water. Approximately 10% or 1 liter of urine subsample was placed in plastic bottles and stored in a cooler during the collection period. At the end of the collection period, approximately 500 ml of sample was retained and frozen for nitrogen determination.

Chemical Analysis

Dry matter determination. Moisture was determined on the feed and feces samples. Feed samples were dried for a period of 24 hours in a forced air oven at 60°C. Approximately 200 g of feces was acidified with 25 ml of 4 N sulfuric acid and then dried similarly.

Acid-detergent fiber determination. Feed samples collected during the metabolism studies were dried and used to determine the acid detergent fiber level by using the standard Van Soest procedure (Van Soest, 1963; Van Soest and Wine, 1967).

Energy determination. Gross energy (Mcal/g) of the feed samples were determined by the Parr Adiabatic Oxygen Bomb Caliorimeter System. Bomb caliorimetry was performed on fecal samples. Metabolizable energy was estimated from digestible energy using a correction factor of .82 (NRC, 1976).

Nitrogen determination. Total nitrogen of the feed, urine and feces collected during the metabolism study was determined by the Technicon Auto Kjeldahl System.

Statistical Analysis

Statistical tests were designed to analyze the effect of ration grain content on feedlot performance and carcass characteristics. In both trials, least square regression analysis was applied to estimate parameters (Searle, 1971; Rao and Miller, 1971; Seber, 1977). Additional details in describing the analytical procedure may be found in Black and Harpster (1978). Parameter estimations were based upon least square procedures, as follows:

$$y_i = \Sigma\beta_k \, x_{ik} + u_i$$

where: y is the dependent variable (e.g., average daily gain, carcass characteristics), x_i are the independent variables (e.g., ration grain content, carcass weight) and u_i is the error term.

Feedlot performance. As previously reviewed, steers were fed corn silages varying in grain content, silage plus added grain or high concentrate rations in a two-year study. The impact of ration grain level in the diet on feedlot performance was analyzed. Dependent variables included average daily gain, feed efficiency, NE_m, NE_g and dry matter intake. Independent variables included percentage of grain in the ration, source of grain and year. The following test was typical:

Hypothesis:

H_n: Feedlot performance is not influenced by increasing the percentage of grain in the ration.

vs

N_a: Steers receiving high grain rations had superior feedlot performance.

Model:

$$\text{Feedlot performance} = B_0 + B_1\ \%\text{Grain} + B_2\ \text{year}$$

$$\text{where: year} = \{ {-1 \atop +1}$$

Test: $B_1 = 0$ vs $B_1 > 0$.

Carcass characteristics. The impact of ration grain level in the ration on carcass characteristics was analyzed. Among the dependent variables estimated were marbling, maturity, quality grade, fat thickness, ribeye area, kidney, heart and pelvic fat, yield grade, carcass fat and dressing percent. The independent variables were percentage of grain in the ration, carcass weight and year. The test, for example, was:

Hypothesis:

H_n: Carcass characteristics are not influenced by increasing the percentage of grain in the ration.

vs

N_a: Steers receiving high grain rations are fatter than those fed all silage.

Model:

$$\text{Carcass} = B_0 + B_1\ \%\text{Grain} + B_2\ \text{Year} + B_3\ \text{carcass weight}$$

$$\text{where: year} = \{ {-1 \atop +1}$$

Test: $B_1 = 0$ vs $B_1 > 0$.

Model comparisons. Carcass data were analyzed in two steps. First, the hypothesis that hot carcass weight should be included as an independent variable was tested against the hypothesis that it should not. The following test was employed:

$$\frac{(RSSE-URSSE)/\#\text{ of restrictions}}{SSE/(I-K)} \sim F_{\alpha},\ \#\text{ of restrictions},\ I-K$$

where: RSSE is the error mean sum of squares when the restriction is imposed while URSSE is the error sum of squares when there is no restriction.

Second, the hypothesis was tested for all parameters described in the previous section.

Significance levels. Values at the $P < .20$ level were presented to allow for pooling similar data in later trials (Black and Harpster, 1978). For example, when the results of four trials are pooled with each a significance value of .10, they would have a significance value of .03 when combined.

RESULTS AND DISCUSSION

Corn Plot Study--Trial 1

Dry Matter Distribution of Corn Silage Harvested From Varying Plant Populations

The plant dry matter distribution for the different plant populations in the first trial is reported in Table 12. Grain percent was highest for the 24,709 plant population (48.9%) and reduced to 42.6% and 27.4% when plant populations were increased to 49,419 and 74.128 plants/hectare, respectively. With increased plant density, percent stalk in the corn plant increased from 20.1% to 36.9%. Also, leaf content was increased from 16.9% to 28.1% with an increase in plant population. As grain content decreases with increasing population, a decrease in cob (31.3%) and husks (65.5%) were observed.

Total dry matter yields were increased by 11.3% when plant populations were increased to 49,419, but no further increase was found at 74,128 plants/hectare, as shown in Table 13. With increased plant density, grain yield/hectare was reduced by 38.3%. There was a drastic increase in barren stalks from 6.6% to 47.5% when plant populations were increased. The lack of increase in dry matter yield at the high population was most likely due to a large reduction in grain content and a high degree of barren stalks. Increasing plant populations and thus reducing the grain content resulted in lower protein in the corn silage.

Table 12. Dry Matter Distribution in Corn Plants (Trial 1)

	Plants/hectare		
	24,709	49,419	74,128
	--- % in plant dry matter ---		
Plant component:			
Grain	49.0	42.6	27.4
Stalk	20.1	24.6	36.9
Leaves	16.9	21.9	28.1
Cob	8.0	7.1	5.5
Husks	6.1	3.8	2.1

Table 13. Characteristics of Corn Silage Harvested From Three Plant Populations (Trial 1)

	Plants/hectare		
	24,709	49,419	74.128
Dry matter yield (ton/hectare)	11.22	12.65	12.35
Grain yield (bu/hectare)	230.3	225.8	142.1
Barren stalks, %	6.6	21.8	47.5
Protein, %	9.74	8.66	8.65
Acid detergent fiber, %	22.8	24.7	26.7

Increasing plant populations from 24,709 to 74,128 plants/hectare reduced the silage protein content from 9.74% to 8.65%. Acid detergent fiber was 15.0% higher for the silage containing 27.0% grain.

Dry Matter Distribution of High Oil and Brown Midrib Corn Silage

The plant dry matter distribution for the high oil and brown midrib corn silage as compared to the normal variety of similar plant population of 49,419 plants/hectare is reported in Table 14. Percent grain in the high oil and brown midrib plants were 8.7% and 15.0% lower in the normal 49,419 population, respectively. High oil corn was similar in stalk content but the brown midrib variety had 13.4% more stalk. Also, brown midrib corn had a 4.8% increase in leaf content but no increase was found for the high oil variety, as compared to the normal population. High oil and brown midrib varieties were 29.7% and 12.1% higher in cob and husk content, respectively.

Dry matter yields of high oil and brown midrib corn silage as compared to a normal variety of similar plant population of 49,419 plants/hectare are reported in Table 15. The high oil variety was similar but the brown midrib variety had a 9.0% lower dry matter yield than the 49,419 population. Grain yields were reduced by 19.2% and 22.6% for the high oil and brown midrib corn, respectively. The high oil variety had a protein content of 9.74% while the brown midrib silage was the lowest of those studied. Acid detergent fiber content was similar to normal for the high oil but was reduced by 8.9% for brown midrib.

Table 14. Dry Matter Distribution in High Oil and Brown Midrib Corn Plants (Trial 1)

	Normal[a]	High oil[a]	Brown-midrib[a]
	--- % in plant dry matter ---		
Plant component:			
Grain	42.6	38.9	36.2
Stalk	24.6	24.5	28.4
Leaves	21.9	21.1	23.0
Cob	7.1	9.4	8.4
Husks	3.8	6.1	4.0

[a]Population--49,419 plants/hectare.

Table 15. Characteristics of Corn Silage Harvested From Normal Plant Populations, High Oil and Brown Midrib Corn (Trial 1)

	Normal[a]	High oil[a]	Brown midrib[a]
Dry matter yield (ton/hectare)	12.65	12.63	11.51
Grain yield (bu/hectare)	225.8	206.6	174.7
Barren stalks, %	21.8	14.1	5.7
Protein, %	8.66	9.74	7.90
Acid detergent fiber, %	24.7	24.3	22.5

[a]Population--49,419 plants/hectare.

Corn Plot Study--Trial 2

Dry Matter Distribution of Corn Silage Harvested From Varying Plant Populations

The plant dry matter distribution for plants grown at 24,709, 49,419 and 123,548 plants/hectare is reported in Table 16. Grain percent was highest for the 24,709 plant population (53.8%) and was reduced to 50.7% and 36.9% when plants/hectare were increased to 49,419 and 123,548, respectively. As plant density was increased, stalk and leaf content was increased by 38.9% and 42.9%, respectively. With increasing plant population and a reduction in grain content, there was a decrease in cob (20.7%) and husk (22.6%).

Yields of corn silage harvested from varying plant populations in trial 2 are reported in Table 17. Total dry matter yields were reduced by 5.2% when plant populations were increased to 49,419 but an increase in yield of 34.6% was found at 123,548 plants/hectare. When plant density was increased to 49,419 plants/hectare grain yield was reduced by 10.7%. As population was further increased, there was a 4.8% increase in bushels/hectare. There was an increase in barren stalks to 23.6% with the highest population. Increasing plant populations from 24,709 to 123,548 plants/hectare reduced the protein content from 8.7% to 8.1%. Acid detergent fiber was 21.1% lower for the silage containing 53.8% grain compared to silage harvested from the high population with 36.0% grain.

Table 16. Dry Matter Distribution in Corn Plants (Trial 2)

	Plants/hectare		
	24,709	49,419	123,548
	--- % in plant dry matter ---		
Plant component:			
Grain	53.8	50.7	36.9
Stalk	15.1	18.3	24.7
Leaves	14.5	16.6	25.4
Cob	8.2	7.3	6.5
Husk	8.4	7.1	6.5

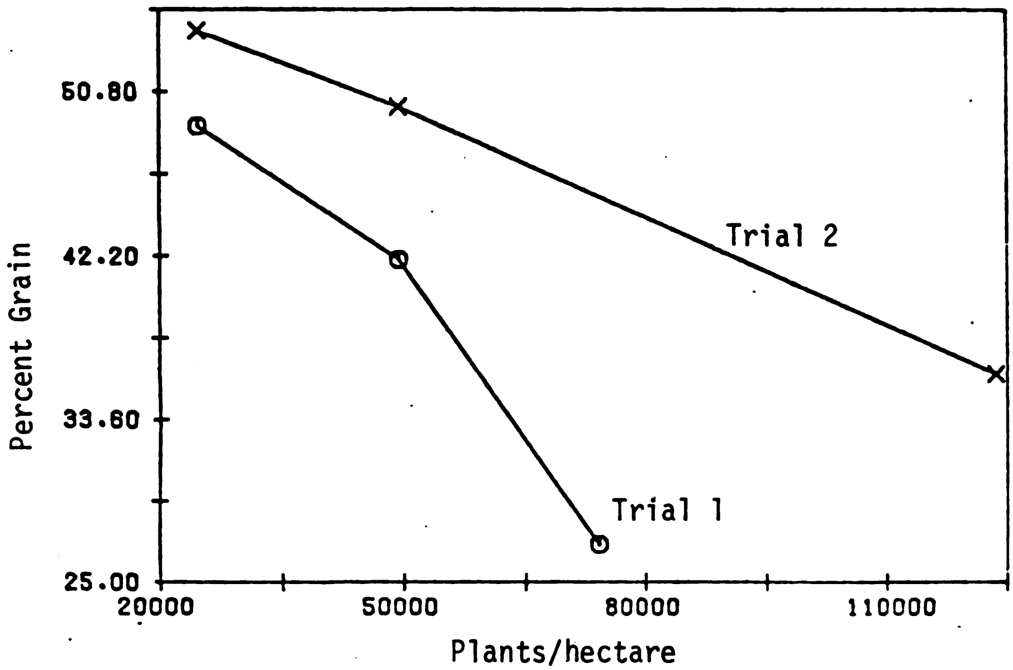
Table 17. Characteristics of Corn Silage Harvested From Three Plant Populations (Trial 2)

	Plants/hectare		
	24,709	49,419	123,548
Dry matter yield (ton/hectare)	10.40	9.86	15.91
Grain yield (bu/hectare)	235.2	210.0	247.1
Barren stalks, %	--	4.1	23.6
Protein, %	8.7	8.4	8.1
Acid detergent fiber, %	19.5	21.7	24.7

Comparison of the Two-Year Study of Corn Silage Grown in Different Plant Populations

The effect of corn plant population on dry matter distribution of plant components is plotted in Figures 4 and 5. As corn plant populations increased, there was a dramatic reduction in percent grain in the ration dry matter. Percent grain was lower at the lower plant population in trial 1 than in trial 2 due to an increase in stalk barrenness. These data are in agreement with most studies; the percent grain in the dry matter is reduced when the plant population is increased. Duncan (1958), Rutger and Crowder (1967) and Fairburn et al. (1970) reported a reduction in the amount of grain per plant as corn plant populations increased. As plant population increased from 48,999 to 86,000 plants/hectare, ear content was reduced by 10% (Cummins and Dobson, 1973). An increase in corn plant population from 9,884 to 59,303 plants/hectare resulted in a reduction of ear weight from .32 to .13 kg. The amount of dry grain produced/plant and the ratio of dried shell grain to total dry matter decreased as the plant population increased (Fairbourn et al., 1970 and Lutz et al., 1971). In view of these studies, the energy value of corn silage would be expected to vary due to varying grain content and the ear to stover ratio.

The percent stalk and leaf in the corn plant dry matter increased with increased plant density. Percent stalk increased at a greater rate in trial 1 due to a dramatic decline in the grain content of the corn plant. Cummins and Dobson (1973) reported a 5.0% reduction in stalk content as plant population was increased from



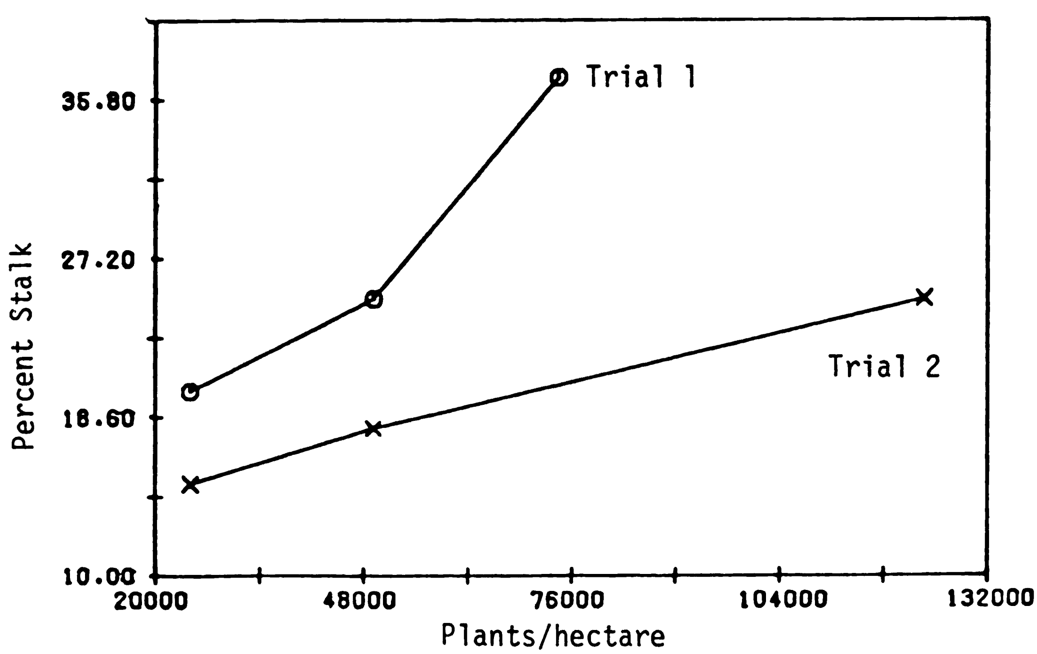
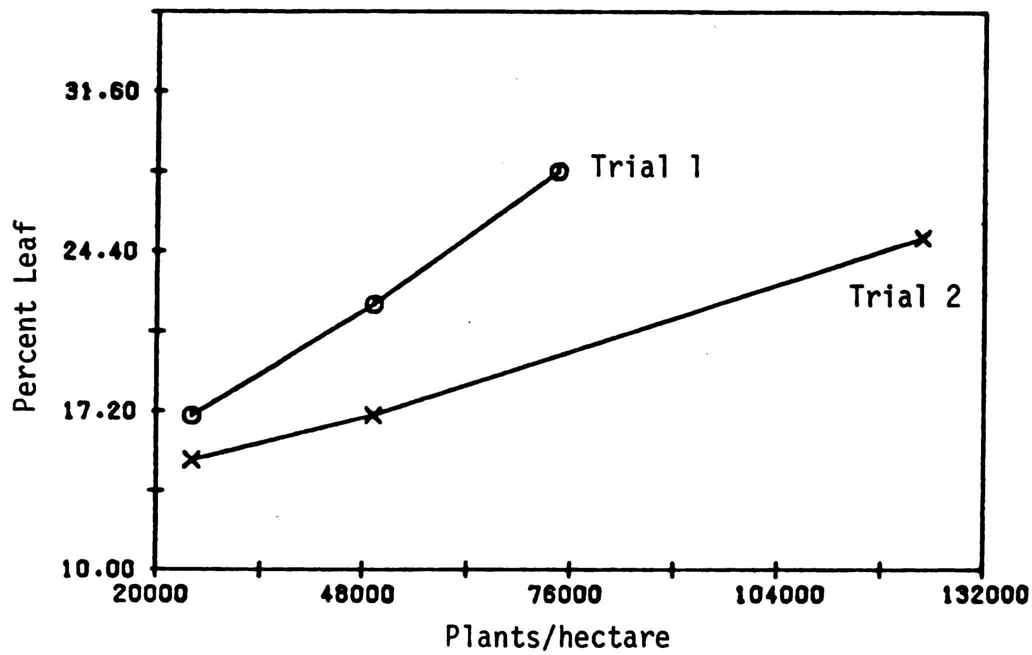


Figure 4. Relationship between corn plant population and percent grain and stalk in the ration.



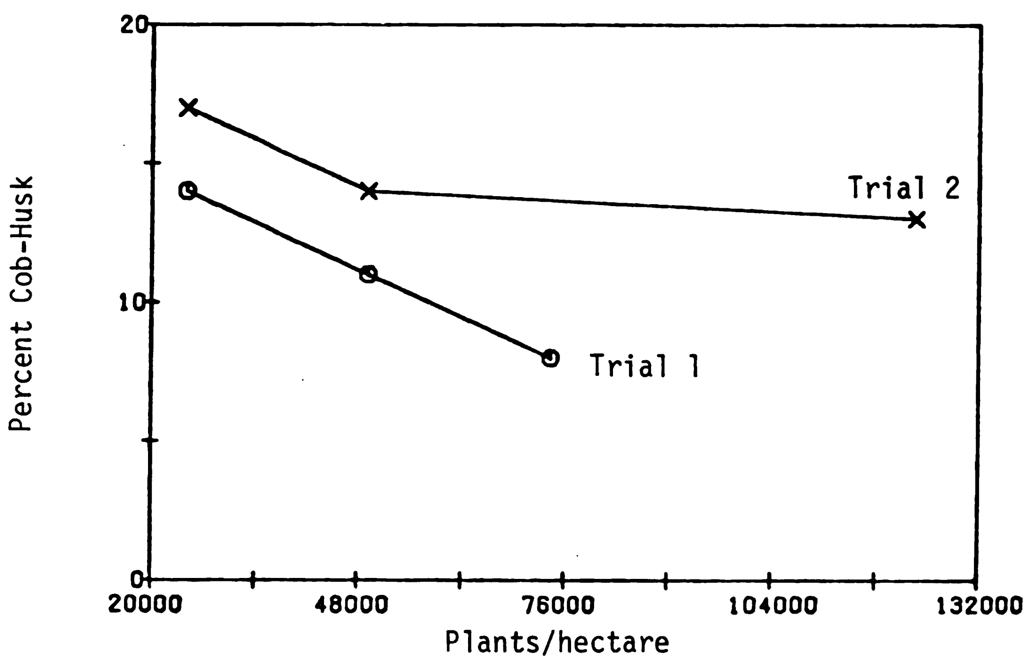


Figure 5. Relationship between corn plant population and percent leaf and cob-husk in the ration.

48,999 to 86,000 plants/hectare. Bryant and Blaser (1968), however, noted only a slight altered ration of ear, stalk and leaf to whole plant weight when plant population was increased from 38,999 to 98,799 plants/hectare. Similar results were reported by Robinson and Murphy (1972), who found no significant change in the ratio of forage to grain yield in populations of 29,503 to 98,802 plants/hectare.

Regression equations were developed from mean values of 240 samples for the two-year study for the prediction of relative dry matter distribution of corn silage with varying levels of grain content (Tables 18 and 19). As the grain content in the corn silage dry matter increased from 30% to 55%, percent leaf and stalk decreased by 48.6% and 56.2%, respectively, while cob and husk content increased. The grain content in the silage was highly correlated with the leaf ($R^2 = .97$), stalk ($R^2 = .94$), cob ($R^2 = .92$) and husk ($R^2 = .68$) content of the corn silage dry matter. These results are in agreement with Ayres and Buchele (1971) who reported a similar decrease in stalk and leaf content as grain increased in the corn plant when harvested at varying maturity levels.

Increased corn plant population resulted in increased dry matter yield (Figure 6). As reported in trial 1, total dry matter yields were increased by 11.3% when plant populations were increased to 49,419, but no further increase was found at 74,128 plants/hectare. The reduction in dry matter yield at the high population was due to a dramatic reduction in grain content. In trial 2, dry matter yields were reduced by 5.2% when plant populations were increased to 49,419

Table 18. Regression Equations Developed for the Prediction of Relative Dry Matter Distribution in Corn Silage From Silage Grain Content[a]

Plant component	Regression equation	$s_{\hat{y}}$	R^2
Leaf	Y = 44.01 - .54 grain (%) (11.41)	1.05	.97
Stalk	Y = 55.72 - .75 grain (%) (8.16)	2.03	.94
Cob	Y = 2.91 + .10 grain (%) (45.44)	0.32	.92
Husk	Y = -2.67 + .19 grain (%) (2.93)	1.45	.68

[a]Regression equations developed from mean values of 240 samples over 2-years. "T" values in parentheses.

Table 19. Relative Dry Matter Distribution of Corn Silage Varying in Grain Content[a]

Plant component	Percent grain in silage					
	30	35	40	45	50	55
Leaf	27.8	25.1	22.4	19.7	17.0	14.3
Stalk	33.3	29.6	25.8	22.1	18.4	14.6
Cob	5.8	6.3	6.8	7.2	7.7	8.2
Husk	3.0	4.0	4.9	5.9	6.8	7.8

[a]Predicted values by linear regression analysis of mean values over 2-years.

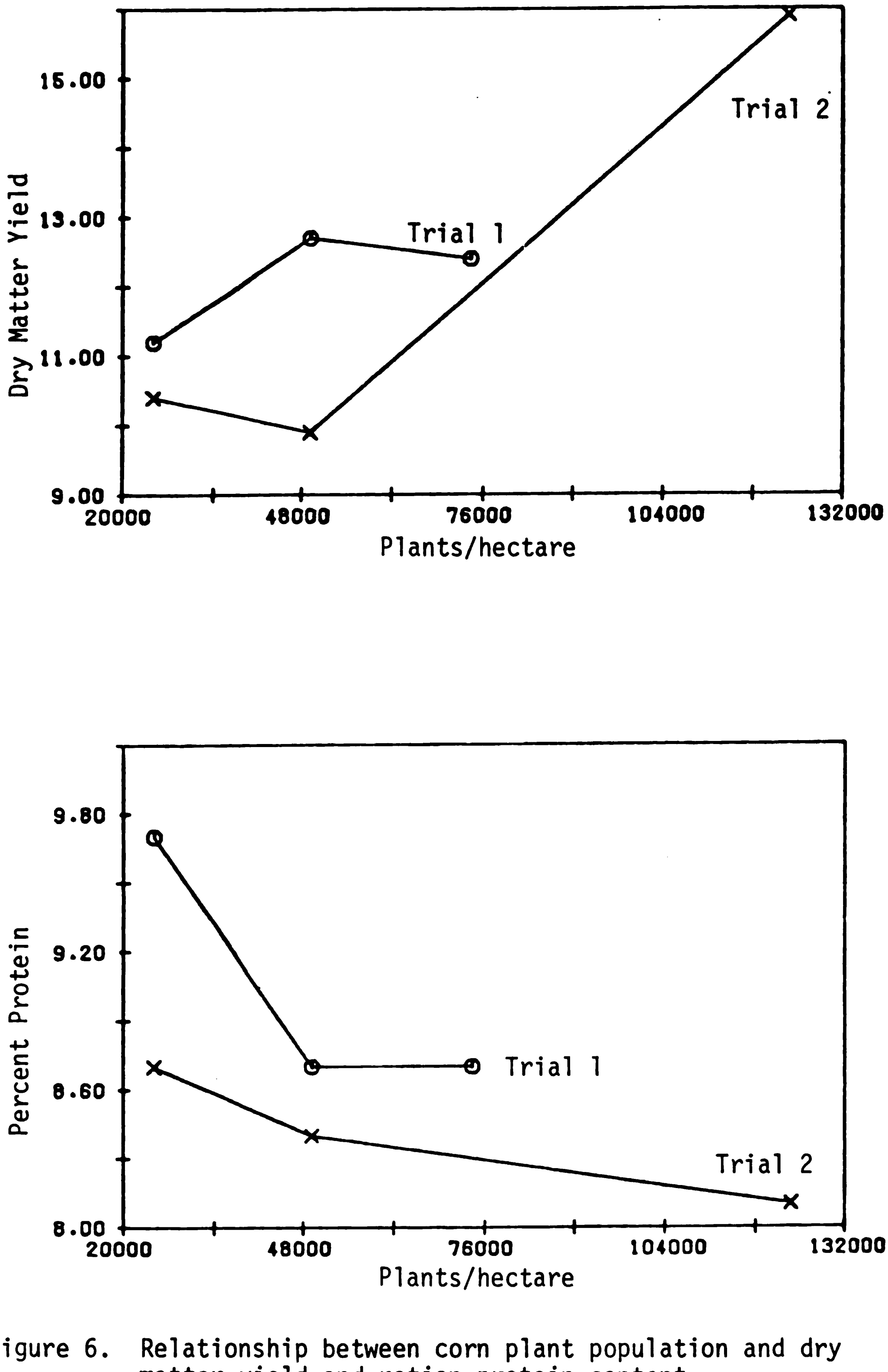


Figure 6. Relationship between corn plant population and dry matter yield and ration protein content.

plants/hectare but dry matter yields were increased by 34.6% at the higher populations. In numerous studies, increased corn plant population consistently increased dry matter production per hectare (Washko and Kjelgaard, 1966; Rutger and Crowder, 1967; Lutz and Jones, 1969; Robinson and Murphy, 1972). In these studies corn silage dry matter yields increased linearly with increased population up to 98,839 plants/hectare. Alexander et al. (1963) found that increasing the plant population from 16,679 to 33,358 plants/hectare increased yield of dry matter by 47.9%. Fairbourn et al. (1970) reported similar increases in dry matter yields when corn plant populations were increased from 21,000 to 44,972 plants/hectare. Rutger and Crowder (1967) and Stivers et al. (1971) reported a 4.0% to 6.0% increase in total dry matter yield when plant populations increased from 49,419 to 86,484 plants/hectare.

The effect of corn plant populations on the protein content of the whole corn plant is shown in Figure 6. In trial 1 protein was reduced from 9.74% to 8.65% with increased plant populations. There was also a decline of protein content from 8.7% to 8.1% in the second study. Alexander et al. (1963) compared 41,216 to 82,431 plants/hectare and found a reduction in protein content in the whole corn plant from 7.2% to 6.0%. Lang et al. (1956) reported a significant decline in protein content of corn grain from 11.8% to 9.8% when corn was harvested from 9,884 to 59,303 plants/hectare. Holter and Reid (1959) and Huber et al. (1965) reported that higher plant populations resulted in decreased protein digestibility, but results were not significant.

The effect of corn silage harvested from different plant populations and with varying grain content on acid detergent fiber is shown in Figure 7. In trial 1, acid detergent fiber was lower for the corn silage harvested from the low population and containing 49.0% grain compared to the silage harvested from the high population with 27.0% grain. In trial 2, acid detergent fiber was 21.1% lower for the silage containing 53.8% grain compared to silage with 36.0% grain harvested from the highest population.

The relationship between acid detergent fiber of the whole plant and the non-grain portion at various corn silage grain levels is shown in Figure 8. As the percent grain in the silage was increased, percent ADF of the whole corn plant was reduced but the percent of ADF in the non-grain portion increased. Johnson et al. (1978) reported the results of 50 corn silages that were harvested at different stages of maturity (Figure 9). There were small differences in digestibility and the increased grain levels were offset by increased levels of ADF in the non-grain portion. Our results are in agreement with those of Johnson et al. (1978), as percent grain in the silage was increased, ADF of the whole corn plant was reduced while ADF in the non-grain portion increased.

As corn plant population increased, grain proportion is reduced and the percent leaf, stalk, cob and husk in the dry matter increased. The non-grain portion is high in fiber and is increased considerably when the grain portion is reduced. Studies have indicated that a decline in digestibility of fibrous components in feedstuffs directly

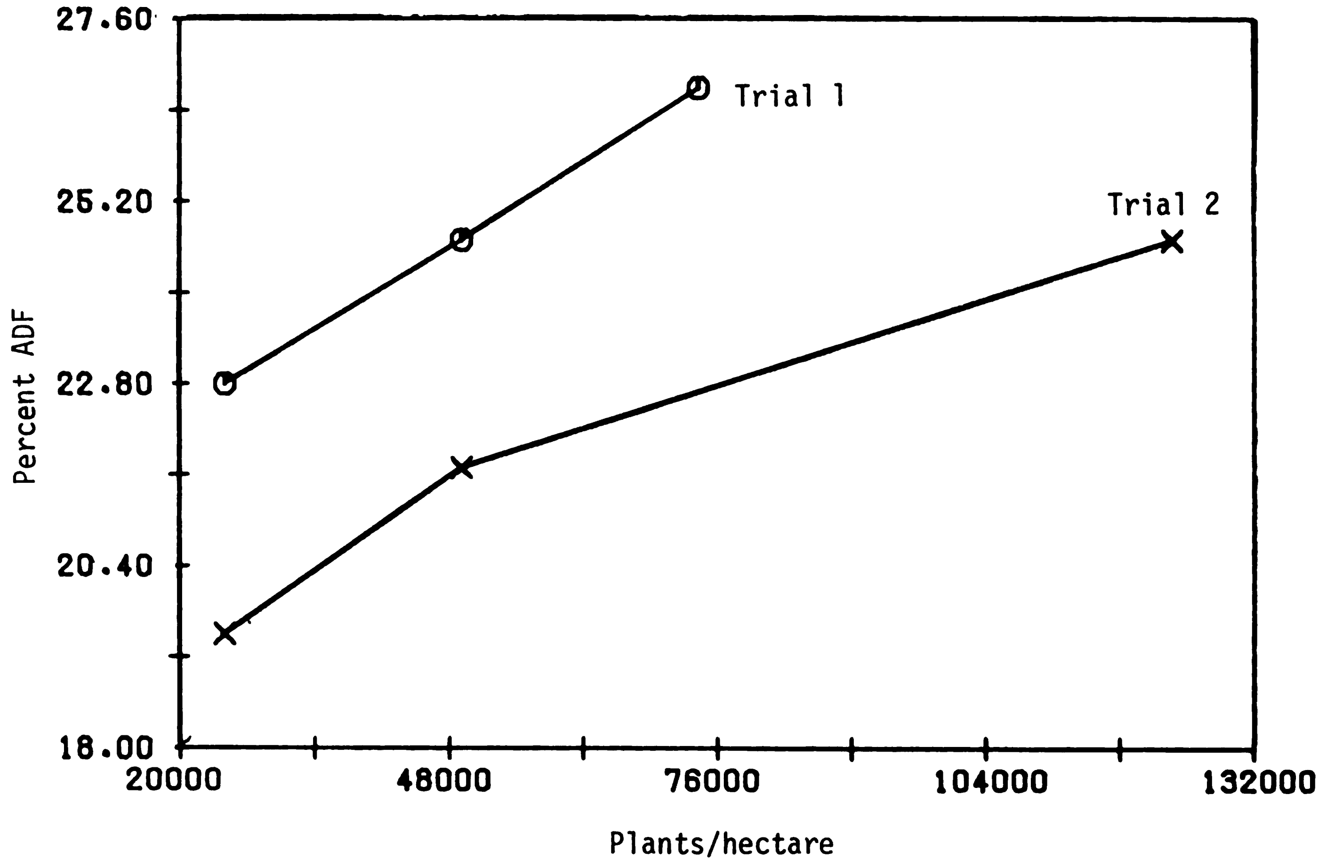


Figure 7. Relationship between corn plant population and ration ADF (%) level.

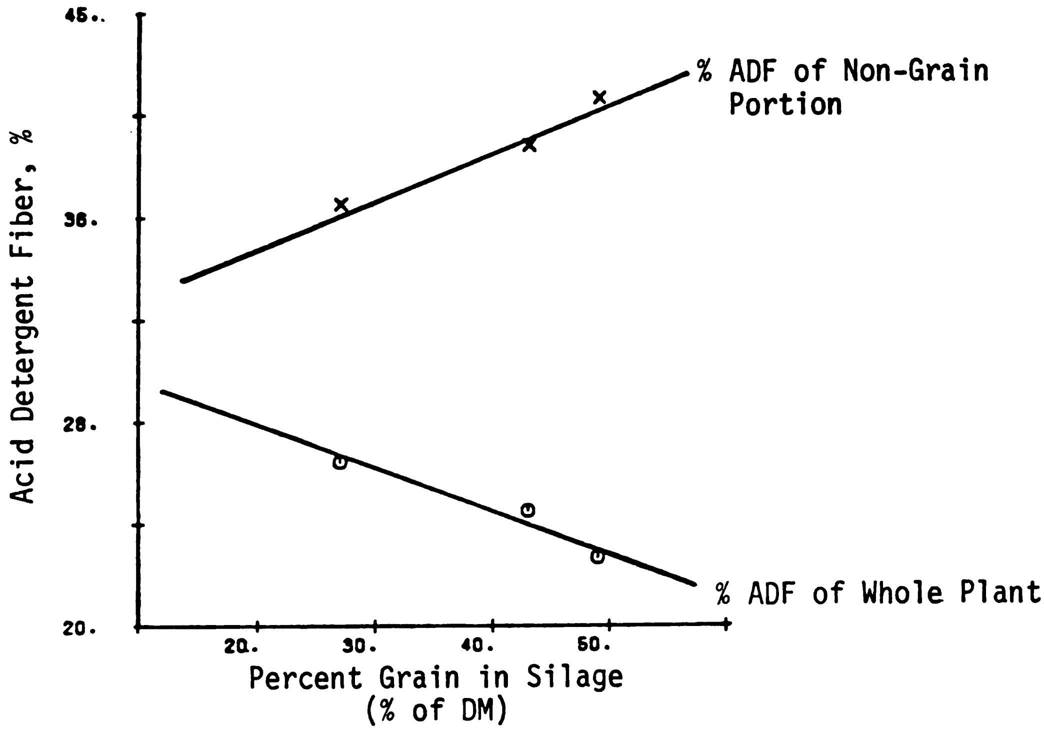


Figure 8. Acid detergent fiber of the whole plant vs the non-grain portion at various corn silage grain levels.

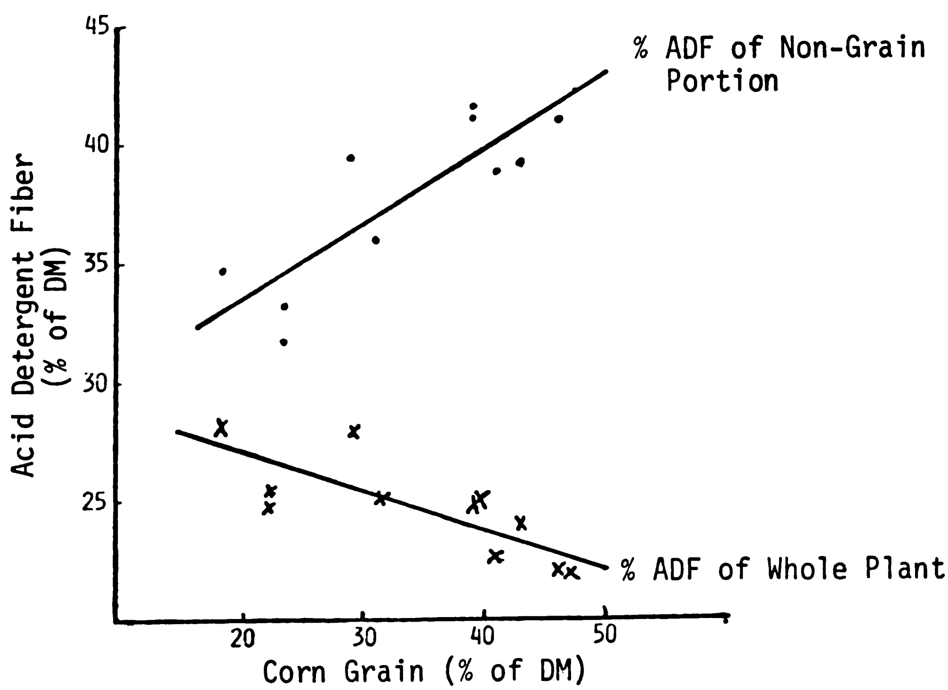


Figure 9. Acid detergent fiber of the whole plant vs the non-grain portion at varying stages of maturity of the corn plant (Johnson et al., 1978).

accounts for changes in cell wall digestibility (Van Soest, 1971). Cell wall is the most important component in feedstuffs of plant origin and includes cellulose, hemicellulose and lignin. The lignin within the cell wall is indigestible and appears to be the major factor in reducing the digestibility of high forage rations. The acid detergent fiber procedure determines the lignocellulose constituent of feedstuffs.

Feeding Studies

Description of Initial Slaughter Cattle

The composition of steers selected at random by weight groups and slaughtered to estimate initial carcass composition is reported in Table 20. The mean dressing percentage and carcass composition was used to estimate initial weight and composition of the cattle placed on experiment.

Table 20. Shrunk Weight, Carcass Weight and Carcass Composition of Initial Slaughter Cattle

Cattle type	No. head	Shrunk wt., kg	Carcass wt., kg	Dressing (%)	Carcass protein (%)	Carcass fat (%)
Charolais cross	6	232.7	131.1	56.4	18.3	14.7
Hereford	4	272.4	153.3	55.9	17.8	18.1

Feedlot Performance

The effect of ration grain content on feedlot performance in Trial 1 is reported in Table 21. Performance data were adjusted to a constant dressing percentage of 62.2%. Steers fed the all-silage rations with 50% grain gained faster and were more efficient than those fed 29% grain. As grain was increased from 55% to 96%, steers had higher average daily gains and improved feed efficiency.

The effect of ration grain content on feedlot performance in Trial 2 is reported in Table 22. Performance data were calculated on a constant dressing percentage of 61.7%. When the percent grain in the all-silage rations was increased from 38% to 54%, gains and feed efficiency were improved. As ration grain level was increased to 96%, steers gained faster and required less feed per unit gain.

The pooled data for the two-year trial is shown in Figures 10 and 11 and reported in Table 23. Average daily gains increased and feed required per unit gain was improved as the percentage of grain in the ration increased ($P < .0005$). Steers fed all silage rations increased in gain by 17% (.81 vs .98 kg) and feed efficiency improved by 12.3% (8.38 vs 9.55) as silage grain content was increased from 30% to 50%. Steers fed 69% grain gained 14.0% faster (1.16 vs .98 kg) and were 13.4% more efficient (7.22 vs 8.38) than those fed all silage with 50% grain. Steers fed a high concentrate ration with 90% grain gained 6.6% faster (1.24 vs 1.16 kg) and required 16% less feed per unit gain (6.05 vs 7.22) than those fed 70% grain. However the data was not consistent across years.

Table 21. Effect of Silage and Total Ration Grain Content on Performance of Steer Calves (Trial 1)[a]

Measure	Ration composition (DM basis)							
	93% silage 6% supplement			35% corn 59% silage 6% supplement			82% corn 12% silage 6% supplement	94% corn 6% supplement
Percent total corn in ration DM	29	40	50	55	64	68	91	96
Initial wt., kg	237	240	239	242	239	238	240	238
Final wt., kg	462	511	527	496	528	534	531	530
Days on feed	268	268	282	240	268	240	198	240
Daily gain, kg	0.83	1.01	1.02	1.06	1.08	1.23	1.47	1.22
Daily DM intake, kg[b]	8.13	8.84	8.50	9.02	8.76	9.03	8.23	7.42
Corn silage	7.61	8.27	7.98	5.33	5.14	5.45	1.01[c]	0.14[c]
HM corn	--	--	--	3.05	3.00	3.06	6.76	6.85
Supplement	0.53	0.57	0.52	0.64	0.62	0.51	0.52	0.43
Feed/gain	9.74	8.74	8.33	8.50	8.11	7.31	5.65	6.10
Carcass fat, %[d]	29.4	28.7	31.1	30.0	32.4	30.9	29.4	33.3

[a]Each treatment included 8 Charolais crossbred steer calves. Data were adjusted to a constant dressing percentage, 62.2%. Includes added grain and grain in silage.

[b]Corn and corn silage intake were adjusted upwards for errors in dry matter determination by factors of 1.03 and 1.068, respectively.

[c]Corn silage was fed during a two-week adaptation to all concentrate ration.

[d]Carcass fat determined by 9-10-11 rib analysis.

Table 22. Effect of Silage and Total Ration Grain Content on Performance of Steer Calves (Trial 2)

Measure	Ration composition (DM basis) 92% silage 8% supplement			31% corn 60% silage 9% supplement			80% corn 12% silage 8% supp.	92% corn 8% supp.	Two-phase[b] Low grain silage	Two-phase[b] High grain silage
Percent total corn in ration DM	38	51	54	59	67	69	90	96	57	68
Initial wt., kg	276	273	274	273	275	273	274	273	273	273
Final wt., kg	469	479	507	496	486	500	521	512	496	508
Days on feed	230	230	230	209	202	202	202	202	209	209
Daily gain, kg	0.84	0.90	1.01	1.06	1.04	1.12	1.22	1.18	1.07	1.12
Daily DM, kg[c]	7.88	7.54	7.86	7.92	7.85	7.91	6.87	6.49	7.53	7.30
Corn silage	7.19	6.94	7.27	4.64	4.74	4.78	0.92[d]	0.20[d]	4.64	4.51
HM corn	--	--	--	2.53	2.40	2.44	5.46	5.86	2.29	2.23
Supplement	0.69	0.59	0.60	0.75	0.71	0.68	0.49	0.42	0.61	0.55
Feed/gain	9.34	8.39	7.78	7.46	7.52	7.03	5.62	5.50	7.07	6.49
Carcass fat, %[e]	28.4	30.6	31.8	31.5	30.3	32.9	34.6	34.3	30.8	31.8

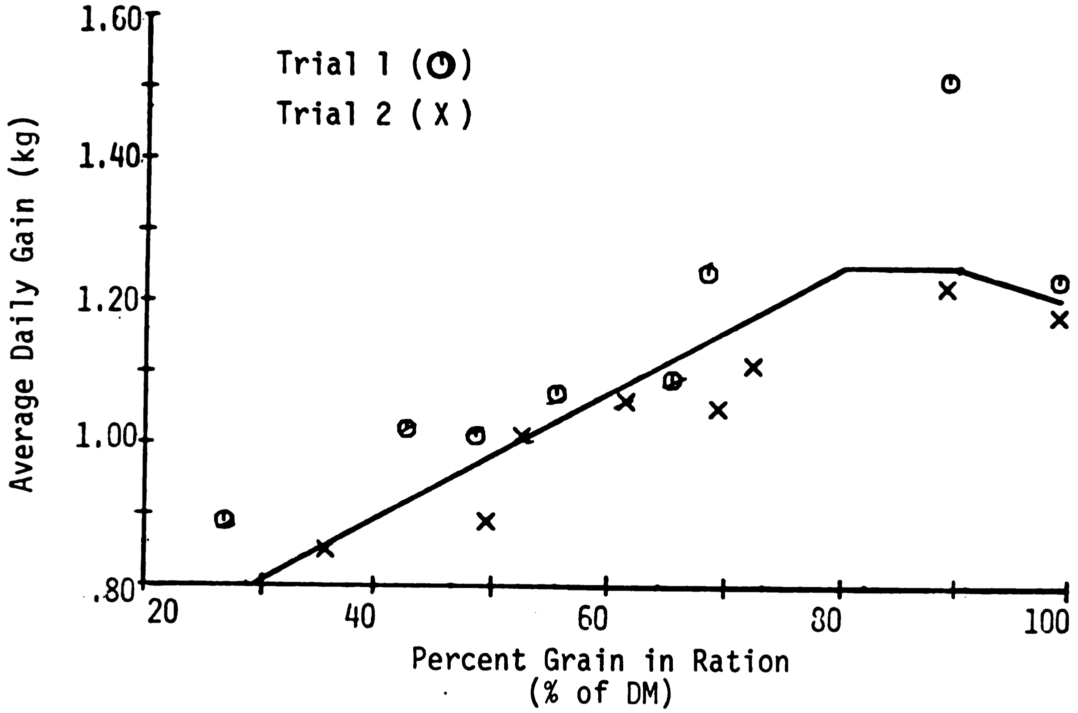
[a]Each treatment included eight Hereford steer calves. Data were adjusted on a constant dressing percentage (61.7%). Includes added grain and grain in silage.

[b]Steers switched from corn silage containing low (36%) and high (53%) grain content to the all concentrate ration at 415 kg.

[c]Corn and corn silage intakes were adjusted upwards for errors in dry matter determination by factors of 1.03 and 1.068, respectively (Harpster et al., 1978).

[d]Corn silage was fed during a two-week adaptation to cattle receiving all concentrate rations.

[e]Carcass fat determined by specific gravity technique.



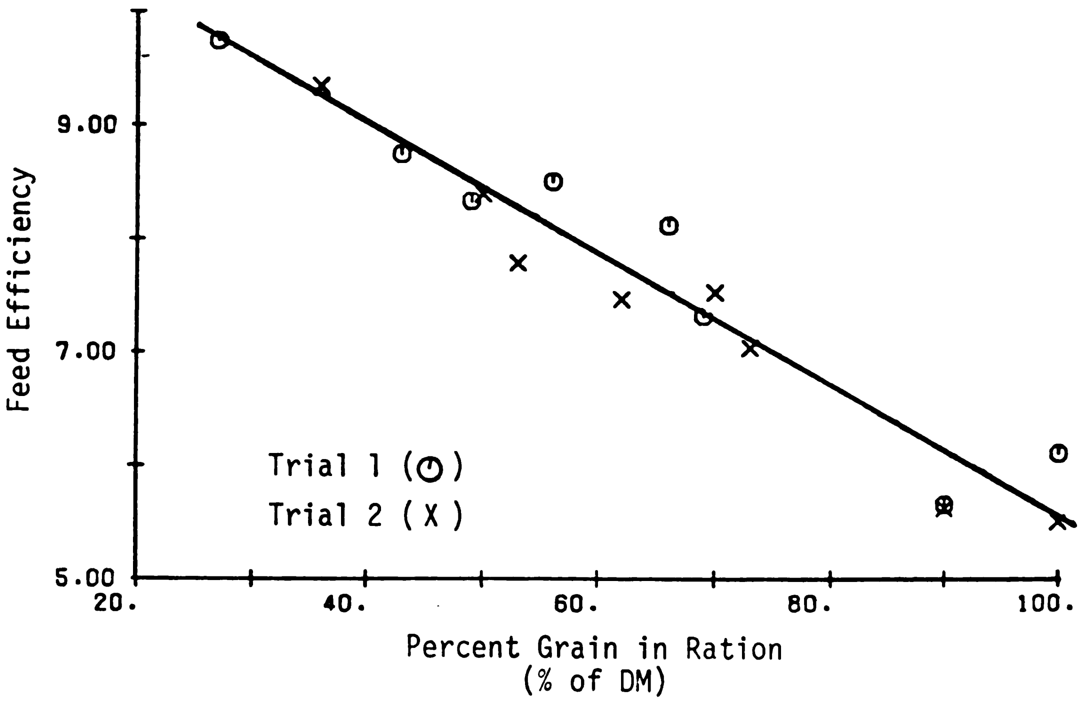


Figure 10. Effect of ration grain content on average daily gain and feed efficiency.

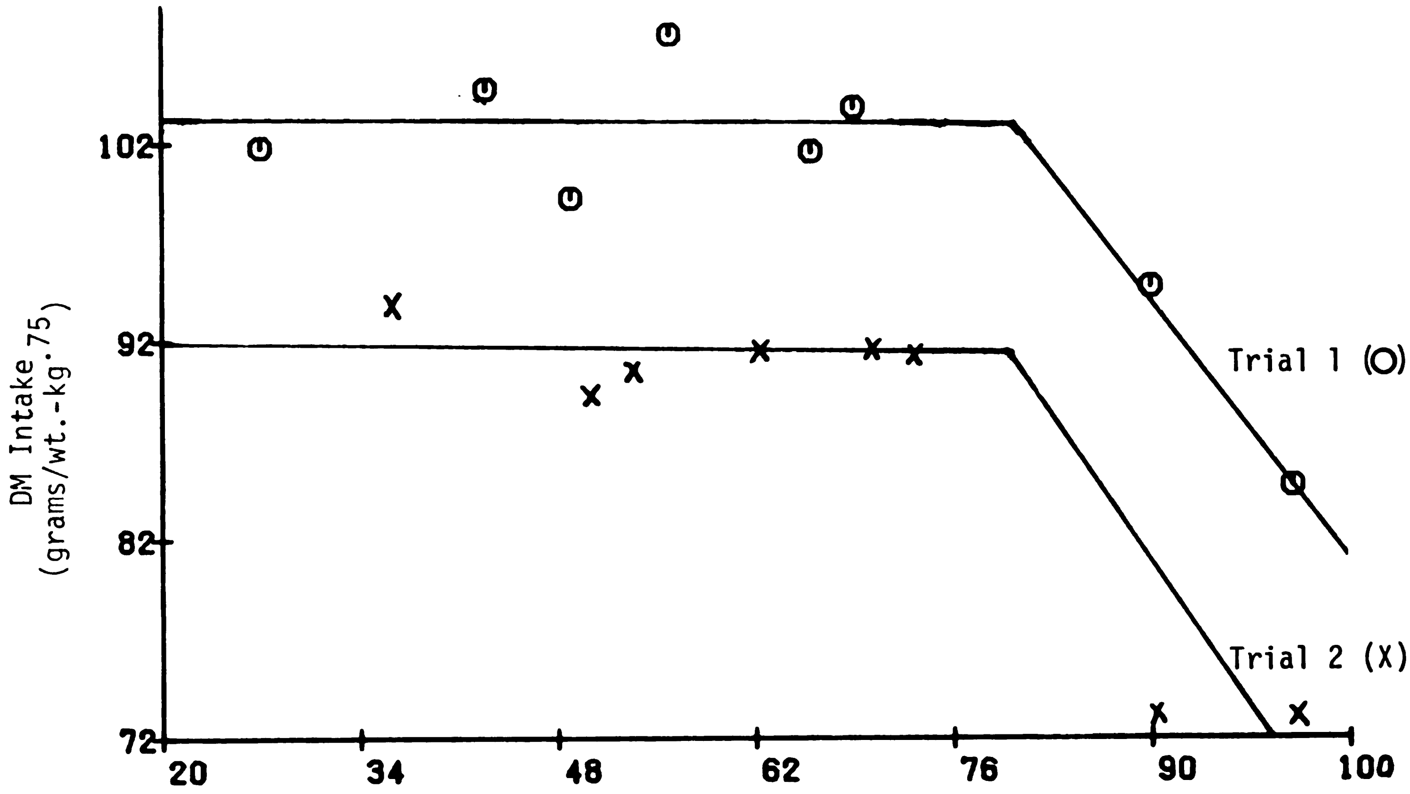


Figure 11. Effect of ration grain content on dry matter intake.

Table 23. Significance of Pooled Results on the Influence of Ration Grain Content on Feedlot Performance and Carcass Characteristics

Carcass characteristics	Significance level
Average daily gain (kg)	<.0005
Feed efficiency	<.0005
Maturity	NS[a]
Marbling	NS
Quality grade	NS
Fat thickness (cm.)	.04
Ribeye area (sq. cm.)	NS
Kidney, heart, pelvic fat (%)	NS
Yield grade	.16
Carcass fat (%)	.02
Dressing (%)	.01
NE_g (Mcal/kg)	<.0005

[a]NS = not significantly different: $P > .20$.

An examination of Figure 10 reveals that gains were increased by .009 kg per 1% unit increase in ration grain content up to 70%. Feed efficiency was improved by .058 per 1% unit increase in grain. The source of grain, whether added grain or grain in silage, does not appear to be an important factor. The feed efficiency for the steers fed the low grain silage plus 35% added grain was equal to the weighted average of those fed high grain silage (7.98 vs 7.94). Steers fed 91% grain in trial 1 performed better than expected, based on previous studies. The results in trial 2 were consistent with previous studies.

Dry matter intake ($g/wt_{kg}^{.75}$) remained constant as percent grain in the ration increased, but was dramatically reduced for steers fed the high concentrate rations (Figure 11).

It is concluded from the results of this study that an alteration in the ear-stover ratio of corn silage influences feedlot performance. As silage grain content is increased from 30% to 50%, average daily gain is increased (17%) and feed efficiency is improved (12%). This is in contrast with NRC (1976) that lists only one energy value for corn silage.

The impact of added grain on feedlot performance was examined in view of various studies. As the percent grain in the ration was increased by 1%, gains were increased and feed efficiency improved. The results of the literature reviewed were as follows:

	Gain (kg)	Feed/Gain
Woody (1978)	.009	-.058
Peterson et al. (1973)	.006	-.052
Gill et al. (1976)	.005	-.052
Newland et al. (1976)	.005	-.039
Danner (1978)	.007	-.050
Goodrich et al. (1974)	.007	-.047

The results of this study were consistent with the other studies reviewed. In this study, percent grain in the ration had a greater impact on performance. This is due to adjusting gains to a constant dressing percent and correcting for errors in dry matter determination for calculating feed/gain. The impact of grain in the ration on performance may vary due to the level fed. Goodrich et al. (1974) reported a greater decline in gain when corn was reduced in high roughage than in high concentrate rations.

In this study, as ration grain content was increased up to 80%, gains were improved. At this point, gains leveled off and were reduced for the steers fed 96% grain due to a dramatic reduction in dry matter intake. These results were supported by Fox (1977), Jesse et al. (1976a) and Prior et al. (1977) who reported that average daily gain increased as the energy density in the ration increased up to 70% to 80% corn in corn-corn silage rations.

The comparison in feedlot performance for steers fed high silage vs high concentrate rations are in agreement with previous studies (Pinney et al., 1973; Minish et al., 1967; Riley, 1969; Peterson et al, 1973; Gill et al., 1976). These studies conclude that as ration grain content increased, gains were improved and days on feed and non-feed costs were reduced. Utley et al. (1975) fed crossbred steer calves and yearlings all forage or high concentrate rations. Steers fed the high concentrate ration gained 21.5% faster than those fed all forage ($P < .05$). Minish et al. (1966) reported a 36.6% increase in gain when steers were fed a 60% concentrate-40% silage vs all silage rations. In the second trial, Minish et al. (1967) reported that steers gained 20.7% faster when fed the 60% concentrate ration over the all-silage fed steers. Peterson et al. (1973) found a linear response in gain and feed efficiency ($P < .01$) when the level of grain was increased in the ration when steers were fed corn silage:corn ratios of 100:0 to 0:100. Gill et al. (1976) reported that steers had higher gains (18.4%) and improved feed efficiency (25.8%) when the corn:corn silage ratio was increased from 25:75 to 76:24.

Carcass Characteristics

The influence of percent gain in the ration on carcass characteristics in trial 1 is reported in Table 24. All measurements were adjusted to a final empty body weight of 469.9 kg. As the percent grain in the ration increased, steers had a higher degree of carcass fat and a more desirable quality grade.

The influence of percent grain in the ration on carcass composition in trial 2 is reported in Table 25. All parameters were adjusted to an equal final empty body weight of 448 kg. Steers fed the high grain rations were fatter and had poorer yield grades.

Table 24. Influence of Total Ration Grain Content on Carcass Characteristics (Trial 1)[a]

Measure	Ration composition (DM basis): 93% silage, 7% supplement			35% corn, 59% silage, 6% supplement			82% corn, 12% silage, 6% supplement	94% corn, 6% supplement
Percent total corn in ration DM	29	40	50	55	64	68	91	96
Dressing %	62.1	61.2	62.6	61.5	61.3	63.5	62.2	62.4
Maturity[b]	2.1	2.0	2.0	1.8	2.1	2.0	1.9	2.1
Fat thickness, cm	0.91	0.79	0.74	0.74	0.91	0.81	0.71	1.04
Ribeye area, sq. cm	77.4	83.2	82.6	80.7	80.0	79.4	86.5	78.7
Kidney fat, %	2.7	2.9	2.5	2.1	3.2	2.8	2.5	2.8
Marbling[c]	12.5	11.2	12.3	10.8	12.3	13.0	9.3	14.0
Quality grade[d]	9.9	9.0	10.2	9.5	10.0	10.6	9.2	11.0
Yield grade	2.8	2.4	2.3	2.4	2.8	2.6	2.1	2.9
Carcass fat, %[e]	30.0	28.8	31.0	30.2	32.1	30.7	29.3	33.1

[a]Adjusted to a constant empty body weight of 465 kg that corresponds to a final shrunk weight of 513 kg. Includes added grain and grain in silage.

[b]Maturity: A- = 1; A = 2; A+ = 3.

[c]Marbling: Modest- = 13; Small+ = 12; Small° = 11; Small- = 10.

[d]Quality grade: Average good = 8; High good = 9; Low choice = 10.

[e]Carcass fat determined by 9-10-11 rib analysis.

Table 25. Influence of Total Ration Grain Content On Carcass Characteristics (Trial 2)[a]

Measure	Ration composition (DM basis)								Two-phase[b]	
	92% silage 8% supplement			31% corn 60% silage 9% supplement			80% corn 12% silage 8% supp.	92% corn 8% supp.	Low grain silage	High grain silage
Percent total corn in ration DM	38	51	54	59	67	69	90	96	57	68
Dressing %	59.8	60.8	61.7	62.1	61.0	62.0	62.8	62.8	61.6	62.2
Maturity[c]	2.4	2.4	2.2	2.5	2.4	2.7	2.7	2.7	2.5	2.4
Fat thickness, cm.	0.94	1.14	1.04	1.63	1.17	1.30	1.45	1.40	1.35	1.22
Ribeye area, sq. cm.	82.6	77.4	74.2	76 8	78.1	76.1	74.8	76.1	81.9	77.4
Kidney fat, %	2.9	3.1	3.2	3.3	2.9	3.3	3.1	3.0	2.9	3.2
Marbling[d]	9.8	8.9	11.9	8.3	9.6	9.4	9.1	9.4	8.3	7.8
Quality grade[e]	8.9	8.6	10.0	8.6	8.9	8.9	8.9	8.4	8.0	7.8
Yield grade	2.5	3.0	3.1	3.5	2.9	3.3	3.5	3.3	2.9	3.1
Carcass fat, %[f]	29.1	31.1	31.5	31.5	30.6	32.9	33.9	33.8	31.5	30.8

[a]Adjusted to a constant empty body weight of 448 kg that corresponds to final shrunk weight of 497.5 kg. Includes added grain and grain in silage.

[b]Steers switched from corn silage containing low (36%) and high (53%) grain content to the all concentrate ration at 415 kg.

[c]Maturity: A- = 1; A = 2; A+ = 3.

[d]Marbling: Modest- = 13; Small+ = 12; Small° = 11; Small - = 10; Slight+ = 9; Slight = 8; Slight- = 7.

[e]Quality grade: Average good = 8; High good = 9; Low choice = 10.

[f]Carcass fat determined by specific gravity technique.

The analysis of the pooled data on the effect of ration grain content on carcass characteristics for the two-year study is reported in Table 23. The percent grain in the ration influenced carcass fat, fat thickness and dressing percent ($P < .05$) when adjusted to an equal carcass weight, as shown in Figures 12 and 13. Maturity, marbling, quality grade, ribeye area and kidney, heart and pelvic fat were not influenced by ration grain content. The impact of grain was the same irrespective of whether the source was from silage or added grain. The developed regression equations for the prediction of carcass characteristics is reported in Table 26.

Numerous studies have been reported on the influence of ration energy level on carcass composition. The results of this study are consistent with other studies that conclude that ration energy level influences carcass composition (Guenther et al., 1965; Oltjen et al., 1971; Utley et al., 1975). Guenther et al. (1965) reported increased carcass fat when cattle were fed on a higher plane of nutrition. Utley et al. (1975) concluded that steers fed high concentrate rations had more marbling, poorer yield grade and more fat thickness than steers fed all forage rations when adjusted to a constant weight ($P < .05$). Oltjen et al. (1971) reported that carcass grade was higher for steers finished on all concentrate vs those finished on all forage ($P < .05$).

In contrast, other workers have concluded that composition of gain is not influenced by ration energy level (Pinney et al., 1966; Garrett, 1971; Preston et al., 1975; Perry and Beeson, 1976; Jesse

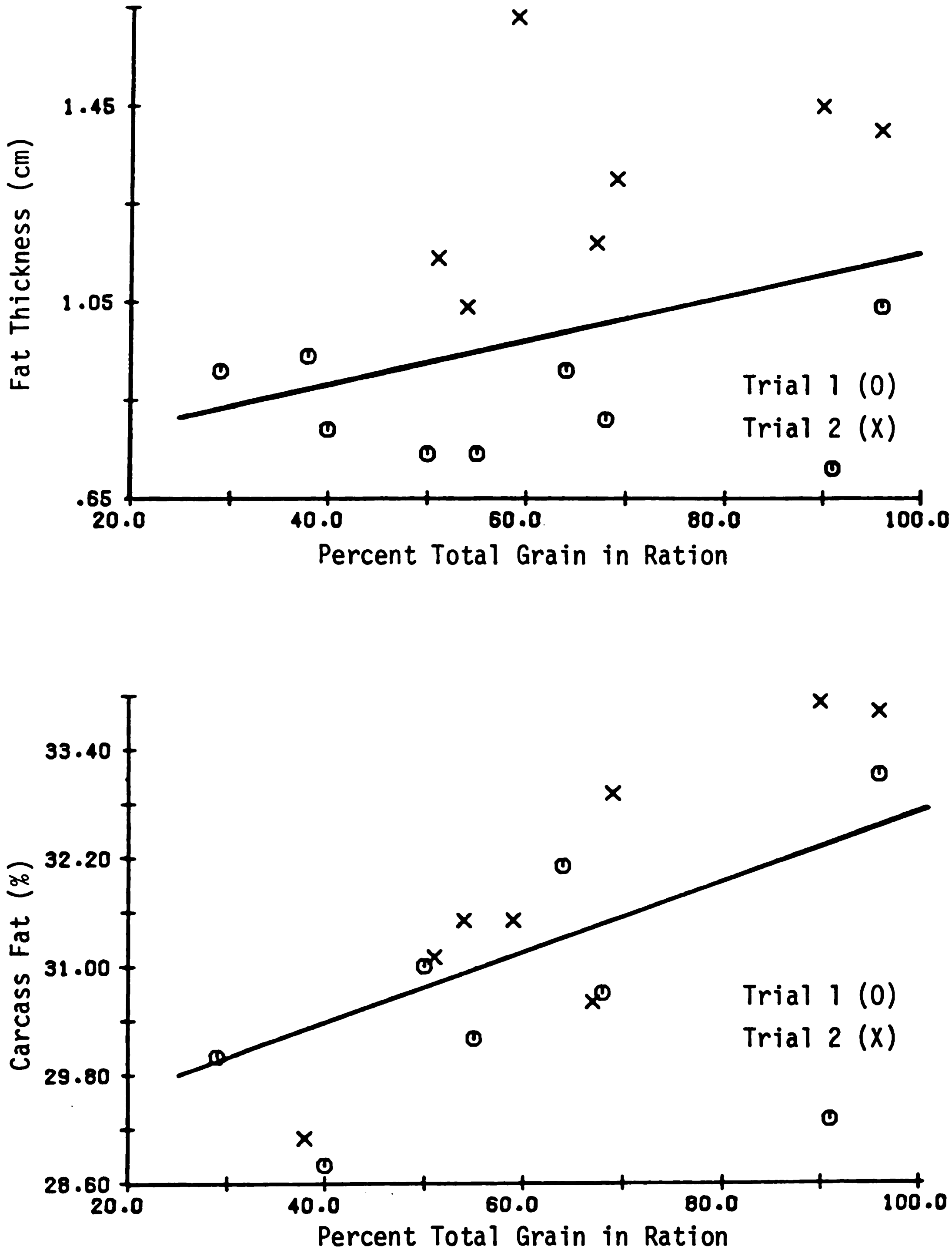


Figure 12. Influence of ration grain content on fat thickness and carcass fat.

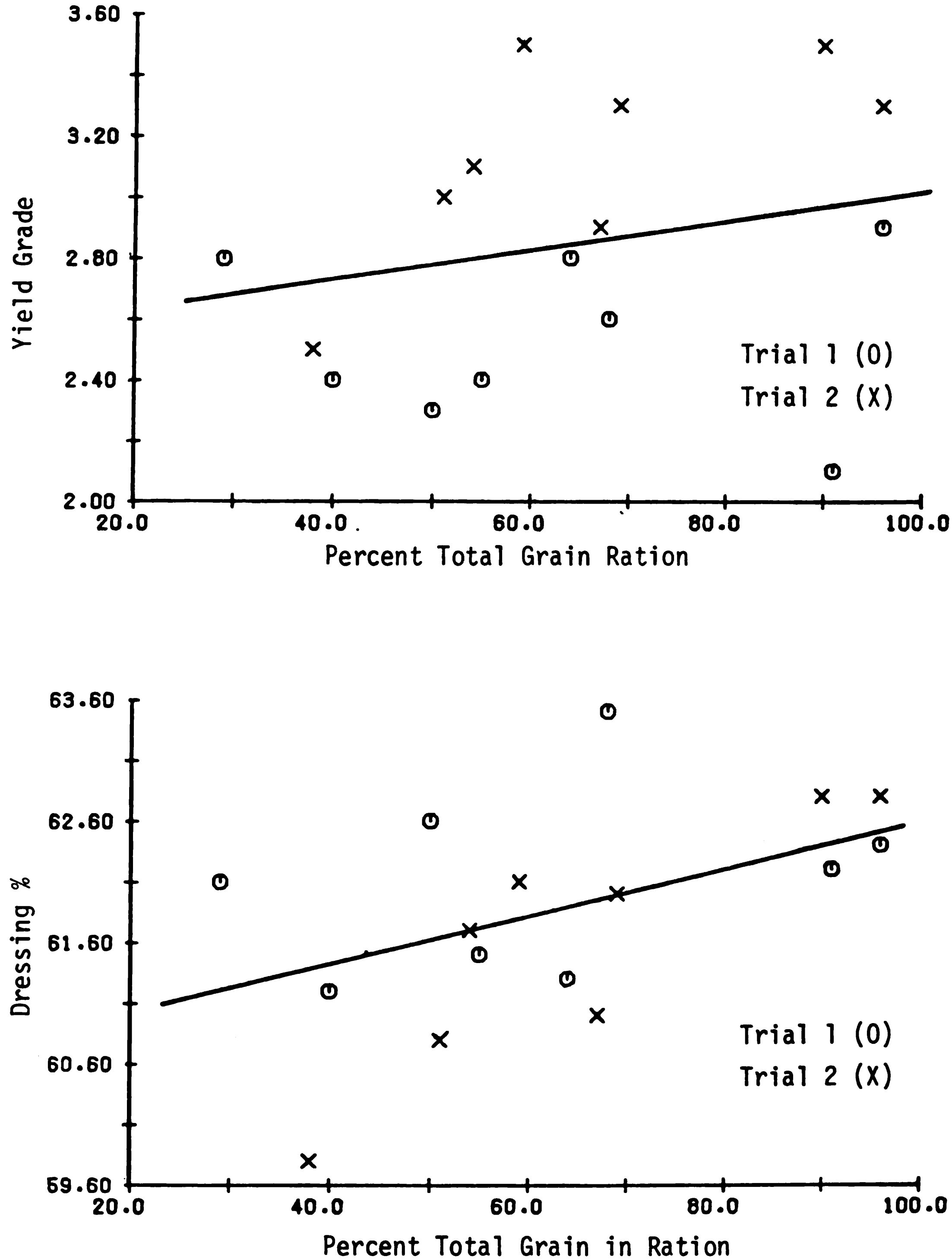


Figure 13. Influence of ration grain content on yield grade and dressing percent.

Table 26. Regression Equations Developed for the Prediction of Carcass Traits[a]

Measure	Regression equation	$s_{\hat{y}}$	R^2
Maturity	= 1.77 + .0026 Grain% + .261 Year + .0004 HCW (1.30) (6.57) (.62)	0.42	.30
Marbling	= .343 - .012 Grain% - .929 Year + .016 HCS (.82) (3.11) (2.86)	3.13	.19
Quality grade	= 6.55 - .0002 Grain% - 4.51 Year + .004 HCS (.04) (3.22) (1.57)	1.46	.13
Fat thickness	= -1.00 + .001 Grain% + .098 Year + .001 HCW (2.05) (7.50) (4.24)	0.14	.40
Ribeye area (sq. cm.)	= 34.71 - .001 Grain% - .161 Year + .01 HCW (.26) (1.77) (5.81)	0.95	.31
KPH (%)	= 1.25 - .001 Grain% + .239 Year + .003 HCW (.55) (4.46) (2.47)	0.56	.15
Yield grade	= .177 + .0004 Grain% + .341 Year + .004 HCW (1.41) (6.35) (3.47)	0.56	.31
Carcass fat (%)	= 15.52 + .039 Grain% + .812 Year + .019 HCW (2.35) (2.45) (3.04)	3.47	.18
Dressing (%)	= .537 + .0001 Grain% - .0001 Year + .0001 HCW (2.55) (.10) (4.81)	0.01	.28

[a]Regression equations developed from 2-year feeding trial. "t" values in parentheses.

et al., 1976a). When steers were fed to an equal weight, Garrett (1971) found little difference in body composition when fed varying roughage-to-concentrate ratios. Perry and Beeson (1976) fed steers high silage or high concentrate rations and reported no difference in quality grade. Preston et al. (1975) reported that carcass characteristics were not influenced by ration energy level when steers were fed various roughage-to-concentrate levels. Also, Jesse et al. (1976a) fed steers various proportions of corn:corn silage of 30:70 to 80:20 and concluded that composition of carcass gain for a given weight was not affected by ration ($P < .05$).

Net Energy Value of Rations Varying in Grain Content

Net energy values determined for each of the rations fed in the two-year feeding trial are reported in Tables 27 and 28. Ration grain content influenced ME ($P = .02$), NE_m and NE_g ($P < .0005$). When the developed regression equations were applied, ME, NE_m and NE_g were non-additive as ration grain content increased from 30% to 70%, but increased sharply when grain level was further increased to 100%, as shown in Figure 14. When energy values were determined by analysis of silage and silage plus grain (30% to 70%) vs high concentrate rations (70% to 96%) as compared to analyzing across all diets (30% to 96%), ME, NE_m and NE_g were 2.9%, 4.3% and 8.9% lower than predicted, respectively, at the 70% grain level. Energy values for the 69% grain ration in trial 2 were omitted from the analysis due to the inconsistency with the other data.

Table 27. Influence of Ration Grain Content on Net Energy Values (Trial 1)

Measure	Ration composition (DM basis)							
	93% silage 7% supplement			35% corn 59% silage 6% supplement			82% corn 12% silage 6% supplement	94% corn 6% supplement
Percent total corn in ration DM	29	40	50	55	64	68	91	96
Gross energy (Mcal/kg)[a]	4.25	4.32	4.35	4.23	4.28	4.30	4.22	4.18
Digestible energy (Mcal/kg)	2.67	2.87	2.92	2.83	2.72	2.98	3.56	3.30
Metabolizable energy[b] (Mcal/kg)	2.19	2.36	2.39	2.32	2.23	2.44	2.92	2.70
NE_m (Mcal/kg)	1.44	1.42	1.55	1.50	1.49	1.60	1.94	1.87
NE_g (Mcal/kg)	1.06	0.84	1.08	0.99	1.12	1.10	1.27	1.39

[a]Determined by bomb calorimetry.

[b]Calculated by digestible energy x .82 (NRC, 1976).

Table 28. Influence of Ration Grain Content on Net Energy Values (Trial 2)

Measure	Ration composition (DM basis) 92% silage 8% supplement			31% corn 60% silage 9% supplement			80% corn 12% silage 8% supplement	92% corn 8% supplement
Percent total corn in ration DM	38	51	54	59	67	69	90	96
Gross energy (Mcal/kg)[b]	4.08	4.13	4.21	4.14	4.97	5.86	4.20	4.17
Digestible energy (Mcal/kg)	2.75	2.82	2.85	2.53	3.53	4.41	3.56	3.44
Metabolizable energy[b] (Mcal/kg)	2.26	2.31	2.07	2.07	2.90	3.62	2.93	2.82
NE_m (Mcal/kg)	1.40	1.49	1.53	1.53	1.83	2.30	2.04	2.05
NE_g (Mcal/kg)	0.90	1.05	1.09	1.34	1.10	1.08	1.61	1.74

[a]Determined by bomb calorimetry.

[b]Calculated by digestible energy x .82 (NRC, 1976).

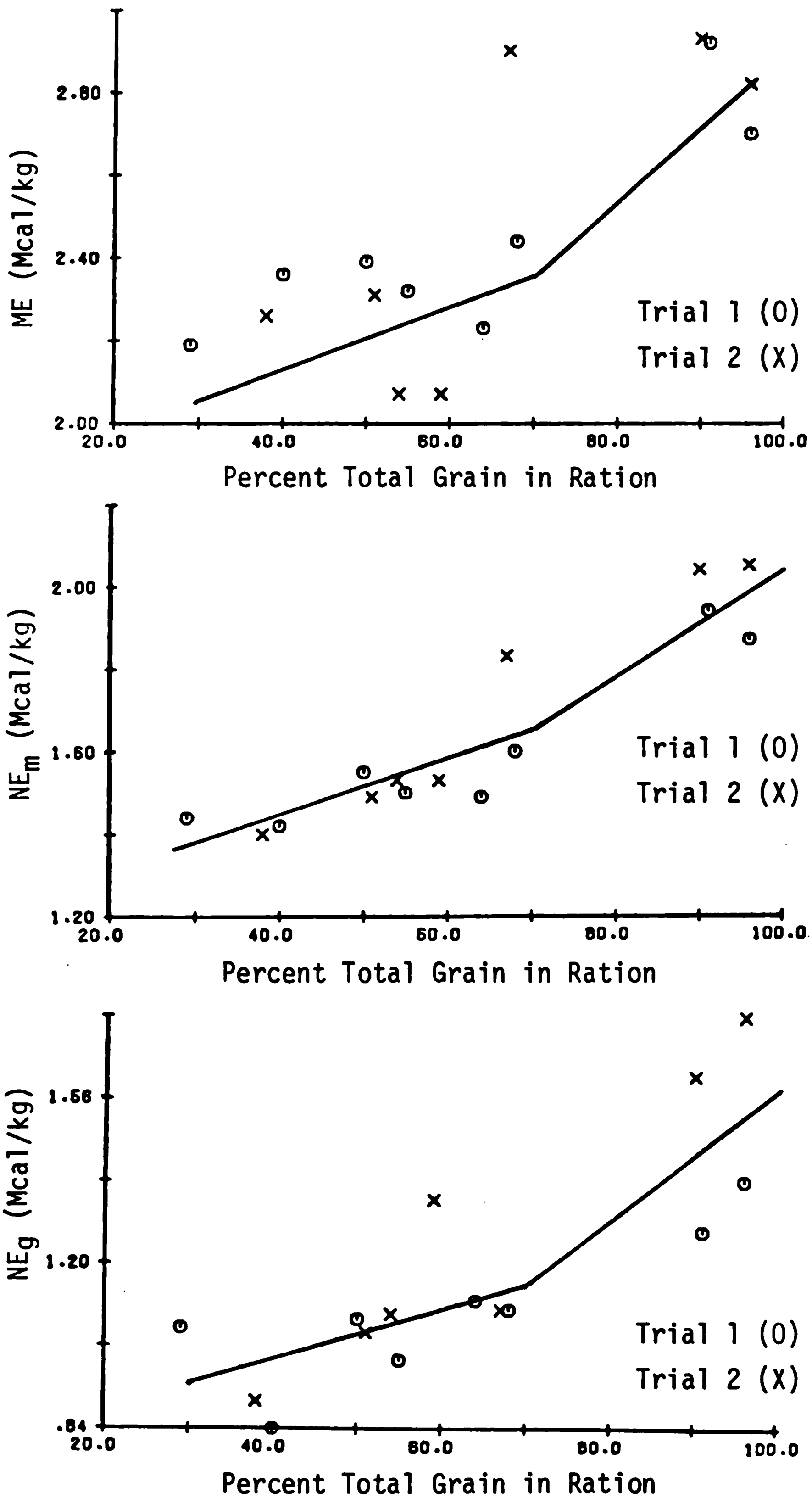


Figure 14. Effect of ration grain content on metabolizable energy and net energy for maintenance and gain.

The impact of silage grain content on net energy value of the ration was lower than predicted. Net energy for gain for all silage rations increased from .94 to 1.04 Mcal/kg as silage grain content increased from 30% to 50%. This is an increase of .05 Mcal/kg with each 10% increase in silage grain level. A similar trend was found as added grain in the ration was increased to 70%. Grain content had a greater impact on the enrgy value of the ration when increased from 70% to 100%; NE_g was increased .14 Mcal/kg for each 10% increase in grain level. Thus, the impact of grain on the energy value of the ration was lower than predicted up to 70% grain, then had a greater impact. The depression in NE_g at the 70% grain level accounts for the improvement in efficiency when steers are fed on the two-phase system vs constant added grain rations.

In agreement with previous studies, the greatest change in digestibility was found between 50% and 80% grain in the ration. Vance et al. (1971a) reported a curvilinear relationship for NE_g as percent grain in the ration was increased from 36% to 97%. NE_g of the corn grain increased while that of corn silage decreased as varying increments of corn grain was added to the ration. Byers, Matsushima and Johnson (1975a, 1975b) reported a depression in dry matter digestibility, ME, NE_m and NE_g by 6.2%, 12.1%, 14.8% and 12.2% when the total ration contained 67% grain, respectively. As grain content was increased from 70% to 100%, NE_g increased more dramatically.

Two-Phase System Versus Constant Added Grain

Performance data were pooled for the steers fed on the two-phase and compared to those fed silage plus a constant amount of added grain. Due to a high value for the silage plus added grain fed steers, NE_g was calculated using developed regression equations and compared to actual values for those fed on the two-phase system.

For the two-phase system, steers fed all corn silage during the growing phase and switched to an all concentrate ration at 415 kg had similar gains (1.09 vs 1.10 kg) but improved in feed efficiency by 6.5% and net energy for gain by 5.1% (1.11 vs 1.17 Mcal/kg) when compared to steers fed silage plus a constant amount of added grain throughout the entire feeding period (Table 29). The steers fed on the two-phase system had a larger ribeye and an improved yield grade ($P < .05$); no differences were found for the other carcass characteristics (Table 30).

These results agree with Dexheimer et al. (1971) where gains were equal but feed efficiency was improved when steers were fed on the two-phase system in comparison to silage plus added grain fed simultaneously. Fox and Black (1975) suggested three factors that lead to improved efficiency when cattle are fed on a two-phase system (high roughage ration fed during the growing phase followed by a high concentrate ration fed during the finishing phase) in comparison to steers fed a constant amount of added grain throughout the entire feeding period. First, associative effects are present in feedlot rations when grain comprises 50% to 80% of the ration. Due to an

Table 29. Comparison of Steers Fed on Two-Phase System *vs* Constant Added Grain Rations[a]

	Silage plus added grain	Two-phase[b] system	Significance level
Daily gain, lb.	1.09	1.10	NS
Daily DM intake ($g/WT_{kg}{}^{.75}$)	91.3	85.3	.13
Feed/gain	7.27	6.80	.10
Carcass fat, %	32.2	31.3	NS
NE_g, Mcal/kg	1.11	1.17	Not tested

[a]Data calculated on a constant dressing percentage (61.7%).

[b]Steers switched from corn silage to all concentrate ration at 415 kg.

Table 30. Carcass Characteristics of Steer Fed on Two-Phase System *vs* Constant Added Grain Rations[a]

	Silage plus added grain	Two-phase system	Significance level
Dressing %	62.1	61.9	NS
Maturity[b]	2.6	2.5	NS
Fat thickness, cm	1.47	1.47	NS
Ribeye area, sq. cm.	76.8	80.0	.05
Kidney fat, %	3.3	3.1	NS
Marbling[c]	8.9	8.1	NS
Quality grade[d]	8.8	7.9	NS
Yield grade	3.4	3.0	.0005
Carcass fat[e]	32.2	31.2	.16

[a]Adjusted to a constant carcass weight of 343.5 kg.

[b]Maturity: A- = 1; A = 2; A+ = 3.

[c]Marbling: Small+ = 12; Small° = 11.

[d]Quality grade: Average good = 8; High good = 9.

[e]Carcass fat determined by specific gravity technique.

interaction of the fiber and grain portion in the ration there is an alteration in digestion and metabolism of nutrients and a depression of dry matter digestibility and metabolizable energy; thus, resulting in a reduction in efficiency of energy utilization (Byers et al., 1975a). The 5.1% improvement of NE_g for the two-phase system vs constant added grain rations support the results obtained when grain content was increased from 30% to 100% in the ration. When NE_g was determined by analysis of grain from 30% to 70% and from 70% to 100%, as compared to analyzing across all diets with grain from 30% to 96%, NE_g was depressed by 8.9%. Byers et al. (1975b) also reported a 12.2% depression in NE_g when the ration contained 67% grain. Secondly, when cattle are switched from a high roughage ration fed during the growing phase to a high concentrate ration, there is compensatory performance, resulting in a more efficient use of dietary energy during the finishing phase (Fox et al., 1970). Thirdly, cattle are fed for slower rates of gain during the growing phase when they are of lighter weight and their maintenance requirements are lower. During the finishing phase the cattle are heavier which results in higher maintenance requirements. When fed a high grain ration during this period they have a higher rate of gain and spend less time in this phase. Thus, a lower percent of feed is used for maintenance requirements and more is available for gain under the two-phase system.

Performance of Steers Fed High Oil or Brown Midrib Corn Silage

Feedlot performance for steer calves fed high oil or brown midrib *vs* normal corn silage is reported in Table 31. Steers fed brown midrib gained 5.6% faster and required 6.4% less feed per unit of gain than those fed normal silage. These results are in agreement with Colenbrander *et al*. (1977) who reported that steers fed brown midrib gained 8.2% faster and required 12.7% less feed per unit of gain as compared to those fed normal silage. Similar results were shown by Colenbrander *et al*. (1973, 1975) who reported improvements in average daily gain and feed efficiency for steers fed brown midrib corn silage. Dry matter intake was similar for steers fed brown midrib and normal silage. This is in conflict with Muller *et al*. (1972) and Colenbrander *et al*. (1972) who reported that steers fed brown midrib silage had increased dry matter intake. The increased intake was related to a 15% increase in dry matter digestibility when the low lignin silage was fed.

Steers fed high oil silage had reduced gains (13.9%) and poorer feed efficiency (7.0%) than those fed normal silage. These results are in agreement with McCollough *et al*. (1972) who reported that steers fed high oil silage had 17.9% reduced gains and a 17.9% poorer feed efficiency.

Carcass characteristics for steers fed high oil, brown midrib and normal silage are reported in Table 32. Steers fed brown midrib silage had a higher degree of fat thickness, kidney fat and carcass fat but a poorer yield grade than those fed normal silage. Steers fed

Table 31. Feedlot Performance of Steer Calves Fed High Oil and Brown Midrib *vs* Normal Corn Silage (Trial 1)[a]

Measure	Corn variety			Main effect	High oil vs normal	Brown midrib vs normal
	Normal	High oil	Brown Midrib			
Initial wt., kg	240	238	239			
Final wt., kg	511	483	527			
Days on feed	268	282	268			
Daily gain, kg	1.01	0.87	1.07	.003	<.005	.05
Daily dry matter intake (kg)[b]	8.84	8.20	8.79		Not Tested	
Corn silage	8.27	7.66	8.12			
Supplement	0.57	0.55	0.67			
Feed/gain	8.74	9.42	8.18		Not Tested	

[a]Each treatment included eight Charolais crossbred steer calves. Data were adjusted to a constant dressing percentage, 62.2%.

[b]Corn silage intake were adjusted upwards for errors in dry matter determination by a factor of 1.068.

Table 32. Carcass Characteristics of Steers Fed High Oil and Brown Midrib *vs* Normal Corn Silage (Trial 1)[a]

Measure	Corn Variety			Main effect	High oil *vs* normal	Brown midrib *vs* normal
	Normal	High Oil	Brown Midrib			
Dressing, %	61.2	62.7	62.8	NS	--	--
Maturity[b]	2.0	2.0	2.0	NS	--	--
Fat thickness, cm	.79	.66	.96	.044	.04	.04
Ribeye area, sq. cm	83.2	80.0	78.1	.023	NS	.025
Kidney fat, %	2.9	1.5	3.1	<.0005	<.0005	.075
Marbling[c]	11.2	10.6	11.2	NS	--	--
Quality grade[d]	9.0	8.8	10.0	NS	--	--
Yield grade	2.4	2.2	2.9	.003	.025	<.005
Carcass fat, %[e]	28.8	26.9	31.4	.011	.025	.007

[a]Adjusted to a constant empty body weight of 465 kg that corresponds to a final shrunk weight of 513 kg.

[b]Maturity: A- = 1; A = 2; A+ = 3.

[c]Marbling: Modest- = 13; Small+ = 12; Small° = 11; Small- = 10.

[d]Quality grade: Average good = 8; High good = 9; Low choice = 10.

[e]Carcass fat determined by 9-10-11 rib analysis.

high oil had a lower degree of fat thickness, kidney fat and carcass fat but a more desirable yield grade than those fed normal silage.

Net energy values of high oil, brown midrib *vs* normal silage are reported in Table 33. NE_g was similar for brown midrib and normal silage but was reduced 7.0% for the high oil silage ration.

Table 33. Net Energy of High Oil, Brown Midrib *vs* Normal Corn Silage (Trial 1)

	Corn variety		
Measure	Normal	High oil	Brown midrib
Gross energy (Mcal/kg)[a]	4.32	4.19	4.12
Digestible energy (Mcal/kg)	2.87	2.94	2.99
Metabolizable energy (Mcal/kg)	2.36	2.41	2.45
NE_m (Mcal/kg)	1.46	1.49	1.55
NE_g (Mcal/kg)	1.01	0.93	1.03

[a]Determined by bomb calorimetry.

[b]Calculated by digestible energy x .82 (NRC, 1976).

Predicting Feedlot Performance from Acid Detergent Fiber and Ration Grain Content

Feedlot Performance

The relationship between acid detergent fiber, ration grain content and feedlot performance for trial 1 is reported in Table 34. When the developed regression equations for the rations increasing in grain from 30% to 80% were applied, a reduction in ADF from 26.7% to 5.7% resulted in increased gains from .80 to 1.35 kg/day and improved feed efficiency from 9.55 to 5.97. Increased grain in the ration resulted in increased gains from .80 to 1.32 kg/day and improved feed efficiency from 9.74 to 5.96.

In trial 2, as ADF was reduced from 21.1% to 5.2%, gains were increased from 8.58 to 5.89 (Table 35). Increased grain level in the ration resulted in increased gains from .88 to 1.32 kg/day and improved feed efficiency from 9.18 to 5.96.

When the results were plotted, ration ADF levels were closely related to feedlot performance (Figure 15). Ration fiber level was inversely related to feedlot performance, in agreement with Chandler and Walker (1972) and Jahn et al. (1970, 1976).

Acid detergent fiber was an adequate predictor of feedlot performance; it accounted for 78%, 89% and 91% of the variation in gain, dry matter intake and feed efficiency, respectively. Regression equations for gains and dry matter intake did not include the high grain rations due to a sharp decline in performance. Regression equations

Table 34. Relationship Between Acid Detergent Fiber, Ration Grain Content and Feedlot Performance (Trial 1)[a]

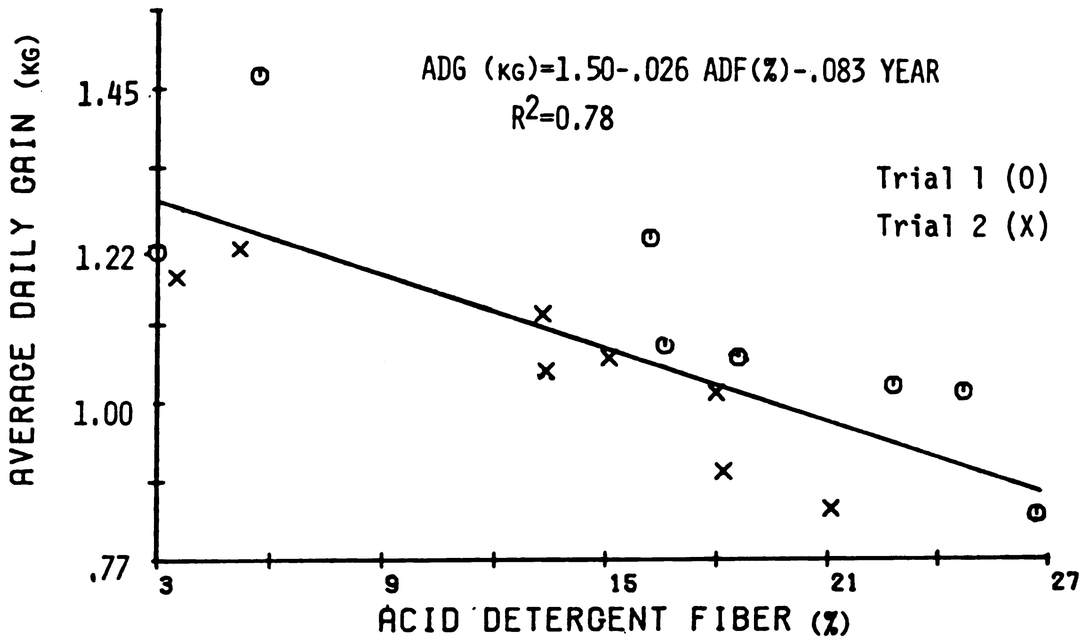
	Ration composition (DM basis)							
Measure	93% silage 7% supplement			35% corn 59% silage 6% supplement			82% corn 12% silage 6% supplement	94% corn 6% supplement
Percent corn in ration including corn in silage	29	40	50	55	64	68	91	96
Acid detergent fiber, %	26.7	24.7	22.8	18.6	16.6	16.2	5.7	3.0
Daily gain, kg	0.83	1.10	1.02	1.06	1.08	1.23	1.47	1.22
Feed/gain	9.74	8.74	8.33	8.50	8.11	7.31	5.65	6.10
DM Intake ($g/wt_{kg}^{.75}$)	101.6	104.7	99.2	107.4	101.5	103.7	94.7	84.7
NE_g, Mcal/kg	1.06	0.84	1.08	0.99	1.12	1.10	1.27	1.38

[a]There were eight Charolais crossbred steer calves/treatment.

Table 35. Relationship Between Acid Detergent Fiber, Ration Grain Content and Feedlot Performance (Trial 2)[a]

Measure	Ration composition (DM basis)							
	92% silage 8% supplement			31% corn 60% silage 9% supplement			80% corn 12% silage 8% supplement	92% corn 8% supplement
Percent corn in ration including corn in silage	38	51	54	59	67	69	90	96
Acid detergent fiber, %	21.1	18.2	18.0	15.1	13.4	13.3	5.2	3.5
Dailv gain, kg	0.84	0.90	1.01	1.06	1.04	1.12	1.22	1.18
Feed/gain	9.34	8.39	7.78	7.46	7.52	7.03	5.62	5.50
DM Intake ($g/wt_{kg}^{.75}$)	93.8	89.2	90.4	91.4	91.4	91.1	72.9	72.9
NE_g, Mcal/kg	0.90	1.05	1.09	1.35	1.10	1.08	1.61	1.74

[a]There were eight Hereford steer calves/treatment.



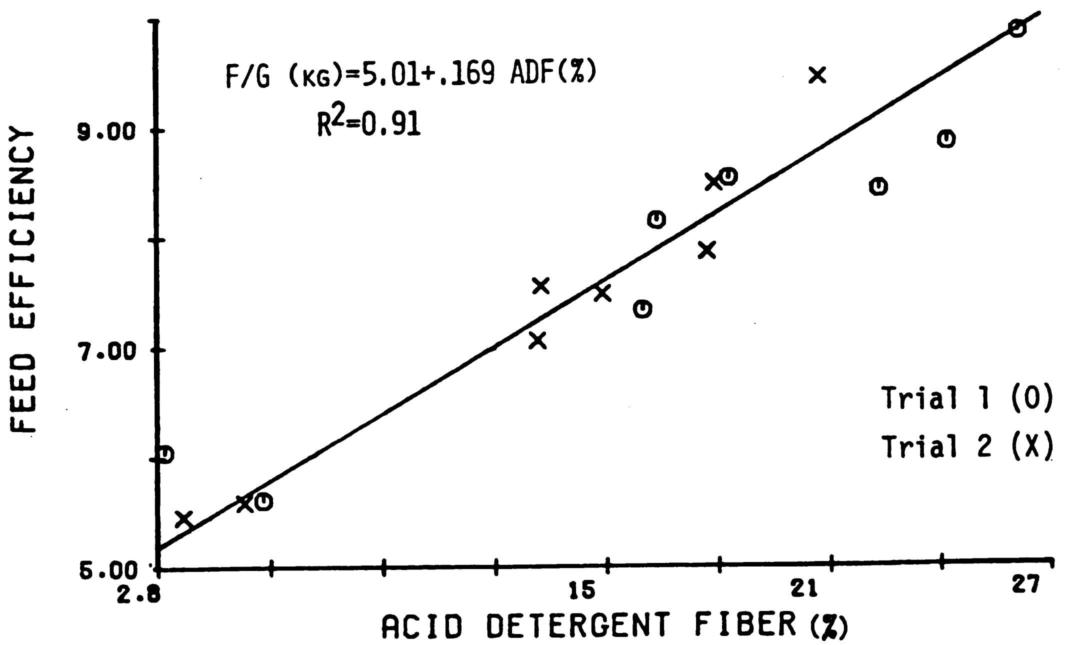


Figure 15. Relationship between acid detergent fiber and average daily gain and feed efficiency.

developed for the prediction of feedlot performance from ADF determination are as follows:

- Across all rations:

$$F/G\ (kg) = 5.01 + \underset{(11.93)}{.169}\ ADF\ (\%) \qquad s_{\hat{y}} = .41 \qquad R^2 = 0.91$$

- 30% to 80% grain:

$$ADG\ (kg) = 1.50 - \underset{(4.97)}{.0260}\ ADF\ (\%) - \underset{(4.01)}{.083}\ year \qquad s_{\hat{y}} = .06 \qquad R^2 = 0.78$$

$$\underset{(g/wt_{kg}{}^{.75})}{DM\ intake} = 98.15 + \underset{(.27)}{.05}\ ADF\ (\%) - \underset{(7.35)}{6.05}\ year \qquad s_{\hat{y}} = 2.40 \qquad R^2 = 0.89$$

The level of grain in the ration had a definite effect on feedlot performance (Figure 16). As the percent grain in the ration increased, steers gained faster and had improved feed efficiency. Total ration grain content accounted for 87%, 89% and 93% of the variation in gain, dry matter intake and feed efficiency, respectively. Regression equations for the prediction of feedlot performance from ration gain content are as follows:

- Across all rations:

$$F/G\ (kg) = 11.54 - \underset{(13.49)}{.062}\ grain\ (\%) \qquad s_{\hat{y}} = .36 \qquad R^2 = 0.93$$

- 30% to 80% grain:

$$ADG\ (kg) = .557 + \underset{(6.86)}{.0085}\ grain\ (\%) - \underset{(3.00)}{.042}\ year \qquad s_{\hat{y}} = .05 \qquad R^2 = 0.87$$

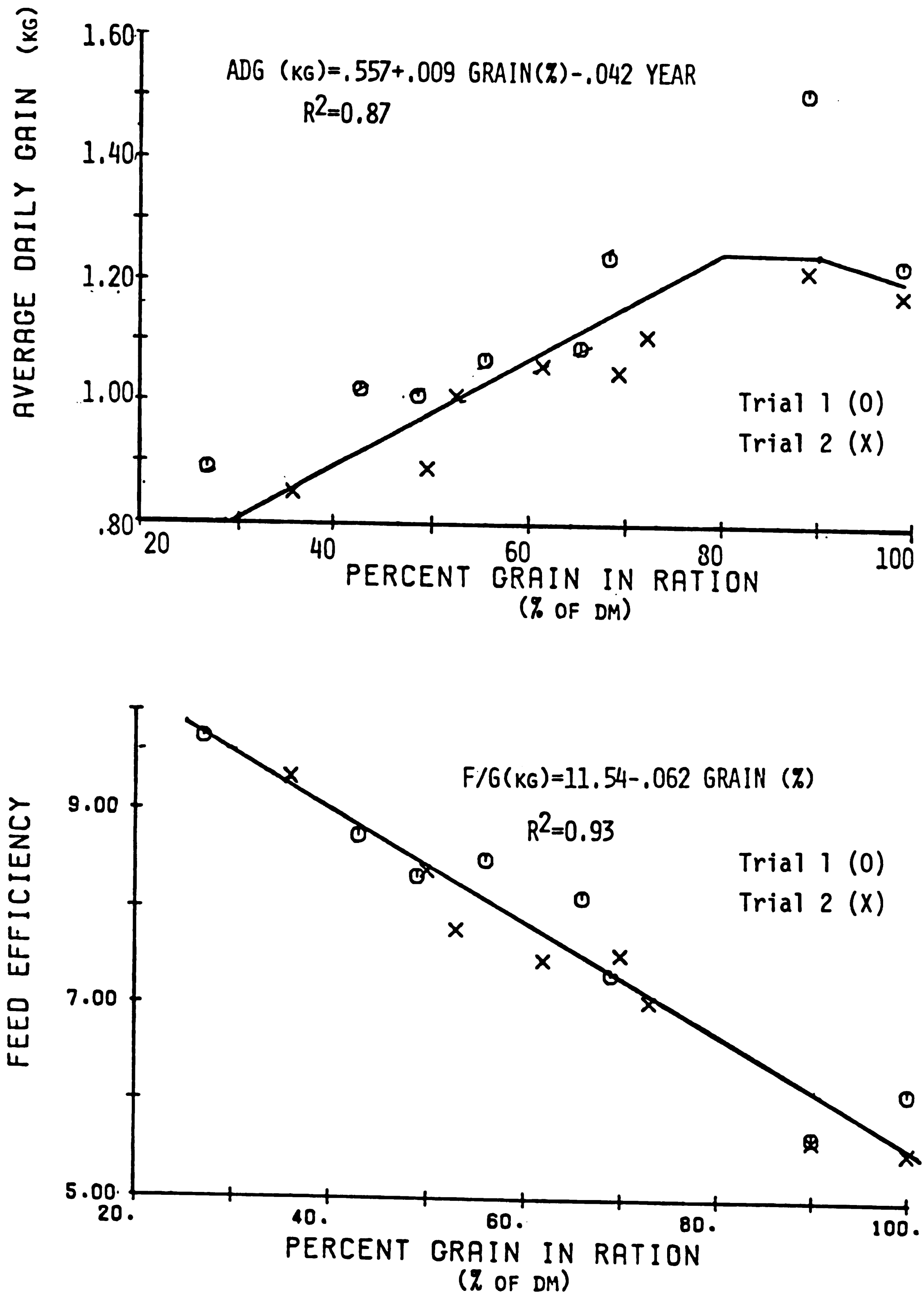


Figure 16. Relationship between ration grain content and average daily gain and feed efficiency.

$$\underset{(g/wt_{kg}^{.75})}{\text{DM intake}} = 96.54 + \underset{(.19)}{.01}\ \text{grain (\%)} - \underset{(i.45)}{5.94}\ \text{year} \quad s_{\hat{y}} = 2.41 \quad R^2 = 0.89$$

Predicting Net Energy Values

As grain level in the ration was increased from 30% to 70%, ADF and ration grain level accounted for 33% and 23% of the variation in NE_g, respectively. In comparison, ADF and grain level accounted for 62% and 63% of the variation of NE_g when ration grain level was increased from 70% to 100%. Due to the presence of associative effects, ADF and ration grain level accounted for a lower percent of the variation in NE_g as the ration grain level was increased to 70%. As grain level in the ration was increased to 100%, ADF and ration grain content were more useful predictors of NE_g due to the greater impact of added grain (Figure 17).

Regression equations developed for the prediction of NE_g of rations varying in grain content are as follows:

- 30% to 70% grain:

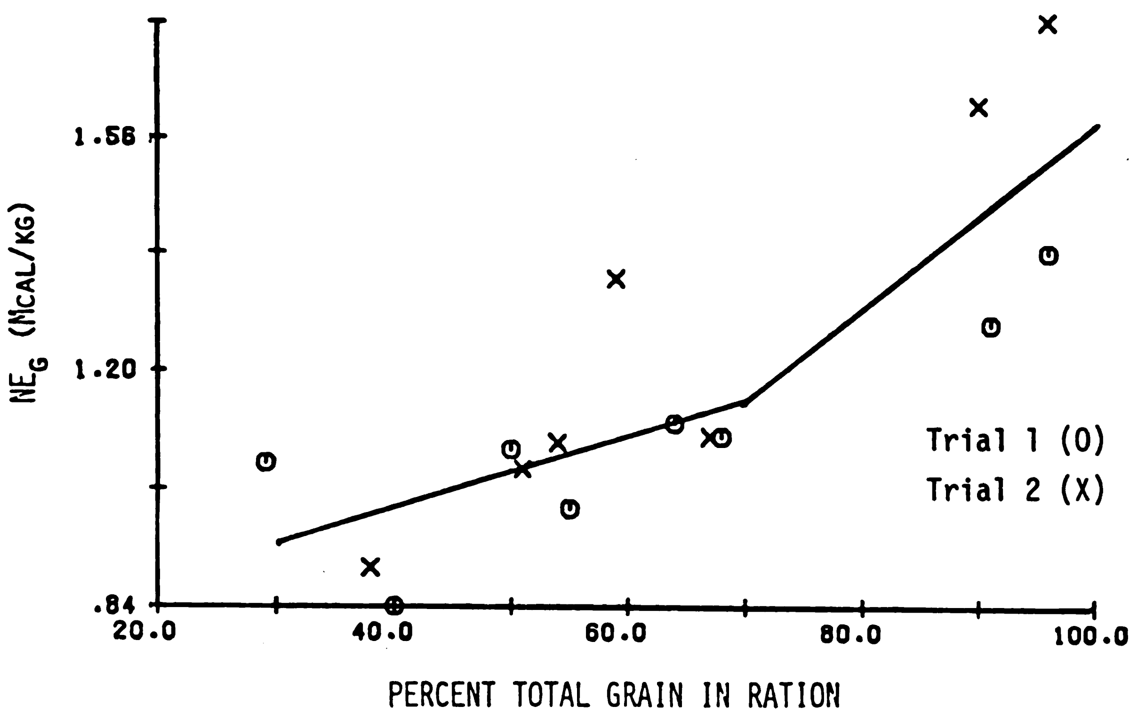
$$NE_g\ (\text{Mcal/kg}) = 1.405 - \underset{(2.12)}{.0179}\ \text{ADF (\%)} \quad s_{\hat{y}} = .11 \quad R^2 = .33$$

$$NE_g\ (\text{Mcal/kg}) = 0.785 + \underset{(1.66)}{.005}\ \text{grain (\%)} \quad s_{\hat{y}} = .12 \quad R^2 = .23$$

- 70% to 100% grain:

$$NE_g\ (\text{Mcal/kg}) = 1.662 - \underset{(2.60)}{.0377}\ \text{ADF (\%)} \quad s_{\hat{y}} = .18 \quad R^2 = .62$$

$$NE_g\ (\text{Mcal/kg}) = 0.077 + \underset{(2.63)}{.015}\ \text{grain (\%)} \quad s_{\hat{y}} = .18 \quad R^2 = .63$$



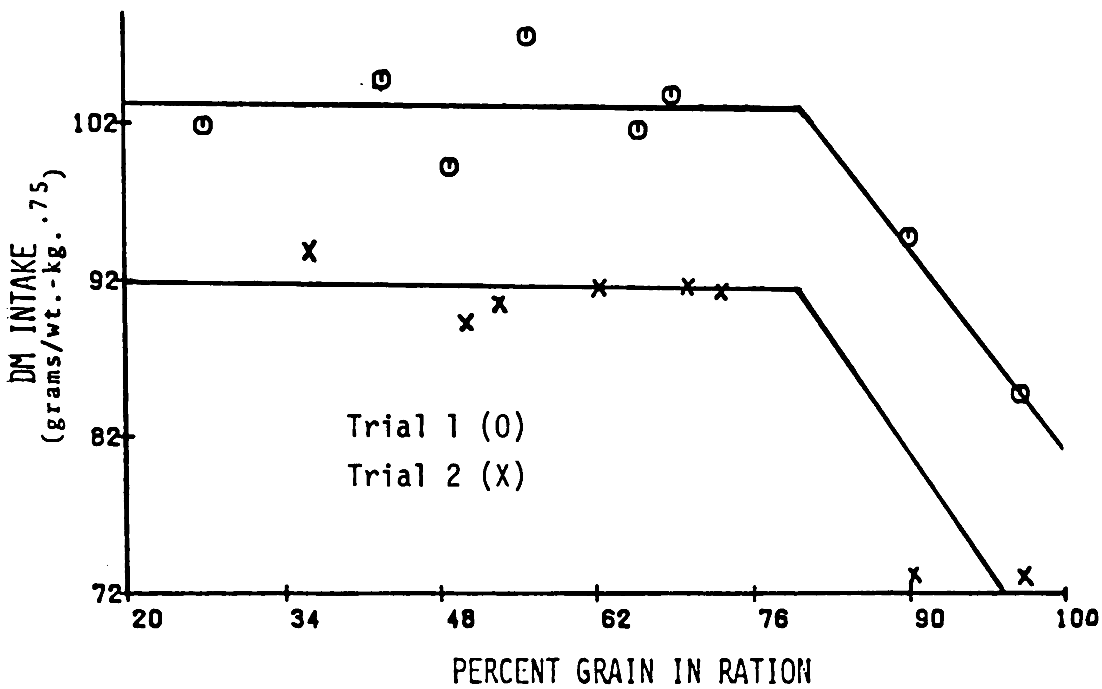


Figure 17. Relationship between ration grain content and dry matter intake and net energy for gain.

Application to Other Corn Varieties

The equations relating performance to ADF were used to predict the performance of steers fed brown midrib and high oil corn silage. The predicted gains were 3.5% higher and feed/gain was 3.2% lower for steers fed high oil than actual performance. Predicted gains for steers fed brown midrib were 12.7% lower than actual but feed efficiency was 7.2% higher. When regression equations relating ration grain content and performance were applied, the predicted feed/gain was 3.2% lower and gains were 4.0% higher than actual for steers fed high oil silage. Predicted gains for steers fed brown midrib silage were 17.3% lower and feed/gain was 12.1% higher than actual values. In comparison, ration grain content and ADF analysis were useful predictors of performance for steers fed high oil silage but was not accurate for steers fed brown midrib.

In conclusion, determination of ration grain content is an alternative method to chemical analysis of feedstuffs for predicting feedlot performance. From a farmer's viewpoint, determination of corn silage grain content from forage yields and bushels of grain produced per acre is a practical method of predicting performance of feedlot rations. ADF was an accurate predictor of feedlot performance; it accounted for 78% and 91% of the variation in gain and feed efficiency, respectively. In comparison, ration grain content accounted for 87% and 93% of the variation in gain and feed efficiency, respectively. When regression equations were applied to high oil and brown midrib corn varieties, ration grain content and ADF analysis were useful predictors of feedlot performance for steers fed high oil but was not accurate for those fed brown midrib silage. With the exception of high grain rations, dry matter intake was not influenced by ADF or ration grain content. Dry matter digestibility was increased as ration grain content increased and ADF was reduced. When steers were fed rations with 30% to 70% grain, ADF and ration grain content accounted for a low degree of the variation in NE_g but increased to 62% and 63% as ration grain content increased to 100%. Associative effects pose a problem in accurate estimation of net energy value of feedstuffs, particularly when the ration contains between 60% to 70% grain.

Influence of Ration Grain Content on Cost of Feeding, Manure Handling and Storage, and Manure Credit

Economic analysis of the impact of the level of corn in corn-corn silage rations requires an analysis of nonfeed as well as feed costs (Black and Fox, 1977). Total cost per unit gain is:

$$\left(\frac{\text{Feed}}{\text{Gain}}\right) (\text{Price}_{\text{feed}}) + \left(\frac{\text{Nonfeed cost/day}}{\text{Daily gain}}\right)$$

Increasing the level of corn silage in the ration influences nonfeed costs per day in three ways. First, the amount of feed that must be handled per day is more than three times larger for an all-corn silage ration than an all-concentrate ration. Second, daily manure production goes up as the percent corn silage in the ration increases since corn silage is lower in digestibility than corn grain. More manure requires more storage space and more handling cost. Third, the value of the manure "credit" per day is influenced by the percentage of corn silage in the ration, both in terms of volume and nutrient (N, P_2O_5, and K_2O) density. All of these factors must be considered in the determination of the most profitable feeding program.

The influence of ration grain content on manure storage and nutrient composition was analyzed from data obtained in the two-year feedlot trial (Table 36). A slatted floor housing area is assumed; input-output coefficients and costs are based on a 600 to 800 head one-time capacity. The cost factors for alternative grain levels are partitioned into annual use cost for building and pit, feeding, labor, manure handling, veterinary and cattle processing expenses.

The facility cost was based upon the cost of the building plus pit for manure storage of a six-month period. Pit investment cost per head capacity is given by:

$$\text{Investment cost} = \$94 + 5 \times \text{pit depth (ft.)}$$

The investment cost is based upon discussions with builders and data from Petritz (1977). Daily use cost was estimated as investment cost times 17% depreciation and interest, repairs, and property tax (given annual use cost per year) divided by 340 days (effective capacity). Cost of the building structure with slatted floor was figured at \$5.40 per sq. foot; 20 sq. feet was allotted per steer (Petritz, 1977). Daily building cost was:

$$\text{Building cost} = \left[(\text{cost per sq ft} \times 20 \text{ sq ft/steer}) \times 17\%\right] \div 340 \text{ days}$$

Table 36. Effect of Ration Grain Content on Manure Volume and Nutrient Composition[a]

Ration	% grain in ration	Urine (l)	Wet feces (lb)	Feces (% DM)	Feces DM (lb)	Urine % N	Feces % N	Dry matter intake
Trial 1:								
All silage	29	6.7	35.0	19.47	6.81	0.797	1.85	17.6
	40	7.2	30.0	21.10	6.33	0.709	1.85	15.7
	50	6.7	31.5	19.89	6.27	0.676	1.99	15.3
Added grain	55	8.2	28.2	22.54	6.36	0.554	1.95	17.1
	64	6.2	30.3	24.21	7.34	0.848	2.18	16.5
Silage plus	68	6.3	30.3	21.95	6.65	0.763	2.18	16.6
High concentrate	91	7.0	12.2	28.82	3.52	0.640	2.37	14.5
	96	6.9	9.3	35.81	3.33	0.786	2.73	15.8
Trial 2:								
All silage	38	6.2	19.6	21.02	4.12	1.02	1.85	15.8
	51	6.1	18.4	21.61	3.98	1.14	2.03	11.5
	54	5.9	14.8	23.69	3.51	1.01	2.12	13.6
Added grain	59	6.1	16.2	22.70	3.68	1.17	2.32	13.8
	67	5.9	17.7	22.95	4.06	0.951	2.29	14.3
Silage plus	69	5.5	15.2	22.97	3.49	1.03	2.37	18.2
High concentrate	90	5.5	8.0	27.48	2.20	0.887	2.82	14.0
	96	5.6	9.0	26.88	2.42	0.974	3.04	12.8

[a]Data collected from a two-year metabolism study.

The manure handling costs reflect labor and machinery expense (Hughes, 1973). Labor charge was calculated at .00041 hours required per gallon times the total gallons of manure per day at an hourly wage rate ($5.00):

Labor cost = (hrs/gal x total gal/day) x hourly wage rate

Pump and spreader use cost was .49¢ per gallon times the number of hours required for handling the manure (.00041 hours per gallon times gallons per day).

Feeding cost was divided into labor and machinery components (Hughes, 1973). Time was estimated at .0001 hours per pound of feed times the number of pounds fed per steer (as-fed basis). The labor cost for feeding was calculated at an hourly wage rate ($5.00). The machinery cost consisted of wagon plus tractor expenses. A cost of 62¢ was charged per hour of feeding time. Tractor cost for feeding was calculated as previously for manure ($6.00 per hour times hours required per day). Labor cost for handling and processing cattle was estimated at .6¢ per day.

The nutrients available were developed from metabolic trial data and their economic value given ration grain content were determined. A 40% storage loss and a 5% application loss of N was assumed (Beef Housing and Equipment Handbook, 1976). Phosphorous availability was determined by conversion of elemental P to P_2O_5 by division of .44; 75% of P_2O_5 is available to the plant. Available potassium was determined by conversion of elemental K to K_2O by a division factor of .83, 90% of which is available. Nutrient availability from manure was in agreement with Peverly (1966) who reported values for nitrogen (51%) and phosphorous (81%). Fertilizer value (¢ per day) was determined using values of 11.5¢ N; 16$ P_2O_5; and 8¢ per pound for K_2O.

The impact of ration grain content (corn in silage plus added corn) is reported in Table 36. Urine production is independent of ration grain content. Feces, in contrast, is a linear function of ration grain content. Wells et al. (1972) reported a manure volume of 2.3 pounds (DM) for steers receiving an all-concentrate ration and 5.0 lbs/day for those receiving a high roughage ration. Snapp and Neuman (1960) reported a yield of 63 pounds of wet manure for steers fed high roughage rations compared to 36 pounds for high grain.

Nutrient density is influenced by ration grain content. Nitrogen excretion per day is constant except for the high concentrate diets, which are 15% lower. Thus, the nitrogen per pound of manure is lower for a high silage than a high concentrate diet. The daily excretion of phosphorous tends to fall as the percent concentrate increases; potassium shows a similar but more pronounced pattern.

Manure handling costs and feeding costs vs ration grain content are reported in Table 37. As total grain (corn in silage plus added corn) in the ration increases from 30% to 100%, there is a decrease in the manure storage (.72 cu. ft. vs .37 cu. ft.), reduced pit depth (8.58 ft. vs 4.90 ft. per head capacity) and a lower manure handling cost per day (6.87¢ vs 5.95¢).

Table 37. Manure Handling and Feeding Costs as Influenced by Total Ration Grain Content

	All silage			Silage plus added grain			High Concentrate	
Measure	30	40	50	60	70	80	90	100
	Percent grain in ration dry matter							
Facility cost (¢/day):								
Cu. ft. of pit required/hd/day	0.72	0.67	0.62	0.57	0.52	0.47	0.42	0.37
Pit depth (20 sq. ft/hd)	8.58	8.06	7.53	7.00	6.48	5.95	5.42	4.90
Pit cost, $[a]	137.43	134.83	132.18	129.53	126.93	124.28	121.63	119.03
Pit use cost/day[b]	6.87	6.74	6.64	6.48	6.35	6.21	6.08	5.95
Building use cost/day	5.40	5.40	5.40	5.40	5.40	5.40	5.40	5.40
Total	12.27	12.14	12.40	11.88	11.75	11.61	11.48	11.35
Manure handling cost (¢/day):								
Labor[c]	1.11	1.10	0.95	0.88	0.80	0.73	0.65	0.57
Machinery	3.97	3.69	3.43	3.15	2.88	2.60	2.33	2.06
Total	5.08	4.79	4.38	4.03	3.68	3.33	2.98	2.63
Feeding cost (¢/day):								
Labor[d]	2.73	2.73	2.73	1.37	1.27	1.18	0.97	0.91
Machinery	1.47	1.36	1.26	1.16	1.06	0.96	0.86	0.76
Total	4.20	4.09	3.99	2.53	2.33	2.14	1.83	1.67
Labor for vet. plus handling (¢)	.6	.6	.6	.6	.6	.6	.6	.6
Total cost/day (¢)	22.15	21.62	21.01	19.04	18.36	17.68	16.89	16.25

[a]Cost of pit: $94.53 + 5 times number of square ft.

[b]Use cost: (Pit cost x 17%)/340 days.

[c]Labor cost: [Hours per gal (.00041) x total gal per day] x hourly wage.

[d]Labor for feeding: Hours required for feeding (.0001 hr/lb) x hourly wage.

Building cost, including building structure plus slatted floor, is constant. Total facility cost is reduced from 12.27¢ per day to 11.35¢ per day as the ration grain level is increased.

Manure handling cost is divided into labor and machinery components. The labor cost required for manure handling is 1.11¢ per day for the all-silage ration vs .57¢ per day for the all-concentrate ration. Machinery cost, including pump and spreader, is reduced from 3.97¢ per day to 2.06¢ per day. Total cost for manure handling is 2.35¢ per day less for the steers fed the high concentrate ration. Feeding cost for the rations varying in grain content was divided into labor and machinery components. The labor cost is reduced from 2.73¢ to .92¢ per day as ration grain level increases. Machinery cost falls from 1.47¢ to .76¢ per day. Total feeding cost per day is lower for the high grain ration (4.20¢ to 1.67¢ per day).

Manure handling plus feeding cost is 5.90¢ lower per day for the high grain ration. When comparisons are made for the total feeding period, steers fed all concentrate rations for 217 days had a facility, manure handling and feeding cost of $35.26 per steer as compared to $65.79 for the steers receiving the high silage ration for 297 days.

The influence of ration grain content on total nutrients available from manure and corresponding fertilizer values is reported in Table 38. Nitrogen availability (pounds per day) was constant as grain level was increased, but decreased slightly for the high concentrate diets. Phosphorous decreased from .10 to .07 pounds per day and potassium was reduced from .12 to .06 pounds per day. These values

Table 38. Nutrients Available and Fertilizer Value of Manure as Influenced by Ration Grain Content

Measure	All silage			Silage plus added grain			High concentrate	
	30	40	50	60	70	80	90	100
	------------ Percent grain in ration dry matter ------------							
Urine (l)	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
Feces (lb)	30.3	27.4	24.4	21.4	18.4	15.5	12.5	9.5
Total volume (gal)	5.34	5.02	4.65	4.28	3.91	3.54	3.17	2.80
Nutrients available (lb/day)[a]								
Nitrogen (N)	.13	.13	.13	.13	.13	.13	.11	.11
Phosphorus (P_2O_5)	.10	.10	.09	.08	.08	.07	.07	.06
Potassium (K_2O)	.12	.10	.10	.09	.08	.07	.07	.06
Fertilizer value (¢/day)[b]								
Nitrogen (N)	1.50	1.50	1.50	1.50	1.50	1.50	1.27	1.27
Phosphorus (P_2O_5)	1.60	1.60	1.44	1.28	1.28	1.12	1.12	1.12
Potassium (K_2O)	.96	.80	.80	.72	.64	.56	.56	.48
Total return from manure (¢/day)	4.06	3.90	3.74	3.50	3.42	3.18	2.95	2.87

[a]Percent of nutrients available to corn plant: N 55%; P_2O_5 75%; K_2O 90%.

[b]Cost/lb: N 11.5¢; P_2O_5 16¢; K_2O 8¢.

are similar to estimated fertilizer nutrient in liquid beef waste, as reported by Pherson (1973). Fertilizer value from the manure was calculated from the nutrient availability for the various grain rations. Nitrogen value was 1.50¢ per day for the silage rations but was slightly reduced to 1.27¢ per day for the high concentrate rations. Phosphorous (P_2O_5) and potassium (K_2O) were reduced by .48¢ per day as grain level was increased.

Total returns (credits) from manure (¢ per day) are 4.06¢ for the steers fed the low grain vs 2.87¢ for the steers fed the all concentrate ration (Table 39). When comparisons are made for the total feeding period, steers fed all concentrate for 217 days had a lower return for manure ($6.23/steer) as compared to steers fed all-silage ($12.06/steer) for 297 days.

Pricing Corn Silage

Economic analysis of feedlot trials, particularly those involving alternative levels of corn in the diet, requires prices for shelled corn and corn silage. A whole farm budgeting approach (Connor et al., 1976) is required to accurately assess the roles of corn silage and shelled corn in farmer-feeder operations including factors such as labor and machinery scheduling and machinery inventory. A good approximation can be developed based upon the fact that producers have the option of selling corn as cash grain as well as harvesting it as silage. Thus, the "cost" of producing corn silage is influenced by the market value of corn grain through the opportunity

Table 39. Net Cost of Feeding, Manure Handling and Storage and Manure Credit[a]

	Percent gain in ration dry matter							
	30	40	50	60	70	80	90	100
Feeding, manure storage and handling cost (¢/day)	22.15	21.62	21.01	19.04	18.36	17.68	16.89	16.25
Manure credit (¢/day)	4.06	3.90	3.74	3.50	3.42	3.18	2.95	2.87
Net cost/day (¢)	18.09	17.72	17.27	15.54	14.94	14.50	13.95	13.38

cost of land--the net earning capacity of land if it were used to grow corn. Other costs indlude fertilizer, seed, herbicides and insecticides, field operations, storage and interest on operating capital. When corn is harvested as silage, the corn stalks are not returned to the soil; the dollar values for nitrogen, phosphorous and potassium must be adjusted accordingly. Too, adjustments must be made for handling and storage losses between the field and at the feedbunk.

The cost of growing, harvesting and storing corn vs corn silage for different plant populations is reported in Table 40. Total nonland costs are partitioned into seed, fertilizer, herbicide and insecticide, field operations, management and supervisory labor, and interest on operating capital. A seed cost of $45 per unit (80,000 seeds per unit) was budgeted; a 10% loss during germination was assumed.

Table 40. Cost of Corn and Corn Silage Production

Item	Price/unit ($)	Corn grain 20,000 100 bu ($)	Corn silage (plants/acre) 10,000 14 T ($)	20,000 16 T ($)	30,000 18 T ($)	50,000 20 T ($)
Seed[a]	45/80,000	12.50	6.24	12.50	18.75	31.25
Fertilizer[b]						
N	.115/lb	12.65	20.13	21.85	23.58	25.30
P_2O_5	.16/lb	8.00	9.12	10.40	11.68	12.96
K_2O	.08/lb	4.80	21.00	24.00	27.00	30.00
Lime	11.00/T	0.80	0.90	1.10	1.30	1.50
Herbicides and insecticides[c]	16.00/A	16.00	16.00	16.00	16.00	16.00
Field operations[d]						
Plowing		8.50	8.50	8.50	8.50	8.50
Disking		4.40	4.40	4.40	4.40	4.40
Planting		6.00	6.00	6.00	6.00	6.00
NH_3 application		3.00	3.00	3.00	3.00	3.00
Cultivating		3.20	3.20	3.20	3.20	3.20
Spraying		2.50	2.50	2.50	2.50	2.50
Combining		17.00	--	--	--	--
Grain hauling	.07/bu	7.00	--	--	--	--
Chopping, hauling & silo filling		--	27.00	30.00	33.00	36.00
Drying	.023/point	23.00	--	--	--	--
Grain storage	.15/bu	15.00	--	--	--	--
Silage storage[e]	1.75/T	--	24.50	28.00	31.50	35.00
Management and supervising labor		6.00	8.00	8.00	8.00	8.00
Interest on operating capital	Avg. 7 mo. 10%/yr	5.42	6.31	7.19	8.07	9.31
Total nonland cost						
Per acre		155.77	166.80	186.64	206.48	232.92
Per bushel		1.56	--	--	--	--
Per ton		--	11.91	11.67	11.47	11.65

[a]$45/unit (80,000 seeds per unit), 90% germination.

[b]Warncke *et al.*, 1976.

[c]Nott *et al.*, 1977.

[d]Schwab and Gruenewald, 1978 (costs include fuel plus labor).

[e]Hoglund, 1977 (calculated as bunker cost x 17% for property tax, depreciation and interest.

Fertilizer cost was determined by accounting for the removal of nutrients from the soil when corn is harvested as silage as compared to harvesting as grain. Corn yielding 100 bushels of grain per acre when harvested as shelled corn is estimated to remove 110 pounds of nitrogen, 50 pounds of P_2O_5 and 60 pounds of K_2O per acre (Warncke et al., 1976).

It is estimated that 16 tons of corn silage removes 175 pounds of nitrogen, 57 pounds of P_2O_5 and 262 pounds of K_2O per acre. Prices used were: 11.5¢, N; 16¢, P_2O_5; and 8¢ per pound for K_2O. Lime was budgeted at $11 per ton. Herbicides and insecticides were budgeted at $16 per acre (Nott et al., 1977).

Field operations were priced at custom rates (Schwab and Gruenwald, 1978). They were adjusted upward if it appeared they were inadequate to yield an adequate return on machinery investment as well as covering depreciation, labor and cash costs such as fuel and repairs (Black, 1978). Silage costs were increased as yield per acre was increased. Silage storage costs are based upon a moderately large bunker; a 12 year life and 10% opportunity cost on capital were used in pricing. The nonland costs reflect the differences in the cost of growing and harvesting corn as silage vs grain.

The total "cost" of corn silage based upon yielding the same net per acre to land as corn grain is derived as follows:

Step 1.

"Imputed" rental on land	=	Gross return if sold as grain	=	Sum of nonland costs of growing, harvesting and storing corn as grain

Step 2.

$$\text{Calculate the cost of silage (\$/acre)} = \text{Step 1} + \text{Sum of nonland costs of growing, harvesting and storing corn as corn silage}$$

Step 3.

$$\text{Calculate the cost of silage (\$/ton)} = \left[\text{Cost of silage per acre} \div \text{Yield}\right] \div \text{Net retention}$$

where net retention is the ratio of corn plant forage dry matter into the silo compared to the corn silage dry matter that is removed. A 7% loss was assumed (Prigge and Owens, 1976). This is a low estimate compared to many literature values; however, part of the losses reported in the literature reflect errors in dry matter determination for corn silage that run between 6% and 13% (Fox and Fenderson, 1977).

The total nonland cost for corn grain and for corn silage grown at different plant populations is reported in Table 40. Seed cost increased from $6.24 to $31.25 per acre as plant population was increased. The silage yield increased from 14 to 20 tons per acre. There was an increase in the nitrogen cost from $20.13 to $25.30, P_2O_5 from $9.12 to $12.96 and K_2O from $21 to $30. Fertilizer costs increase considerably when corn is harvested as silage as compared to grain due to the removal of stalks and leaves from the field during harvest (Warncke _et al_., 1976).

Field operations, including the cost of plowing, disking, planting, nitrogen application, cultivating and spraying, were the same for corn grain and for corn silage harvested for all plant populations. Grain hauling was estimated at 7¢ per bushel and drying at 2.3¢ per point of moisture removed. Cost for chopping and silo filling increased from $27 to $36 per acre as yields increased. Interest on operating capital was based upon 10% per year. As corn silage yields per acre increased, interest on operating capital increased from $6.31 to $9.31.

Total nonland costs per acre increased from $166.80 to $232.92 as silage yield increased from 14 to 20 tons/acre. However, on a dollars per ton basis, cost was reduced from $11.91 to $11.65.

The price of corn silage per ton required to give the same net return as when crop is harvested as grain, is shown in Figure 18. This relationship was obtained by first determining the "imputed rental charge" on land--the net return to land if the corn had been sold as cash grain. As the price of shelled corn increased from $2.00 to $3.50/bushel, the "imputed" land rental increased from $44.23 to $194.23. Second, silage cost per acre considers the land rental charge plus the sum of nonland costs for corn grown, harvested and stored as silage. With a $2.00/bushel shelled corn price, silage costs per acre were $211.00, $230.90, $250.70 and $277.15 per acre as yields increased from 14 to 20 tons per acre, respectively. With a $3.50/bushel corn price silage costs were $361.00, $400.70 and $427.15 per acre as yields increased from 14 to 20 tons per acre. As reported in Table 41, total costs of silage/ton at $2.00/bushel shelled corn price are $16.20, $15.52, $14.98 and $14.90 for yields of 14, 16, 18 and 20 tons, respectively; at $3.50/bushel they increased to $27.73, $25.60, $23.94 and $22.97 per ton.

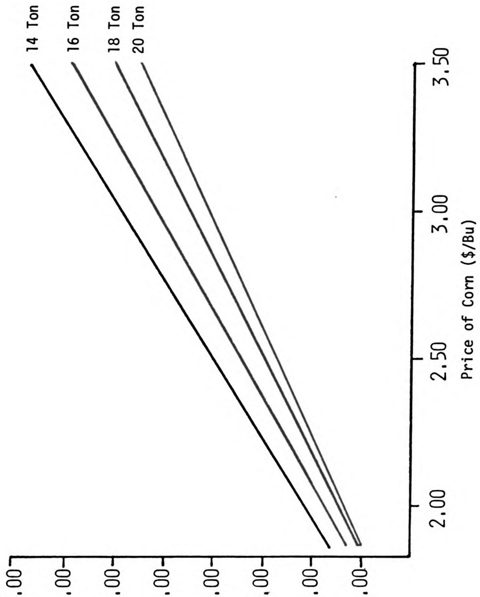


Figure 18. Price of silage relative to grain price.

Table 41. Price of Corn Silage Per Ton as Influenced by Corn Price

Corn price ($/bu)	Corn silage yield/ton			
	14 ton	16 ton	18 ton	20 ton
2.00	16.20	15.52	14.98	14.90
2.50	20.05	18.88	17.96	17.59
3.00	23.89	22.24	20.95	20.28
3.50	27.73	25.60	23.94	22.97

The following equations describe the relationship between the season average price of shelled corn and the price of corn silage:

- Silage yield of 14 ton per acre (10,000 population)

  Price of corn silage = $0.82 + 7.69 • price of corn

- Silage yield of 16 ton per acre (20,000 population)

  Price of corn silage = $2.08 + 6.72 • price of corn

- Silage yield of 18 ton per acre (30,000 population)

  Price of corn silage = $3.04 + 5.97 • price of corn

- Silage yield of 20 ton per acre (50,000 population)

  Price of corn silage = $4.14 + 5.38 • price of corn.

In summary, the costs of growing corn silage, dollars per ton, is developed for alternative prices of shelled corn. Silage is priced such that it yields equivalent net returns to land as could be achieved growing shelled corn. The standard price is based upon a loamy clay soil capable of producing 100 bushels of shelled corn or 16 tons of corn silage per acre. The "out of the silo" price is \$15.50, \$18.00, and \$22.25 at \$2.00, \$2.50, and \$3.00 per bushel, season average shelled corn prices, respectively. Additionally, corn silage prices were developed for alternative plant populations, hence different yields and grain:forage ratios were considered.

Economic Analysis

The economic impact of the level of grain in the ration is evaluated from a total cost/cwt gain perspective; namely,

$$\frac{\text{Cost}}{\text{Gain}} = \left(\frac{\text{Feed}}{\text{Gain}}\right)(\text{Price}_{\text{feed}}) + \frac{\text{Nonfeed cost/day}}{\text{ADG}}$$

The framework is described in Black and Fox (1977).

Nonfeed costs included labor and machinery for feeding, labor for observing cattle, housing and machinery for manure storage and handling. The costs are adjusted for manure credit. The costs of manure storage and handling and the manure credit adjustment are reported in Table 39. As the ration grain content was increased from 30% to 100%, costs were reduced by 5.9¢ per day (22.1¢ vs 16.2¢) but the manure credit increased by 1.19¢ per day (4.06¢ vs 2.87¢ per day). The resultant net cost per day was 4.71¢ higher (18.09¢ _vs_ 13.38¢) for the cattle receiving all silage with 30% grain than those receiving the 100% concentrate ration.

As reported in Table 42, feed disappearance for rations varying in grain content from 30% to 100% was determined from developed equations, as previously discussed.

The cost of producing corn silage from different plant populations is reported in Table 41. Corn silage is priced such that it yields the same net return per acre as corn grain. The additional costs for fertilizer and handling are reflected in the silage price. At $2.00 per bushel corn, the prices are $15.52 and $14.90 per ton for silage containing 47% and 30% grain, respectively. At $3.50 per bushel corn, the prices are $25.60 and $22.97, respectively. The prices of urea and minerals were held constant for all corn prices, as was the interest charge per head per day.

The cost summary, based upon the feed disappearance summary in Table 42, is given in Table 43. A basic question is: "How high does the price of corn have to get before the relatively higher non-feed costs per cwt gain, associated with the high silage system, are more than offset by the widening feed cost differential following from the fact that corn prices rise faster than silage prices?" The high concentrate system has a clear advantage at $2.00 per bushel corn over the all-silage ration containing 50% grain. But, at $2.75 per bushel corn, the all-silage ration with 50% grain has an advantage. The 30% grain, all-silage ration is never competitive.

Table 42. Feed Disappearance

Measure	Percent grain in ration dry matter			
	30[a]	50[b]	70[c]	90[d]
Performance[e]				
Daily gain, kg	0.82	0.99	1.16	1.24
Feed/gain	9.55	8.38	7.22	6.05
Days on feed to gain 600 lbs	333	275	234	219
Feed disappearance/cwt gain				
Corn silage (T, 32% DM)	1.37	1.22	0.56	0.12
Corn (bu, 85% DM)	--	--	6.52	10.25
Supplement (lbs, 90% DM)[f]	84.9	74.5	57.1	47.0

[a]Low grain corn silage (27% grain in silage DM), 92%; supplement, 8%.

[b]High grain corn silage (47% grain in silage DM), 92%; supplement, 8%.

[c]High grain corn silage, 50%; corn grain, 43%; supplement, 7%.

[d]High grain corn silage, 12.3%; corn grain, 80.7%; supplement, 7%.

[e]Developed from regressions on pooled data. The 80% added corn rations were excluded due to the "erratic" values in Trial 1 relative to Tril 2 and previous experimental work.

[f]Corn-urea-mineral supplements are described in Table 10.

Table 43. Cost Summary ($/CWT Gain)[a]

Measure	Percent grain in ration dry matter			
	30 ($)	50 ($)	70 ($)	90 ($)
Nonfeed costs:				
Yardage, net manure[b]	10.05	8.13	5.84	5.09
Interest on feeder[c]	4.50	3.72	3.16	2.96
Total	14.55	11.85	9.00	8.05
Feed costs:				
$2.00/bu corn	24.41	22.39	24.28	24.30
$2.75/bu corn	30.66	29.21	32.50	33.06
$3.50/bu corn	36.92	36.06	40.70	41.71
Total costs:				
$2.00/bu corn	38.96	34.24	33.28	32.35
$2.75/bu corn	45.21	41.06	41.50	41.11
$3.50/bu corn	51.47	47.87	49.70	49.75

[a]See Table 42 for performance data. Costs reflect experimental condition; they are not adjusted for death loss, very poor doers, or time to get on feed.

[b]See Table 39. Excludes veterinary and marketing costs since they are similar across feeding systems.

[c]The interest charge budgeted is 8.1¢/head/day irrespective of corn price. In fact higher corn prices reduce feeder prices and resultant interest cost. However, in the long run, high corn prices reduce beef supplies which raises fed beef prices; resultant increase in feeder prices will raise the interest charge although not the previous levels.

As reported in Table 44, the two-phase system is competitive with the high concentrate system at $2.00 corn and is competitive with the all silage system at $3.50 corn.

Table 44. Cost Summary of Various Feeding Systems

	Feeding systems			
Total costs ($/bu corn)	100% corn silage	Two-phase	50%[a] corn silage	90% concentrate, 12% silage
2.00	34.24	31.70	33.28	32.35
2.75	41.06	39.39	41.50	41.11
3.50	47.87	47.05	49.70	49.75

[a]Approximately 50% grain in silage.

CONCLUSIONS

1. Corn silage grain content increased from 27% to 53% as plant population was decreased.
2. Average daily gain and feed efficiency was influenced by ration grain content ($P < .01$).
3. Ration grain content influenced carcass fat, fat thickness and dressing percentage ($P < .05$).
4. Steers fed all silage increased in gain 17% and feed efficiency improved 12.3% as silage grain content increased from 30% to 50%.
5. NE_g of corn silage increased from .94 to 1.04 Mcal/kg as grain content increased from 30% to 50%.
6. NE_g was 8.9% lower than predicted when the ration contained 70% grain.
7. NE_g sharply increased from 1.14 to 1.28 Mcal/kg as ration grain content was increased from 70% to 96%.
8. Steers fed on the two-phase system had similar gains but improved in feed efficiency by 6.5% over those fed constant added grain.
9. Acid detergent fiber or ration grain content were equally useful for predicting performance and NE_g.

10. Relative to corn price, silage costs were \$15.50, \$18.90 and \$22.25/ton at \$2.00, \$2.50 and \$3.00/bushel.
11. Non-feed cost minus manure credit was 4.71¢ higher per day for steers fed silage _vs_ those fed high concentrate rations.
12. At \$2.00 per bushel the high concentrate system is more economical, but at \$2.75 per bushel all silage (50% grain) has an advantage. The two-phase system was competitive at \$2.00 and \$3.50 per bushel corn.

APPENDIX

Table A.1 Acid Detergent Fiber Determinations of Plant Components of Silages Varying in Grain Content in Trial 1

Plant component	Percent grain in silage dry matter		
	27	43	49
	(% ADF)		
Leaf	35.1	35.1	37.7
Stalk	38.1	42.7	44.0
Husk	35.6	37.8	38.1
Cob	42.0	43.9	45.2
Grain	3.8	3.6	4.0

Table A.2 Crude Protein Determinations of Plant Components of Silages Varying in Grain Content in Trial 1

Plant component	Percent grain in silage dry matter		
	27	43	49
	(% protein)		
Leaf	11.5	9.5	11.1
Stalk	5.7	5.7	6.0
Husk	4.4	4.8	5.1
Cob	4.0	3.8	3.2
Grain	11.0	11.1	12.4

Table A.3 Acid Detergent Fiber Determinations of Plant Components of High Oil, Brown Midrib and Normal Corn Silage in Trial 1

Plant component	Normal	High oil	Brown midrib
	(% ADF)		
Leaf	35.1	34.3	35.4
Stalk	42.7	40.0	33.6
Husk	37.8	37.7	35.5
Cob	43.9	45.4	37.4
Grain	3.6	4.9	4.2

Table A.4 Crude Protein Determinations of Plant Components of High Oil, Brown Midrib and Normal Corn Silage in Trial 1

Plant component	Normal	High oil	Brown midrib
	(% protein)		
Leaf	9.5	14.3	8.5
Stalk	5.7	6.8	6.3
Husk	4.8	5.1	5.0
Cob	3.8	3.0	3.4
Grain	11.1	10.8	10.1

Table A.5 Acid Detergent Fiber Determinations of Plant Components of Silages Varying in Grain Content in Trial 2

Plant component	Percent grain in silage dry matter		
	36	50	53
	(% ADF)		
Leaf	38.0	34.4	33.4
Stalk	48.4	42.7	36.0
Husk	3916	38.6	37.9
Grain	3.3	3.3	4.3

Table A.6 Crude Protein Determinations of Plant Components of Silages Varying in Grain Content in Trial 2

Plant component	Percent grain in silage dry matter		
	36	50	53
	(% protein)		
Leaf	8.3	9.2	12.2
Stalk	6.3	4.1	6.5
Husk	3.8	3.9	4.0
Grain	9.7	10.1	11.7

Table A.7 Fermentation Values for Silage Varying in Grain Content, High Oil and Brown Midrib Corn

	Plant population				Corn variety	
	10,000	20,000	30,000	50,000	High oil	Brown midrib
Trial 1:						
Lactic acid, %	4.28	3.89	5.49	--	6.36	4.50
Soluble N, %	43.71	56.9	57.69	--	54.23	42.18
pH	3.83	3.72	3.88	--	3.73	3.97
Trial 2:						
Lactic acid, %	3.55	3.62	--	3.24		
Soluble N, %	48.70	49.63	--	44.88		
pH	3.93	3.90	--	3.92		

Table A.8 Individual Performance and Carcass Data (Trial 1)

Pen no.	Steer no.	Treatment no.	% grain	Days on feed	Initial carcass wt, kg	Final carcass wt, kg	Carcass ADG kg	Marb.[a]	Qual grade[b]	Fat thick cm	KPH fat %	Rib eye area cm	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain kg	Daily fat gain kg	Daily protein energy kcal	Daily fat energy kcal
24	626	1	50	282	124.1	304.8	0.64	12	10	0.76	2.0	76.1	2.5	15.29	34.02	0.1288	0.3968	732.4	3716.8
24	639	1		282	138.1	327.0	0.67	8	9	0.51	3.0	87.7	2.0	16.31	30.93	0.1450	0.3716	824.5	3480.6
24	657	1		282	148.4	355.6	0.73	18	12	1.14	2.5	83.9	3.0	14.90	34.14	0.1382	0.4571	785.8	4281.7
24	671	1		282	135.6	293.9	0.56	9	9	0.13	1.5	85.8	1.2	17.80	20.25	0.1379	0.1779	784.1	1666.4
24	677	1		282	127.9	307.5	0.64	13	11	0.89	3.5	78.1	2.8	14.90	38.95	0.1221	0.4706	694.3	4408.1
24	680	1		282	144.5	356.0	0.75	12	10	0.76	1.5	91.0	2.0	16.01	28.62	0.1581	0.3672	899.0	3439.6
24	681	1		282	125.3	338.8	0.76	17	11	1.02	3.5	80.0	3.1	15.45	32.63	0.1563	0.4239	888.7	3970.7
24	695	1		282	134.3	339.2	0.73	12	10	1.02	3.0	85.8	2.7	15.69	29.46	0.1506	0.3668	856.3	3435.8
23	629	2	68	240	118.9	332.9	0.89	13	11	0.64	2.0	81.9	2.3	15.19	33.31	0.1819	0.5062	1034.3	4741.6
23	630	2		240	126.6	324.3	0.82	12	10	0.89	3.0	80.7	2.7	15.75	31.08	0.1735	0.4449	986.5	2077.0
23	634	2		240	131.7	317.5	0.77	11	10	0.64	3.0	83.9	2.2	16.20	27.71	0.1673	0.3693	951.3	3459.2
23	651	2		240	140.7	337.0	0.82	9	9	0.76	3.0	74.8	3.0	15.93	30.44	0.1711	0.4411	972.9	4131.8
23	655	2		240	143.2	330.2	0.78	18	11	0.76	2.5	81.9	2.5	15.87	28.90	0.1603	0.3994	911.5	3741.2
23	662	2		240	129.2	335.6	0.86	12	10	1.14	3.0	81.3	3.0	15.77	30.11	0.1813	0.4425	1030.9	4144.9
23	690	2		240	147.1	363.7	0.90	20	13	1.27	3.5	93.6	2.9	15.93	30.88	0.1887	0.4860	1072.9	4552.4
23	736	3		240	136.8	320.2	0.76	13	11	1.02	3.0	68.4	3.4	14.95	34.58	0.1448	0.4923	823.3	4611.4
22	623	3	40	268	149.6	348.8	0.74	20	8	0.76	3.0	86.5	2.5	16.52	26.07	0.1620	0.3283	921.1	3075.2
22	637	3		268	134.3	323.8	0.71	8	8	1.14	3.0	92.3	2.4	16.45	26.00	0.1559	0.3090	886.4	2894.4
22	659	3		268	125.3	326.1	0.75	8	8	0.89	3.5	85.2	2.6	16.53	27.12	0.1688	0.3370	959.8	3156.7
22	664	3		268	124.1	299.8	0.66	11	10	0.76	3.0	72.9	2.8	15.80	32.82	0.1379	0.3916	784.1	3668.1
22	674	3		268	143.2	296.6	0.57	12	10	0.38	2.5	77.4	2.0	15.79	30.61	0.1139	0.3389	647.6	3174.5
22	683	3		268	138.1	333.3	0.73	9	9	0.76	2.5	84.5	2.4	16.02	28.18	0.1541	0.3541	876.2	3316.9
22	697	3		268	131.7	324.3	0.72	13	11	0.89	2.5	91.0	2.1	16.06	27.26	0.1540	0.3324	875.6	3113.6
22	735	3		268	136.8	293.0	0.58	8	8	0.64	3.0	74.8	2.5	14.91	31.66	0.1070	0.3546	608.4	3321.5
21	624	4	64	268	126.6	308.8	0.68	9	9	1.02	3.0	87.1	2.8	14.92	34.11	0.1311	0.4232	745.4	3964.1
21	627	4		268	133.0	326.1	0.72	12	10	0.89	3.6	87.1	2.5	15.27	31.94	0.1430	0.4099	813.1	3839.5
21	632	4		268	145.8	361.0	0.77	18	7	0.81	8.0	92.9	1.8	16.91	24.77	0.1749	0.3124	994.6	2926.3
21	648	4		268	142.0	382.3	0.90	14	11	0.89	4.0	94.2	2.7	14.91	36.96	0.1109	.4491	630.6	4206.7
21	656	4		268	133.0	345.6	0.76	18	12	1.02	4.0	76.8	3.4	14.33	34.57	0.1456	0.4844	827.9	4537.4
21	672	4		268	120.2	281.6	0.60	13	11	1.14	3.0	66.5	3.3	14.94	35.41	0.1164	0.4043	661.9	3787.1
21	679	4		268	138.1	353.3	0.80	11	10	2.03	3.5	71.6	4.6	14.06	29.90	0.1421	0.4102	808.0	3842.3
21	693	4		268	138.1	358.7	0.82	15	11	0.76	3.0	82.6	2.8	15.64	31.67	0.1701	0.4493	967.2	4208.6
20	614	5	29	268	134.3	304.8	0.64	12	11	0.76	2.5	67.7	3.0	14.67	34.47	0.1163	0.4166	661.3	3902.3
20	616	5		268	113.8	230.8	0.45	8	9	0.76	2.0	71.6	2.0	17.07	24.40	0.1031	0.1951	586.2	1827.5
20	631	5		268	145.8	288.9	0.54	18	12	0.76	4.5	68.4	3.2	14.74	35.32	0.1427	0.4979	811.4	4663.8
20	642	5		268	125.3	278.0	0.57	8	8	0.38	1.5	76.8	2.0	16.40	30.74	0.1251	0.3286	711.3	3078.0
20	650	5		268	139.4	299.8	0.60	12	10	0.51	2.5	78.7	2.1	16.06	28.26	0.1243	0.3108	706.8	2911.3
20	669	5		268	131.7	283.0	0.56	16	12	1.02	3.0	69.0	3.1	15.01	30.61	0.1057	0.3289	601.0	3080.8
20	684	5		268	140.7	313.8	0.65	7	7	0.64	2.0	76.1	2.5	16.98	22.63	0.1471	0.2392	836.4	2240.6
20	737	5		268	138.1	300.7	0.61	9	9	0.89	3.0	81.3	2.5	16.41	28.88	0.1310	0.3226	744.9	3021.8

Table A.8--Continued

Pen no.	Steer no.	Treat-ment no.	% grain	Days on feed	Initial carcass wt, kg	Final carcass wt, kg	Carcass ADG kg	Marb.[a]	Qual grade[b]	Fat thick cm	KPH fat %	Rib eye area cm	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain kg	Daily fat gain kg	Daily protein energy kcal	Daily fat energy kcal
19	647	6	55	240	135.6	301.1	0.69	11	10	0.51	1.5	80.0	1.9	16.53	26.09	0.1514	0.3156	860.9	2956.2
19	654	6		240	143.2	315.6	0.72	12	10	0.76	2.0	85.8	2.1	15.79	29.24	0.1455	0.3844	827.3	3600.7
19	670	6		240	133.0	302.5	0.71	11	10	0.51	2.5	76.8	2.3	15.70	29.25	0.1441	0.3733	819.4	3496.7
19	673	6		240	139.4	326.5	0.78	9	9	0.76	2.0	93.6	1.8	16.41	42.01	0.1698	0.6373	965.5	5969.6
19	676	6		240	126.6	269.8	0.60	11	10	1.02	3.0	74.2	2.7	15.62	30.22	0.1200	0.3446	682.3	3227.9
19	691	6		240	153.5	335.6	0.76	8	8	0.25	1.0	74.2	2.1	16.40	25.75	0.1615	0.3400	918.3	3184.8
19	692	6		240	122.8	317.5	0.81	12	10	0.89	2.5	77.4	2.7	16.18	27.48	0.1779	0.3729	1011.5	3493.0
19	734	7		240	135.6	301.1	0.69	9	9	0.64	2.0	71.0	2.6	16.13	29.96	0.1457	0.3811	828.5	3569.8
18	622	7	91	198	140.7	339.7	0.01	12	10	1.14	3.5	89.7	2.7	15.28	31.89	0.1978	0.5731	124.7	5368.2
18	635	7		198	139.4	330.2	0.96	9	9	0.76	2.0	82.6	2.3	15.83	28.54	0.1992	0.4801	132.7	4497.1
18	665	7		198	133.0	346.9	0.08	9	9	0.38	3.0	87.1	2.1	16.43	28.84	0.2402	0.5097	365.8	4774.5
18	666	7		198	131.7	334.2	0.02	9	9	0.38	1.5	91.6	1.5	16.68	29.95	0.2314	0.5272	315.7	4938.3
18	667	7		198	154.7	327.9	0.87	9	9	0.51	3.0	84.5	2.2	16.57	27.21	0.1875	0.4306	1066.1	4033.4
18	675	7		198	118.9	322.0	0.03	9	9	1.14	3.0	85.8	2.7	15.91	30.55	0.2218	0.5311	261.2	4974.8
18	689	7		198	138.1	339.2	0.02	12	10	1.40	3.0	86.5	3.1	15.37	33.20	0.2025	0.6045	151.4	5662.4
18	700	7		198	126.6	305.2	0.90	9	9	0.38	1.5	91.0	1.2	17.13	25.80	0.2122	0.3921	206.6	3672.8
17	613	8	96	240	136.8	290.7	0.64	12	10	0.51	1.5	78.7	1.9	16.12	28.43	0.1340	0.3391	761.9	3176.3
17	633	8		240	127.9	372.8	0.02	11	10	2.16	3.5	87.7	4.1	14.71	35.79	0.1995	0.6391	134.4	5986.4
17	649	8		240	134.3	344.7	0.88	23	14	1.27	2.0	91.6	2.5	14.92	32.13	0.1698	0.4910	965.5	4599.2
17	652	8		240	140.7	349.7	0.87	15	11	1.52	3.5	70.3	4.2	14.19	40.17	0.1545	0.6506	878.5	6094.2
17	653	8		240	147.1	322.0	0.73	17	12	0.89	3.5	72.3	3.2	14.81	37.55	0.1319	0.5417	750.0	5064.7
17	663	8		240	121.5	305.7	0.77	12	10	1.02	3.0	89.0	2.3	15.04	32.92	0.1518	0.4512	863.1	4225.4
17	668	8		240	126.6	324.7	0.83	13	11	1.02	3.5	74.8	3.2	15.55	29.82	0.1706	0.4224	970.0	3956.6
17	687	8		240	139.4	328.3	0.79	12	10	0.38	2.0	73.6	2.4	15.98	28.58	0.1652	0.3945	939.3	3695.3
16	615	9	High	282	134.3	309.8	0.62	12	10	0.64	2.0	77.4	2.7	15.83	28.98	0.1288	0.3221	732.4	3017.1
16	617	9	oil	282	127.9	276.2	0.53	9	9	0.64	2.0	76.8	2.0	15.81	28.73	0.1079	0.2810	613.5	2632.1
16	640	9	39	282	139.4	307.5	0.60	6	6	0.38	0.5	77.4	1.7	15.56	26.56	0.1182	0.2798	672.1	2620.9
16	641	9		282	145.8	321.5	0.62	12	10	0.64	2.0	75.5	2.5	17.16	24.53	0.1433	0.2601	814.8	2436.4
16	685	9		282	136.8	294.3	0.56	12	10	0.51	1.0	81.9	1.6	16.27	27.71	0.1189	0.2829	676.1	2649.9
16	686	9		282	122.8	288.0	0.59	12	10	0.76	0.5	74.2	2.3	16.87	25.60	0.1354	0.2562	769.9	2399.8
16	688	9		282	125.3	300.7	0.62	11	10	0.51	2.0	80.7	1.9	16.05	29.42	0.1335	0.3235	759.1	3030.2
16	696	9		282	142.0	309.8	0.60	5	5	0.25	0.5	76.1	1.7	16.72	20.95	0.1318	0.1974	749.4	1849.0
15	619	10	Brn	268	149.6	347.8	0.74	12	10	1.02	3.0	84.5	2.9	15.61	30.49	0.1625	0.4038	924.0	3782.4
15	621	10	mid	268	115.1	296.1	0.68	13	11	1.02	3.5	69.0	3.2	14.59	36.24	0.1294	0.4454	735.8	4172.1
15	625	10	36	268	143.2	386.4	0.91	14	11	2.29	3.0	78.1	4.7	14.55	35.38	0.1702	0.5568	967.8	5215.5
15	628	10		268	131.7	313.4	0.68	11	10	0.51	2.5	71.6	2.6	16.13	29.04	0.1453	0.3466	826.2	3246.6
15	644	10		268	139.4	322.4	0.68	9	9	0.64	3.5	83.2	2.5	15.86	27.32	0.1410	0.3249	801.7	3043.3
15	660	10		268	138.1	333.8	0.73	15	11	1.02	3.5	83.9	2.9	15.22	34.23	0.1430	0.4556	813.1	4267.6
15	698	10		268	126.6	322.9	0.73	9	9	0.89	3.0	81.9	2.7	15.77	31.16	0.1541	0.3973	876.2	3721.5
15	699	10		268	135.6	303.9	0.63	9	9	0.76	3.0	77.4	2.6	16.26	28.31	0.1345	0.3197	764.8	2994.6

[a]Marbling: Modest- = 13; Small+ = 12; Small° = 11; Small- = 10; Slight+ = 9; Slight° = 8; Slight- = 7.

[b]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.9 Individual Performance and Carcass Data (Trial 2)

Pen no.	Steer no.	Treatment no.	% grain	Days on feed	Initial carcass wt, kg	Final carcass wt, kg	Carcass ADG kg	Marb.[a]	Qual grade[b]	Fat thick cm	KPH fat %	Rib eye area cm	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain kg	Daily fat gain kg	Daily protein energy kcal	Daily fat energy kcal
24	220	1	54	230	145.7	323.4	0.77	7	7	1.02	3.0	78.7	2.9	15.17	30.95	0.1512	0.4145	859.9	3882.4
24	227	1		230	168.5	336.5	0.73	11	10	0.89	3.5	78.1	3.1	15.26	30.59	0.1317	0.4039	778.1	3783.4
24	338	1		230	152.0	312.0	0.70	17	12	0.76	3.0	72.3	2.9	15.06	31.42	0.1307	0.3973	743.1	3721.3
24	252	1		230	164.7	334.2	0.74	10	10	1.14	3.5	75.6	3.4	13.20	39.31	0.1047	0.5770	595.6	5408.0
24	260	1		230	140.6	292.5	0.66	21	13	1.02	3.5	78.7	2.8	14.80	32.64	0.1222	0.3964	694.8	3712.8
24	265	1		230	158.4	309.3	0.66	12	10	1.02	2.5	78.1	2.7	16.35	25.94	0.1405	0.2849	798.9	2668.9
24	296	1		230	150.8	270.3	0.52	8	8	1.40	3.5	60.6	3.9	14.91	32.05	0.0901	0.3384	512.3	3169.4
24	345	1		230	145.7	320.6	0.76	10	10	1.40	3.0	78.1	3.3	15.02	31.59	0.1462	0.4222	831.5	3955.0
23	212	2	69	202	147.0	296.6	0.74	13	11	1.27	3.0	69.0	3.4	14.17	35.19	0.1237	0.5049	703.3	4729.4
23	223	2		202	145.7	319.3	0.86	10	10	1.27	3.0	89.0	2.7	15.19	30.90	0.1680	0.4630	995.5	4336.8
23	233	2		202	143.2	296.1	0.76	11	10	1.02	3.5	80.0	2.7	14.32	34.55	0.1313	0.4960	746.5	4646.4
23	233	2		202	153.3	296.6	0.71	7	7	0.89	3.5	78.7	2.7	15.21	30.79	0.1325	0.4081	753.8	3822.4
23	275	2		202	164.7	306.6	0.70	11	10	1.27	3.5	73.6	3.4	14.69	33.02	0.1181	0.4592	671.5	4301.3
23	316	2		202	157.1	317.9	0.80	8	8	1.91	3.5	65.8	4.5	14.10	35.51	0.1312	0.5452	746.0	5106.5
23	327	2		202	140.6	311.1	0.84	8	8	1.65	3.5	76.1	3.7	14.54	33.62	0.1546	0.5111	879.3	4787.5
23	351	2		202	166.0	321.1	0.77	7	7	1.27	3.0	78.7	3.2	15.41	29.93	0.1454	0.4199	826.6	3932.8
22	238	3	51	230	168.5	329.7	0.70	10	10	0.89	3.5	80.7	2.9	13.92	36.28	0.1081	0.5043	614.8	4723.7
22	253	3		230	145.7	290.2	0.63	8	8	1.27	3.0	83.9	2.7	15.12	31.19	0.1183	0.3633	672.7	3402.9
22	270	3		230	155.8	300.7	0.63	7	7	1.27	3.0	76.1	3.1	14.77	32.66	0.1108	0.3964	629.8	3713.4
22	292	3		230	149.5	283.4	0.58	7	7	0.76	3.5	78.1	2.5	16.91	23.57	0.1333	0.2184	757.8	2045.7
22	303	3		230	162.2	299.8	0.60	8	8	1.40	3.0	70.3	3.6	15.43	29.84	0.1121	0.3372	637.4	3158.9
22	305	3		230	140.6	286.2	0.63	7	7	1.14	3.0	71.0	3.1	15.58	29.24	0.1275	0.3287	725.1	3079.1
22	307	3		230	143.2	283.9	0.61	13	11	0.51	3.0	70.3	2.5	14.90	32.11	0.1123	0.3712	638.6	3477.3
22	313	3		230	152.0	289.3	0.60	10	10	1.27	2.5	71.0	3.2	15.44	29.81	0.1146	0.3314	651.6	3104.6
21	205	4	67	202	148.2	299.3	0.75	12	10	1.02	3.0	75.5	2.8	16.17	26.71	0.1597	0.3369	908.2	3156.2
21	206	4		202	177.4	330.2	0.76	14	11	1.78	3.0	74.8	3.9	14.71	32.90	0.1259	0.4884	715.9	4574.5
21	210	4		202	139.4	275.7	0.67	8	8	1.27	3.0	72.3	3.1	15.77	28.40	0.1387	0.3416	788.5	3199.7
21	312	4		202	143.2	283.0	0.69	8	8	0.76	3.0	71.0	2.7	16.61	24.85	0.1554	0.2808	883.6	2630.0
21	329	4		202	155.8	305.7	0.74	7	7	1.27	2.5	86.5	2.6	14.65	33.17	0.1293	0.4720	734.9	4420.9
21	336	4		202	152.0	275.3	0.61	7	7	0.89	2.5	76.8	2.4	15.46	29.73	0.1150	0.3498	654.0	3276.3
21	337	4		202	147.0	307.0	0.79	7	10	1.02	3.5	78.7	2.9	14.57	33.49	0.1419	0.4924	806.8	4611.9
21	363	4		202	164.7	319.7	0.77	10	10	1.02	3.0	78.1	2.9	14.69	33.01	0.1323	0.4859	752.3	4551.3
20	204	5	38	230	150.8	293.0	0.62	17	12	0.76	3.0	75.5	2.6	15.17	30.94	0.1158	0.3585	658.5	3358.2
20	221	5		230	152.0	292.1	0.61	12	10	0.38	2.5	82.6	1.8	15.91	27.84	0.1241	0.3011	705.4	2820.2
20	242	5		230	143.2	268.0	0.54	7	7	0.76	2.5	79.4	2.1	15.79	28.32	0.1097	0.2831	623.6	2651.4
20	300	5		230	147.0	254.4	0.47	7	7	0.51	3.0	65.8	2.5	17.10	22.77	0.1086	0.1727	617.8	1617.8
20	304	5		230	140.6	270.3	0.56	10	10	0.89	3.0	69.7	2.8	16.03	27.32	0.1181	0.2724	671.5	2551.4
20	318	5		230	177.4	321.1	0.62	7	7	0.76	3.0	0.0	1.6	16.26	26.35	0.1271	0.2880	722.9	2697.7
20	335	5		230	159.6	312.5	0.66	7	7	1.52	3.0	85.8	3.0	15.19	30.88	0.1236	0.3796	702.8	3556.0
20	340	5		230	162.2	303.9	0.62	10	10	1.14	3.0	76.1	3.0	14.83	32.42	0.1172	0.4296	666.3	4023.7

Table A.9--Continued

Pen no.	Steer no.	Treat-ment no.	% Grain	Days on feed	Initial carcass wt, kg	Final carcass wt, kg	Carcass ADG kg	Marb.[a]	Qual. grade[b]	Fat thick cm	KPH fat %	Rib eye area cm	Yield grade	Carcass protein %	Carcass fat %	Daily protein gain kg	Daily fat gain kg	Daily protein energy kcal	Daily fat energy kcal
19	199	6	59	209	159.6	309.8	0.72	8	8	1.65	4.0	66.5	4.2	14.88	32.21	0.1277	0.4400	726.3	4121.5
19	256	6		209	139.4	277.6	0.66	7	10	1.65	3.5	73.6	3.6	14.69	32.99	0.1191	0.4171	677.2	3907.2
19	263	6		209	169.8	332.4	0.78	8	8	2.03	3.5	83.2	3.9	15.24	30.68	0.1442	0.4376	819.9	4099.1
19	264	6		209	162.2	308.4	0.70	9	9	1.91	3.0	69.0	4.2	14.42	34.13	0.1151	0.4734	654.7	4434.3
19	321	6		209	141.9	276.2	0.64	8	8	1.27	3.0	75.8	2.9	15.28	30.49	0.1232	0.3668	700.3	3426.3
19	343	6		209	148.2	289.8	0.68	8	8	1.02	3.0	79.4	2.6	15.42	29.92	0.1313	0.3717	746.3	3482.0
19	348	6		209	145.7	313.8	0.80	9	9	1.52	3.0	81.9	3.1	15.95	27.66	0.1698	0.3708	965.3	3473.5
19	358	6		209	154.6	338.8	0.88	9	9	1.91	3.0	84.5	3.6	14.55	33.59	0.1587	0.5315	902.5	4978.8
18	207	7	90	202	155.8	308.4	0.76	8	8	1.52	3.0	72.9	3.6	14.85	32.31	0.1357	0.4593	771.4	4302.5
18	215	7		202	166.0	338.3	0.85	9	9	1.27	3.5	80.0	3.4	14.08	35.57	0.1389	0.5806	789.8	5438.2
18	216	7		202	145.7	320.6	0.87	10	10	1.52	3.0	73.6	3.7	14.44	34.08	0.1556	0.5346	884.9	5007.9
18	217	7		202	148.2	307.9	0.79	9	9	1.40	3.5	80.0	3.3	14.95	31.88	0.1478	0.4592	840.6	4301.3
18	228	7		202	147.0	311.6	0.81	9	9	1.91	3.5	78.7	3.8	13.94	36.20	0.1350	0.5586	767.6	5232.5
18	261	7		202	157.1	319.7	0.80	7	7	1.91	3.0	85.8	3.5	13.83	36.67	0.1272	0.5746	723.1	5382.6
18	322	7		202	139.4	314.3	0.87	12	10	1.52	2.5	78.1	3.7	14.55	33.61	0.1600	0.5195	909.6	4866.6
18	349	7		202	167.2	351.0	0.91	10	10	1.27	3.0	74.2	3.6	13.91	36.32	0.1124	0.5500	639.1	5151.7
17	214	8	96	202	171.0	345.1	0.86	10	8	2.29	3.0	81.3	4.2	14.12	35.40	0.1392	0.5848	791.7	5478.1
17	224	8		202	163.4	350.6	0.93	8	8	2.21	3.0	84.5	3.7	13.92	36.27	0.1518	0.6272	863.3	5874.7
17	244	8		202	141.9	280.3	0.69	5	6	1.60	3.0	73.6	2.6	16.17	26.70	0.1465	0.3133	833.0	2934.7
17	246	8		202	149.5	313.4	0.81	11	10	1.14	2.5	75.5	3.0	14.21	35.03	0.1385	0.5350	787.3	5011.3
17	273	8		202	157.1	322.9	0.82	18	12	1.27	3.0	83.2	3.0	13.52	37.98	0.1246	0.6100	708.6	5713.9
17	306	8		202	152.0	343.8	0.95	7	7	2.03	3.0	80.7	4.0	14.27	34.78	0.1677	0.5913	953.5	5538.3
17	314	8		202	145.7	282.1	0.68	10	10	1.14	3.2	68.4	3.3	14.11	35.46	0.1096	0.4807	623.0	4502.7
17	331	8		202	141.9	288.4	0.73	7	7	1.27	3.0	74.2	3.3	14.83	32.40	0.1337	0.4389	759.9	4110.7
16	235	9	Two-phase high	209	154.6	324.7	0.81	8	8	1.40	3.5	81.9	3.2	14.44	34.07	0.1424	0.5141	809.5	4816.0
16	239	9		209	169.8	343.8	0.83	7	7	0.89	3.5	86.5	2.7	16.34	25.99	0.1772	0.3529	1007.4	3305.8
16	262	9		209	139.4	270.7	0.63	10	10	1.40	3.5	65.2	3.6	14.98	31.76	0.1166	0.3822	662.8	3579.8
16	271	9		209	143.2	296.1	0.73	7	7	1.02	3.0	78.1	2.7	15.15	31.03	0.1406	0.4107	799.4	3847.5
16	297	9		209	157.1	341.0	0.88	8	8	1.65	3.0	83.2	3.5	14.01	35.91	0.1475	0.5847	838.6	5477.2
16	311	9		209	159.6	335.1	0.84	8	8	1.14	3.5	83.2	3.0	15.52	29.48	0.1662	0.4283	945.1	4011.7
16	341	9		209	145.7	291.6	0.70	8	8	1.78	3.0	70.3	3.8	14.28	34.72	0.1181	0.4701	671.6	4403.4
16	344	9		209	148.2	304.3	0.75	7	7	0.76	3.0	83.2	2.3	14.98	31.77	0.1395	0.4346	793.1	4070.8
15	202	10	Two-phase low	209	158.4	297.5	0.67	12	10	1.27	3.5	80.0	3.0	14.78	32.62	0.1150	0.4262	653.7	3992.0
15	229	10		209	145.7	298.9	0.73	7	7	1.40	2.5	80.0	2.9	15.46	29.75	0.1450	0.3875	824.3	3629.6
15	267	10		209	147.0	303.9	0.75	8	8	0.89	3.0	75.5	2.8	15.18	30.94	0.1439	0.4183	818.3	3918.2
15	269	10		209	162.2	355.6	0.93	8	8	2.51	3.0	89.0	4.2	14.51	33.76	0.1650	0.5601	938.3	5246.3
15	302	10		209	141.9	259.0	0.56	7	7	1.02	3.0	72.3	2.7	15.16	31.00	0.1031	0.3435	586.3	3217.2
15	332	10		209	141.9	286.2	0.69	7	7	1.14	2.5	87.1	2.2	16.47	25.44	0.1529	0.2885	869.2	2702.3
15	339	10		209	171.0	358.7	0.90	10	10	1.14	3.0	1.3	2.2	14.87	32.26	0.1629	0.5204	926.4	4874.7
15	362	10		209	152.0	285.3	0.64	7	7	1.27	2.5	67.7	3.3	15.28	30.50	0.1189	0.3700	675.9	3465.5

[a]Marbling: Modest- = 13; Small+ = 12; Small° = 11; Small- = 10; Slight+ = 9; Slight° = 8; Slight- = 7.

[b]Quality grade: Average good = 8; High good = 9; Low choice = 10.

Table A.10 Scanoprobe Estimates of Fat Thickness Over the Twelfth Rib (Trial 1)[a]

Pen no.	Steer no.	Estimated fat cm	Actual fat cm	Pen no.	Steer no.	Estimated fat cm	Actual fat cm
24	626	0.25	0.76	20	614	0.76	0.76
	639	0.51	0.51		616	0.25	0.76
	657	0.76	1.14		631	0.64	0.76
	671	0.25	0.13		642	0.51	0.38
	677	0.25	0.89		650	0.38	0.51
	680	0.51	0.76		669	0.76	1.02
	681	0.64	1.02		684	0.51	0.64
	695	0.76	1.02		737	0.64	0.89
23	629	0.76	0.64	19	647	0.76	0.51
	630	0.76	0.89		654	0.76	0.76
	634	0.64	0.64		670	0.51	0.51
	651	0.51	0.76		673	0.64	0.76
	655	0.25	0.76		676	0.76	1.02
	662	0.76	1.14		691	0.25	0.25
	690	1.02	1.27		692	0.76	0.89
	736	0.76	1.02		734	0.76	0.64
22	623	0.76	0.76	18	622	1.02	1.14
	637	1.02	1.14		635	0.51	0.76
	659	0.51	0.89		665	0.64	0.38
	664	0.76	0.76		666	0.51	0.38
	674	0.64	0.38		667	0.51	0.51
	683	0.51	0.76		675	0.64	1.14
	697	0.25	0.89		689	1.02	1.40
	735	0.51	0.64		700	0.38	0.38
21	624	0.76	1.02	17	613	0.76	0.51
	627	0.51	0.89		633	1.52	2.16
	632	0.64	0.51		649	0.76	1.27
	648	0.76	0.89		652	1.02	1.52
	656	0.76	1.02		653	1.02	0.89
	672	1.02	1.14		663	1.02	1.02
	679	1.27	2.03		668	0.76	1.02
	693	0.76	0.76		687	0.51	0.38

[a]ITHACO ultrasonic SCANOPROBE, Ithaca, New York.

Table A.10--Continued

Pen no.	Steer no.	Estimated fat cm	Actual fat cm
16	615	0.25	0.64
	617	0.51	0.64
	640	0.25	0.38
	641	0.25	0.64
	685	0.25	0.51
	686	0.25	0.76
	688	0.25	0.51
	696	0.51	0.25
15	619	0.64	1.02
	621	0.76	1.02
	625	1.02	2.29
	628	0.76	0.51
	644	0.25	0.64
	660	1.27	1.02
	698	0.51	0.89
	699	0.76	0.76

[a]ITHACO ultrasonic SCANOPROBE, Ithaca, New York.

Table A.11 Scanoprobe Estimates of Fat Thickness Over the Twelfth Rib (Trial 2)[a]

Pen no.	Steer no.	Estimated fat cm	Actual fat cm	Pen no.	Steer no.	Estimated fat cm	Actual fat cm
24	220	0.76	1.02	20	204	0.89	0.76
	227	0.64	0.89		221	0.64	0.38
	338	0.64	0.76		242	0.51	0.76
	252	0.89	1.14		300	0.51	0.51
	260	1.14	1.02		304	0.89	0.89
	265	1.02	1.02		318	0.76	0.76
	296	0.64	1.40		335	1.02	1.52
	345	1.02	1.40		340	1.02	1.14
23	212	1.27	1.27	19	199	1.14	1.65
	223	1.14	1.27		256	1.14	1.65
	233	0.89	1.02		263	1.52	2.03
	272	1.02	0.89		264	1.27	1.91
	275	1.14	1.27		321	0.89	1.27
	316	1.52	1.91		343	1.02	1.02
	327	1.14	1.65		348	1.14	1.52
	351	1.02	1.27		358	1.52	1.91
22	238	0.64	0.89	18	207	1.14	1.52
	253	1.02	1.27		215	1.14	1.27
	270	0.89	1.27		216	1.02	1.52
	292	0.76	0.76		217	1.14	1.40
	303	0.76	1.40		228	1.14	1.91
	305	0.76	1.14		261	1.65	1.91
	307	0.64	0.51		322	1.02	1.52
	313	0.76	1.27		349	1.02	1.27
21	205	0.64	1.02	17	214	1.14	2.29
	206	0.89	1.78		224	1.27	2.21
	210	0.89	1.27		244	0.51	1.60
	312	0.76	0.76		246	1.02	1.14
	329	1.02	1.27		273	0.76	1.27
	336	1.02	0.89		306	1.14	2.03
	337	1.40	1.02		314	1.02	1.14
	363	1.14	1.02		331	1.02	1.27

[a]ITHACO ultrasonic SCAOPROBE, Ithaca, New York.

Table A.11--Continued

Pen no.	Steer no.	Estimated fat cm	Actual fat cm
16	235	1.02	1.40
	239	1.02	0.89
	262	1.02	1.40
	271	1.02	1.02
	297	1.65	1.65
	311	1.02	1.14
	341	1.02	1.78
	344	1.14	0.76
15	202	1.02	1.27
	229	1.14	1.40
	267	0.51	0.89
	269	1.78	2.51
	302	1.02	1.02
	332	0.76	1.14
	339	0.51	1.14
	362	1.27	1.27

[a]ITHACO ultrasonic SCANOPROBE, Ithaca, New York.

Table A.12 Effect of Ration Grain Content on Nitrogen Retention (Trial 1)

Measure	Ration composition (DM basis)							
	93% silage 7% supplement			35% corn 59% silage 6% supplement			12% silage 6% supplement	94% corn 6% supplement
Percent total corn in ration (DM)	29	40	50	55	64	68	91	96
Dry matter intake (kg/day)	8.0	7.1	6.9	7.7	7.5	7.5	6.6	7.2
Nitrogen intake (g/day)	159.2	137.1	122.7	148.5	142.5	143.2	131.9	147.3
Urinary nitrogen (g/day)	44.8	50.2	48.8	52.8	44.7	38.6	48.9	42.8
Fecal nitrogen (g/day)	60.9	48.1	50.7	70.3	46.7	59.6	50.3	47.8
Total nitrogen excretion (g/day)	105.7	98.3	99.4	123.0	91.4	98.2	99.1	90.6
Nitrogen retained (g/day)	53.5	38.8	23.3	25.5	51.1	45.0	32.8	56.7
Nitrogen retained (% of intake)	33.6	28.3	19.0	17.2	35.9	31.4	24.9	38.5

Table A.13 Effect of ration grain content on nitrogen retention (Trial 2)

Measure	Ration composition (DM basis)							
	92% silage 8% supplement			31% corn 60% silage 9% supplement			80% corn 12% silage 8% supplement	92% corn 8% supplement
Percent total corn in ration (DM)	38	51	54	59	67	69	90	96
Dry matter intake (kg/day)	7.2	5.2	6.2	6.2	7.5	8.3	6.3	5.8
Nitrogen intake (g/day)	143.8	115.7	128.2	132.6	139.0	177.6	133.0	117.6
Urinary nitrogen (g/day)	71.4	52.8	68.2	67.2	57.5	83.9	67.0	60.1
Fecal nitrogen (g/day)	40.7	28.3	41.5	37.9	42.6	42.7	40.7	32.6
Total nitrogen excretion (g/day)	112.1	81.1	109.7	105.1	100.1	126.6	107.7	92.7
Nitrogen retained (g/day)	31.7	34.6	18.5	27.5	39.0	50.9	25.3	24.9
Nitrogen retained (% of intake)	22.0	29.9	14.4	20.7	28.1	28.7	19.0	21.2

Table A.14 Nitrogen Retention of High Oil and Brown Midrib _vs_ Normal Corn Silage (Trial 1)

	Corn variety		
Measure	Normal	High oil	Brown midrib
Dry matter intake (kg/day	7.1	7.9	7.3
Nitrogen intake (g/day)	137.1	137.8	153.4
Urinary nitrogen (g/day)	50.2	45.0	52.2
Fecal nitrogen (g/day)	48.1	53.2	43.4
Total nitrogen excretion (g/day)	98.3	98.2	95.6
Nitrogen retained (g/day)	38.8	39.6	57.8
Nitrogen retained (% of intake)	28.3	28.7	37.7

Table A.16 Calculation of Net Energy Value of Rations Varying in Grain Content (Trial 2)

	Percent grain in ration dry matter								Two-phase	
	54	69	51	67	38	59	90	96	57	68
Treatment number	1	2	3	4	5	6	7	8	9	10
Average initial wt. (lb)	605.000	600.625	600.625	605.625	608.125	602.500	605.000	603.125	600.625	601.875
% empty body protein, initial	18.320	18.309	18.320	18.320	18.320	18.320	18.320	18.320	18.320	18.320
% empty body protein, final	16.070	15.855	16.298	16.355	16.715	16.133	15.545	15.609	16.061	16.258
% empty body fat, initial	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100	16.100
% empty body fat, final	28.814	29.881	27.675	27.386	25.576	28.493	31.426	31.119	28.851	27.858
Empty body wt., final (lb)	1,005.750	992.000	953.875	966.250	935.875	985.125	1,019.875	1.015.125	1,008.000	984.375
Days on feed	230.000	202.000	230.000	202.000	230.000	209.000	202.000	202.000	209.000	209.000
Average daily DM intake	18.040	16.610	17.300	16.480	18.100	16.640	14.650	13.900	15.310	18.260
Empty body wt., initial	527.076	523.264	523.274	527.620	529.798	524.898	527.076	525.442	523.264	524.353
Average protein gain/steer (lb)	64.823	61.520	59.396	61.140	59.176	62.736	61.935	61.889	66.132	63.748
Ave. energy gain protein (Mcal)	167.158	158.640	153.164	157.660	152.597	161.777	159.710	159.592	170.533	164.386
Average fat gain/steer (lb)	205.052	211.979	180.738	180.818	155.040	196.317	235.873	232.790	206.094	190.925
Ave. energy gain fat (Mcal)	871.076	900.500	767.789	768.129	658.621	833.969	1,002.005	988.911	875.502	811.063
Ave. daily ME-maintenance (Mcal)	6.194	6.144	6.027	6.078	5.991	6.127	6.241	6.219	6.191	6.121
Ave. daily ME-main. + gain (Mcal)	10.708	11.388	10.032	10.661	9.518	10.891	11.992	11.904	11.196	10.788
Ration ME value (Mcal/lb)	0.594	0.686	0.580	0.647	0.526	0.655	0.819	0.856	0.731	0.591
Daily ME intake (Mcal)	19.140	27.257	18.148	21.638	18.516	15.642	19.411	17.764	25.124	17.164
Daily ME intake/unit met wt (kg)	238.356	341.786	232.127	274.718	238.611	197.007	239.656	220.623	313.324	216.751
Heat prod. (ME/kg of metab wt)	182.354	276.012	181.119	216.873	193.436	137.229	168.715	150.603	251.077	158.438
ME-protein equilibrium (Kcal)	117.970	121.032	119.720	121.687	124.366	104.577	110.562	106.279	121.877	111.428
NE for maintenance (Mcal/lb)	0.694	1.044	0.676	0.832	0.635	0.694	0.923	0.930	1.037	0.653
NE for gain (Mcal/lb)	0.495	0.489	0.477	0.500	0.407	0.610	0.729	0.787	0.537	0.525

Table A.15 Calculation of Net Energy Value of Rations Varying in Grain Content (Trial 1)

	Percent gain in ration dry matter									
									High oil	Brown midrib
	50	68	40	64	29	56	91	96	38	36
Treatment number	1	2	3	4	5	6	7	8	9	10
Average initial wt. (lb)	526.875	525.000	529.375	526.250	522.500	532.500	534.286	518.750	523.750	530.556
% empty body protein, initial	18.640	18.640	18.650	18.640	18.640	18.640	18.640	18.640	18.640	18.640
% empty body protein, final	16.731	16.659	10.650	16.208	16.826	16.965	16.899	16.354	17.040	16.692
% empty body fat, initial	12.940	12.940	12.940	12.940	12.940	12.940	12.940	12.940	12.940	12.940
% empty body fat, final	28.133	27.900	25.905	29.326	26.550	27.091	27.036	29.819	24.791	27.420
Empty body wt., final (lb)	1,051.250	1,065.750	1,022.375	1,054.500	953.875	993.875	1,070.571	1,048.625	977.625	1,046.444
Days on feed	282.000	240.000	268.000	268.000	268.000	240.000	198.000	234.750	282.000	268.000
Average daily DM intake	17.620	18.900	18.340	18.400	16.870	18.930	17.720	16.119	17.020	18.240
Empty body wt., initial	468.550	466.882	470.773	467.994	464.659	473.552	475.140	461.324	465.771	471.823
Average protein gain/steer (lb)	88.367	90.541	21.739	83.775	73.518	80.427	92.334	85.145	79.789	86.582
Ave. energy gain protein (Mcal)	227.871	233.476	56.058	216.030	189.580	207.396	238.100	219.561	205.750	223.269
Average fat gain/steer (lb)	235.651	236.933	202.830	246.925	194.986	208.312	228.036	255.179	181.983	227.055
Ave. energy gain fat (Mcal)	1,001.061	1,006.509	861.636	1,048.955	828.316	884.923	968.713	1,084.019	773.075	964.548
Ave. daily ME-maintenance (Mcal)	6.157	6.197	6.075	6.165	5.844	5.997	6.237	6.127	5.924	6.152
Ave. daily ME-main. + gain (Mcal)	10.515	11.364	9.501	10.885	9.642	10.549	12.332	11.665	9.395	10.584
Ration ME value (Mcal/lb)	0.597	0.601	0.518	0.592	0.572	0.557	0.696	0.725	0.552	0.580
Daily ME intake (Mcal)	19.135	20.922	19.587	18.602	16.769	19.933	23.444	19.963	18.620	20.100
Daily ME intake/unit met wt (kg)	239.749	260.195	248.500	232.937	222.042	256.358	289.568	251.576	242.344	252.210
Heat prod. (ME/kg of metab wt)	185.307	195.977	205.083	173.863	172.374	198.005	214.257	182.328	197.222	196.868
ME-protein equilibrium (Kcal)	119.263	117.339	127.134	115.102	117.957	119.742	116.098	112.961	125.062	120.705
NE for maintenance (Mcal/lb)	0.703	0.727	0.647	0.677	0.652	0.679	0.878	0.846	0.674	0.705
NE for gain (Mcal/lb)	0.490	0.498	0.382	0.508	0.480	0.450	0.574	0.628	0.422	0.465

LITERATURE CITED

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Ademosum, A. A., B. R. Baumgardt and J. M. Scholl. 1968. Evaluation of a sorghum-sudangrass hybrid at varying stages of maturity on the basis of intake, digestibility and chemical composition. J. Anim. Sci. 27:818.

Albin, R. C., A. Simnacher and R. M. Durham. 1966. In vitro digestion of all-concentrate ration. Rep. on Texas Tech. College Research 55.

Alexander, R. A., J. F. Hentges, Jr., W. K. Robertson, G. A. Barden and J. T. McCall. 1963. Composition and digestibility of corn silage as affected by fertilizer rate and plant population. J. Anim. Sci. 22:5.

Allison, D. W., and D. F. Osbourn. 1970. The cellulose-lignin complex in forages and its relationship to forage nutritive value. J. Agr. Sci. Camb. 74:23.

Armsby, H. P. 1917. The Nutrition of Farm Animals. New York: MacMillan.

Armstrong, D. G., and K. L. Blaxter. 1957a. The heat increment of steam-volatile fatty acids in fasting sheep. Brit. J. Nutr. 11:247.

Armstrong, D. G., and K. L. Blaxter. 1957b. The utilization of acetic, propionic and butyric acids by fattening sheep. Brit. J. Nutr. 11:413.

Armstrong, D. G., K. L. Blaxter and N. McC. Graham. 1957. The heat increments of mixtures of steam-volatile fatty acids in fasting sheep. Brit. J. Nutr. 11:392.

Armstrong, D. G., K. L. Blaxter, N. McC. Graham and F. W. Wainman. 1958. The utilization of the energy of two mixtures of steam-volatile fatty acids by fattening sheep. Brit. J. Nutr. 12:177.

Asplund, J. M., and L. E. Harris. 1971. Associative effects on the digestibilities of energy and the utilization of nitrogen in sheep fed simplified rations. J. Anim. Sci. 32:152.

Ayres, G. E., and W. F. Buchele. 1971. Harvesting and storing corn plant forage. Am. Soc. Agr. Engr. 71:665.

Badway, A. M., R. M. Campbell, D. P. Cuthbertson, D. F. Fell and W. S. Mackie. 1958. Further studies on the changing composition of the digesta along the alimentary trait of sheep. 2. Volatile fatty acids and energy relative to lignin. But. J. Nutr. 12:384.

Barnes, R. F., L. D. Muller, L. F. Bauman and V. F. Colenbrander. 1971. "In Vitro" dry matter disappearance of brown midrib mutants of maize. (Zea. Mays L.) J. Anim. Sci. 33:881.

Beef Housing and Equipment Handbook. 1976. Midwest Planning Service #6.

Black, J. R. 1978. Cost of producing corn. Ag. Econ. 78:18.

Black, J. R., and D. G. Fox. 1977. Interpretation and use of research results. Mich. Agr. Exp. Sta. Res. Rpt. 328.

Black, J. R., and H. Harpster. 1978. Standard, but seldom used statistical techniques. Mich. Agr. Exp. Sta. Res. Rpt.

Black, W. H., R. L. Hiner, L. B. Burk, L. M. Alexander and C. V. Wilson. 1940. Beef production and quality as affected by method of feeding supplements to steers on grass in the Appalachian region. USDA Tech. Bull. 717.

Blaxter, K. L., and F. W. Wainman. 1961. The utilization of food by sheep. J. Agr. Sci. 57:419.

Blaxter, K. L., and F. W. Wainman. 1964. The utilization of the energy of different rations by sheep and cattle for maintenance and for fattening. J. Agr. Sci. 63:113.

Blaxter, K. L., and J. A. F. Rook. 1953. The heat of combustion of the tissues of cattle in relation to their chemical composition. Brit. J. Nutr. 7:83.

Brown, D. C., and J. C. Radcliffe. 1971. Prediction of in-vivo dry matter, organic matter and energy digestibilities of silage by in-vitro digestion techniques. Aust. J. Agr. Res. 22:787.

Brunson, A. M., F. R. Earle and J. J. Curtis. 1948. Interactions among factors influencing the oil content of corn. J. Amer. Soc. Agron. 40:180.

Bryant, H. T., and R. E. Balser. 1968. Plant constituents of an early and a late corn hybrid as affected by row spacing and plant population. Agron. J. 60:557.

Burroughs, W., C. Ludwig, A. Mukhtar and A. Trenkle. 1965. Completion of new cattle concentrate (Iowa 80 Premix) experiment with emphasis upon the comparative merits of corn silage vs. corn grain finishing rations. Iowa State A. S. Leaflet R69.

Burroughs, W., and E. Topel. 1969. Two-year summary of net energy evaluations of corn grain and corn silage of varying moisture contents when fed to finishing steers receiving supplements with and without stibesterol. Iowa State Univ. Ext. Bull.

Byers, F. M., and R. L. Preston. 1976. Relationship of corn silage of grain diets fed during the growing phase to protein requirements during growing and finishing. Ohio Ag. Res. Dev. Ctr.

Byers, F. M., J. K. Matsushima and D. E. Johnson. 1975a. Application of the concept of associative effects of feeds to prediction of ingredient and diet energy values. Colo. State Univ. Expt. Sta. Bull. 949.

Byers, F. M., J. K. Matsushima and D. E. Johnson. 1975b. The significance of associative effects of feeds on corn silage and corn grain energy values. Colo. State Univ. Expt. Sta. Bull. 947.

Chandler, P. T., and H. W. Walker. 1972. Generation of nutrient specifications for dairy cattle for computerized least cost ration formulation. J. Dairy Sci. 55:1741.

Colenbrander, V. F., L. F. Bauman and V. L. Lechtenberg. 1975. Effect of brown midrib mutant genes on the nutritional quality of corn. 28th Annual Corn and Sorghum Res. Conf. 28:92.

Colenbrander, V. F., W. M. Beeson, T. W. Perry and E. A. Keith. 1977. Performance of feedlot cattle fed brown midrib corn silage. Purdue Cattle Feeders Day Rep.

Colenbrander, V. F., V. L. Lechtenberg and L. F. Bauman. 1973. Digestibility and feeding value of brown midrib corn stover silage. J. Anim. Sci. 37:294. (Abstr.)

Colville, W. L. 1966. Plant populations and row spacing. Proc. 21st Annual Hybrid Corn Industry and Research Conf.

Connor, L. J., et al. 1976. "Beef Feedlot Design and Management in Michigan." Mich. Agr. Exp. Res. Rep. 292.

Crickenberger, R. G., D. G. Fox and W. T. Magee. 1977. Effect of cattle size, selection and crossbreeding on utilization of high corn silage or high grain rations. Mich. Agr. Expt. Sta. Res. Rep. 328.

Cummins, D. G., and J. W. Dobson, Jr. 1973. Corn for silage as influenced by hybrid maturity, row spacing, plant population and climate. Agron. J. 65:240.

Danner, M. L., and D. G. Fox. 1977. Performance and carcass grade of steer calves and yearling steers finished on five different feeding systems. Mich. Agr. Expt. Sta. Res. Rep. 328.

Dexheimer, C. E., J. C. Meiske and R. D. Goodrich. 1971. A comparison of four systems for feeding corn silage. Minn. Beef Cattle Rep.

Duncan, W. G. 1958. The relationship between corn populations and yield. Agron. J. 50:82.

Embry, L. B., and J. F. Frederickson. 1968. Corn silage and high moisture ear corn rations for growing and finishing beef cattle. South Dakota Beef Cattle Field Day Rep.

Fairbourn, M. L., W. D. Kemper and H. R. Gardner. 1970. Effects of row spacings on evapotranspiration and yields of corn in a semiarid environment. Agron. J. 62:795.

Forbes, E. B., W. W. Braman, M. Kriss, R. W. Swift, R. C. Miller, R. B. French, T. V. Letonoff and G. R. Sharpless. 1931. The fasting metabolism of cattle as a base value of heat production. J. Agr. Res. 43:1003.

Fox, D. G. 1974. 1974. Net energy requirements of growing and finishing cattle. Fact Sheet 1011. Mich. Beef Prod. Manual.

Fox, D. G., and R. J. Black. 1975. The influence of cow size, cross-breeding, slaughter weight, feeding system and environment on energetic and economic efficiency of edible beef production. Proc. of 1975 Reciprocal Meats Conf.

Fox, D. G., and J. R. Black. 1977. A system for predicting performance of growing and finishing beef cattle. Mich. Agr. Exp. Sta. Res. Rpt. 328.

Fox, D. G., and C. L. Fenderson. 1977. The influence of oven drying, NPN addition and silage dry matter on error in determining true corn silage dry matter. Mich. Agr. Exp. Sta. Res. Rpt. 328.

Fox, D. G., R. R. Johnson, R. L. Preston, T. R. Dockerty and E. W. Klosterman. 1972. Protein and energy utilization during compensatory growth in beef cattle. J. Anim. Sci. 34:310.

Fox, D. G., R. R. Johnson, R. L. Preston, T. R. Dockerty and E. W. Klosterman. 1970. Factors associated with compensatory gain in beef cattle. Ohio Ag. Res. Dev. Ctr.

Galyean, M. L., D. G. Wagner and R. K. Johnson. 1978. Studies on the feasibility of predicting feedlot performance from certain laboratory grain analysis. J. Anim. Sci. 46:9.

Garrett, W. N. 1958. The comparative energy requirements of sheep and cattle for maintenance and gain. Ph.D. thesis. University of California, Davis.

Garrett, W. N. 1971. Energy level, performance and body composition. Calif. Feeders' Day Rep. 11.

Garrett, W. N., and N. Hinman. 1969. Re-evaluation of the relationship between carcass density and body composition of beef steers. J. Anim. Sci. 28:1.

Garrett, W. N., N. Hinman, R. F. Brokken and J. G. Delfino. 1978. Body composition and the energy content of the gain of Charolais steers. J. Anim. Sci. Meetings. (Abstr.)

Garrett, W. N., J. H. Meyer and G. P. Lofgreen. 1959. The comparative energy requirements of sheep and cattle for maintenance and gain. J. Anim. Sci. 18:528.

Gee, M. S., O. E. Nelson and J. Kuc. 1968. Abnormal lignins produced by the brown midrib mutants of maize. II. Comparative studies on normal and brown midrib-1 dimethylformamide lignins. Arch. Biochem. Biophys. 123:403.

Giesbrecht, J. 1969. Effect of population and row spacing on the performance of four corn (Zea May L.) hybrids. Agron. J. 61:439.

Gill, D. R., J. R. Martin and R. Lake. 1976. High, medium and low corn silage diets with or without monensin for feedlot steers. J. Anim. Sci. 43:363.

Goodrich, R. D., and J. C. Meiske. 1976. Corn silage: Influence of amounts, feeding systems and drought-damage on feedlot performance. Minn. Beef Cattle Rep.

Goodrich, R. D., D. W. Crawford, M. L. Thonney and J. C. Meiske. 1974. Influence of corn silage level on the performance and economic returns of steer calves. Minn. Cattle Feeders Rep. B-195.

Guenther, J. J., D. H. Bushman, L. S. Pope and R. D. Morrison. 1965. Growth and development of the major carcass tissues in beef calves from weaning to slaughter weight, with reference to the effect of plane of nutrition. J. Anim. Sci. 24:1184.

Hamilton, T. S. 1942. The effect of added glucose upon the digestibility of protein and of fiber in rations for sheep. J. Nutr. 23:101.

Hammes, R. C., Jr., J. P. Fontenot, H. T. Bryant, R. E. Blaser and R. W. Engel. 1964. Value of high-silage rations for fattening cattle. J. Anim. Sci. 23:795.

Hankins, O. G., and P. E. Howe. 1946. Estimation of the composition of beef carcasses and cuts. Tech. Bull. U.S. Dept. Agr. No. 926.

Hawkins, D. R., H. E. Henderson and M. R. Geasler. 1967. Corn silage, concentrate levels and hormones for finishing steer and heifer calves. Mich. Beef Cattle Day Rep.

Henderson, H. E., and W. T. Britt. 1974. Effect of protein and level of concentrates and corn silage on steer and heifer calf performance. Mich. Beef Cattle Res. Rep.

Hoglund, C. 1977. Dairy systems analysis handbook. Mich. Ag. Econ. Rep. 300.

Holter, J. B., C. W. Heald and N. F. Colovos. 1970. Heat increments of steam-volatile fatty-acids infused separately and in a mixture into fasting cows. J. Dairy Sci. 53:1241.

Holter, J. A., and J. T. Reid. 1959. Relationship between the concentration of crude protein and apparently digestible protein in forages. J. Anim. Sci. 18:1337.

Huber, J. T., G. C. Graf and R. W. Engel. 1965. Effect of maturity on nutritive value of corn silate for lactating cows. J. Dairy Science 48:1121.

Hughes, H. 1973. Energy consumption in beef production systems as influenced by technology and size. Ph.D. thesis. Mich. State U.

Jahn, E., P. T. Chandler and C. E. Polan. 1970. Effects of fiber and ratio of starch to sugar on performance of ruminating calves. J. Dairy Sci. 53:466.

Jesse, G. W., G. B. Thompson, J. L. Clark, K. G. Wimer and D. P. Hutcheson. 1976a. Effects of various ratios of corn and corn silage and slaughter weight on the performance of steers individually fed. J. Anim. Sci. 43:1049.

Jesse, G. W., G. B. Thompson and J. L. Clark. 1976b. Net energy values of corn and corn silage fed in various combinations to steers slaughtered at 341, 454, and 545 Kg. J. Anim. Sci. 43:1044.

Johnson, D. E., J. Garrett, S. Joanning, J. Crownover, D. Berman, M. Heeney and R. Cuany. 1978. Corn silage nutrient value. Colo. State Univ. Expt. Sta. Bull. (in press).

Jones, G. M., and R. E. Larsen. 1974. Changes in estimates of silage dry matter intake or apparent digestibility as affected by methods of DM determination. Can. J. Anim. Sci. 54:145.

Klosterman, E. W., P. G. Althouse and V. R. Cahill. 1965. Effect of corn silage or ground ear corn full fed at various stages of growth and fattening upon carcass composition of beef cattle. J. Anim. Sci. 24:454.

Kriss, M. 1943. Evaluation of feeds on the basis of net available nutrients. J. Anim. Sci. 2:63.

Kraybill, H. F., H. L. Bitter and O. G. Hankins. 1952. Body composition of cattle. II. Determination of fat and water content from measurement of body specific gravity. J. Appl. Physiol. 4:575.

Kromann, R. P. 1967. A mathematical determination of energy values of ration ingredients. J. Anim. Sci. 26:1131.

Kromann, R. P., E. T. Clemens and E. E. Ray. 1975. Digestible, metabolizable and net energy values of corn grain and dehydrated alfalfa in sheep. J. Anim. Sci. 41:1752.

Kromann, R. P., and E. E. Ray. 1967. Energy metabolism in sheep as influenced by interactions among nutritional and genetic factors. J. Anim. Sci. 26:1379.

Kue, J., and O. E. Nelson. 1964. The abnormal lignins produced by the brown midrib mutants of maize. I. The brown midrib mutants. Arch. Biochem. Biophys. 123:403.

Lancaster, L. R., R. R. Frahm and D. R. Gill. 1972. A comparison in feedlot performance of steers allowed a growing period with steers placed on a finishing ration at weaning. Okla. Ag. Exp. Sta. Rep.

Lang, A. L., J. W. Pendleton, and G. H. Dungan. 1956. Influence of population and nitrogen levels on yield and protein and oil contents of nine corn hybrids. Agron. J. 48:284.

Lechtenberg, V. L., V. F. Colenbrander, L. F. Bauman and C. L. Rhyherd. 1974. Effect of lignin on rate of <u>In vitro</u> cell wall and cellulose disappearance in corn. <u>J. Anim. Sci.</u> 39:1165.

Lechtenberg, V. L., L. D. Muller, L. F. Bauman, C. L. Rhyherd and R. F. Barnes. 1972. Laboratory and <u>in-vitro</u> evaluation of inbred and F_2 populations of <u>brown midrib mutants</u> of Zea Mays L. Agron. J. 64:657.

Leng, E. R. 1967. Changes in weight, germ ratio, and oil content during kernel development in high oil corn. Crop Sci. 7:333.

Lofgreen, G. P., and N. J. Adams. 1976. Feedlot performance and carcass characteristics of cattle fed various roughage levels. Calif. Feeders Day Rep.

Lofgreen, G. P., and D. L. Bath and H. T. Strong. 1963. Net energy of successive increments of feed above maintenance of beef cattle. J. Anim. Sci. 22:598.

Lofgreen, G. P., and W. N. Garrett. 1968. A system of expressing net energy requirements and feed values for growing and finishing cattle. J. Anim. Sci. 27:793.

Lofgreen, G. P., J. L. Hull and K. K. Otagaki. 1962. Estimation of the empty body weight of beef cattle. J. Anim. Sci. 21:20.

Lofgreen, G. P., and K. K. Otagaki. 1960. The net energy of blackstrap molasses for fattening steers as determined by a comparative slaughter technique. J. Anim. Sci. 19:392.

Lutz, J. A., Jr., H. M. Camper and G. D. Jones. 1971. Row spacing and population effects on corn yields. Agron. J. 63:12.

Lutz, J. A., Jr., and G. D. Jones. 1969. Effect of corn hybrids row spacing and plant population on the yield of corn silage. Agron. J. 61:942.

Marten, G. C., R. D. Goodrich, R. M. Jordan, A. R. Schmid and J. C. Meiske. 1976. Evaluation of laboratory methods for determining quality of corn and sorghum silages; III. Biological and chemical methods for predicting animal intake. Agron. J. 68:289.

Marten, G. C., R. D. Goodrich, A. R. Schmid, J. C. Meiske, R. M. Jordan and J. G. Linn. 1975. Evaluation of laboratory methods for determining quality of corn and sorghum silages: II. Chemical methods for predicting in vivo digestibility. Agron. J. 67:243.

McCollough, R. L., C. L. Drake and G. M. Roth. 1972. Feedlot performance of eight hybrid sorghum grains and three hybrid corns. Kansas Ag. Expt. Sta. Bull.

Meiske, J. C., and R. D. Goodrich. 1969. A comparison of four different programs for feeding a given amount of corn silage. Minn. Beef Cattle Feeders Rep.

Meiske, J. C., R. D. Goodrich and T. S. Kahlon. 1974. High silage rations (backgrounding) for various lengths of time prior to finishing. Minn. Beef Cattle Rep.

Meyer, B., J. Thomas, R. Buckley and J. W. Cole. 1960. The quality of grain-finished and grass-finished beef as affected by ripening. Food Technol. 14:4.

Miller, K. P., E. C. Frederick, R. D. Goodrich and J. C. Meiske. 1970. Rations containing various levels of corn silage and corn for growing-finishing Holstein steers. Minn. Cattle Feeders Rep.

Minish, G. L., H. W. Newland, H. E. Henderson and R. A. Merkel. 1967. Concentrate level and calf grade related to growth and carcass. J. Anim. Sci. 26:224. (Abstr.)

Minish, G. L., H. W. Newland, R. A. Merkel and H. E. Henderson. 1966. Relationship of concentrate level and feeder grade to performance and carcass characteristics of fattening calves. J. Anim. Sci. 25:1246.

Muller, L. D., R. F. Barnes, L. F. Bauman and V. F. Colenbrander. 1971. Variations in lignin and other structural components of brown midrib mutants of maize (Zea Mays L.). Crop Sci. 11:413.

Muller, L. D., V. L. Lechtenberg, L. F. Bauman, R. F. Barnes and C. L. Rhykerd. 1972. In vivo evaluation of a brown midrib mutant on Zea Mays L. J. Anim. Sci. 35:883.

Newland, H. W. 1976. Finishing steers and heifers on all corn silage or all concentrates. Ohio Agr. Res. Dev. Ctr.

Newland, H. W., and H. W. Henderson. 1965. Energy levels for different grades of cattle during the late finishing stages. Mich. Beef Cattle Day Rep.

Newland, H. W., D. L. Reed and R. L. Preston. 1975. Methods of feeding corn silage and shelled corn to finishing calves. Ohio Ag. Res. Dev. Ctr.

Newland, H. W., D. L. Reed, R. L. Preston and V. R. Cahill. 1974. Methods of feeding corn silage and shelled corn to finishing calves. II. Backgrounding on corn silage and finishing on all concentrate diets vs. all concentrate rations for Hereford and Charolais-Hereford crossbred calves. Ohio Ag. Res. Dev. Ctr.

Nott, S., G. Schwab, S. Harsh, J. Black and M. Kelsey. 1977. Estimated enterprise budget for Michigan. Mich. Ag. Econ. Rep. 314.

NRC. 1966. Biological Energy Interrelationships and Glossary of Energy Terms. National Research Council, Washington, D.C.

NRC. 1976. Nutrient Requirements of Domestic Animals, No. 4. National Academy of Science--National Research Council, Washington, D.C.

Oltjen, R. R., T. S. Rumsey and P. A. Putnam. 1971. All-forage diets for finishing beef cattle. J. An. Sci. 32:327.

Perry, T. W., and W. M. Beeson. 1976. Ratios of corn to corn silage for finishing beef cattle. J. Anim. Sci. 42:549.

Peterson, L. A., E. E. Hatfield and U. S. Garrigus. 1973. Influence of concentration of dietary energy on protein needs of growing-finishing cattle. J. Anim. Sci. 36:772.

Petritz. 1977. Alternative cattle feeding shelter systems.

Peverly, H. 1966. An economic analysis of alternative cattle feeding systems. Master's thesis. University of Illinois.

Pherson, C. 1973. Economics of alternative waste management systems complying with pollution control regulations on beef feedlots in southwestern Minnesota. Ph.D. thesis.

Pinney, D. O., N. W. Bradley, C. O. Little and J. R. Overfield. 1966. Urea and soybean meal supplementation of corn-corn silage rations containing different levels of energy. J. Anim. Sci. 25:260. (Abstr.)

Porter, P., and A. G. Singleton. 1971. The degradation of lignin and quantitative aspects of ruminant digestion. Brit. J. Nutr. 25:3.

Preston, R. L. 1975. Net energy evaluation of cattle finishing rations containing varying proportions of corn grain and corn silage. J. Anim. Sci. 41:622.

Preston, R. L., V. L. Cahill, G. L. Bennett and C. F. Parker. 1975. Production of beef from Angus or Charolais steers full-fed corn silage or a high concentrate ration. Ohio Ag. Res. Dev. Ctr.

Preston, R. L., V. R. Cahill, W. E. Kunkle and C. F. Parker. 1975. Role of roughage in high-concentrate rations for finishing steer calves. Ohio Ag. Res. Dev. Ctr.

Prigge, E., and F. Owens. 1976. Energy changes with silage making. Calif. Feeders Day Rep.

Prior, R. L., R. H. Kohlmeier, L. V. Cundiff, M. E. Dikeman and J. D. Crouse. 1977. Influence of dietary energy and progein on growth and carcass composition in different biological types of cattle. J. Anim. Sci. 45:132.

Rao, P., and R. L. Miller. 1971. Applied Econometrics. Wadsworth Publishing Co., Belmont, Calif.

Reid, J. T. 1962. Dedication ceremony of Frank B. Morrison Hall and Symposium Papers on Animal Nutrition's Contribution to Modern Animal Agriculture. Ithaca, Cornell Ag. Expt. Sta.

Reid, J. T., G. H. Wellington and H. O. Dunn. 1955. Some relationships among the major chemical components of the bovine body and their application to nutritional investigation. J. Dairy Sci. 38:1344.

Richardson, D., E. F. Smith, F. H. Baker and R. F. Cox. 1961. Effects of roughage-concentrate ratio in cattle fattening rations on gains, feed efficiency, digestion and carcass. J. Anim. Sci. 20:316.

Riley, J. G. 1969. Net energy of corn and corn silage and estimation of bovine carcass composition. Ph.D. thesis. University of Missouri, Columbia.

Robinson, D. L., and L. S. Murphy. 1972. Influence of nitrogen, phosphorous and plant production on yield and quality of forage corn. Agron. J. 64:349.

Rossman, E. C., B. M. Darling and K. Dysinger. 1975. Hybrids compared. Michigan Corn Production Extension Bulletin No. 431.

Rutger, J. N., and L. V. Crowder. 1967. Effect of population and row width on corn silage yields. Agron. J. 59:475.

Schmid, A. R., R. D. Goodrich, G. C. Marten, J. C. Meiske, R. M. Jordan and J. L. Halgerson. 1975. Evaluation of laboratory methods for determining quality of corn and sorghum silages: I. Biological methods for predicting In Vivo digestibility. Agron. J. 67:243.

Schmid, A. R., R. D. Goodrich, R. M. Jordan, G. C. Marten and J. C. Meiske. 1976. Relationship among agronomic characteristics of corn and sorghum cultivars and silage quality. Agron. J. 68:403.

Schneider, E. O., E. B. Early and E. D. DeTurk. 1952. Nitrogen fractions of the component parts of the corn kernel as affected by selection and soil nitrogen. Agron. J. 44:161.

Schwab, G., and G. Gruenwald. 1978. Rates for Custom Work in Michigan. Mich. Ext. Bull. E-458.

Searle, S. R. 1971. Linear Models. Wiley and Sons Publishing Co. New York.

Seber, G. A. F. 1977. Linear Regression Analysis. Wiley and Sons Publishing Co. New York.

Self, H. L., and M. P. Hoffman. 1977. Effect of silage level on feedlot performance on yearling steers. Iowa State Exp. Sta. Rep.

Snapp, R., and A. Newman. 1960. Beef Cattle. 5th edition. New York: John Wiley and Sons, Inc.

Stallings, C. C., B. M. Donaldson, J. W. Thomas and E. C. Rossman. 1977. Brown midrib corn silage as a substitute for regular corn silage. J. Anim. Sci. Meetings. (Abstr.)

Stivers, R. K., D. R. Griffith and E. P. Christmas. 1971. Corn performance in relation to row spacings populations and hybrids on five soils in Indiana. Agron. J. 63:580.

Swift, R. W., J. W. Bratzler, W. H. James, A. D. Tilman and D. C. Meek. 1945. The effect of dietary fat on utilization of the energy and protein of rations by sheep. J. Anim. Sci. 7:475.

Theuninck, D. H., S. R. Burghardi, R. D. Goodrich and J. C. Meiske. 1977. A system of four corn grain-corn silage feeding systems for steer calves. Minn. Beef Cattle Rep.

Topel, D. G., D. L. DeWitt, R. L. Vetter and A. M. Trenkle. 1973. Influence of energy consumption during growth on carcass composition of feedlot cattle. Iowa State Exp. Sta. Rep.

Utley, P. R., R. E. Hellwig and W. C. McCormick. 1975. Finishing beef cattle for slaughter on all-forage diets. J. Anim. Sci. 40:1034.

Vance, R. D., R. R. Johnson, E. W. Klosterman, B. A. Dehority and R. L. Preston. 1970. All concentrate rations for growing-finishing cattle. Ohio Ag. Res. Dev. Ctr.

Vance, R. D., R. L. Preston, V. R. Cahill and E. W. Klosterman. 1971a. Net energy evaluation of rations containing varying proportions of corn grain and corn silage for growing, finishing cattle. Ohio Ag. Res. Dev. Ctr. 52:11.

Vance, R. D., R. L. Preston, E. W. Klosterman and V. R. Cahill. 1971b. Performance of finishing steers fed two different forms of corn with increasing levels of corn silage. Ohio Ag. Res. Dev. Ctr.

Vance, R. D., R. L. Preston, E. W. Klosterman and V. R. Cahill. 1972. Utilization of whole shelled and crimped corn grain with varying proportions of corn silage by growing-finishing steers. J. Anim. Sci. 35:598.

Van Soest, P. J. 1963. Use of detergent in the analysis of fibrous feeds. II. A rapid method for the determination of fiber and lignin. J. Assoc. Off. Agr. Chem. 46:829.

Van Soest, P. J. 1971. Estimations of nutritive value from laboratory analysis. Cornell Nutr. Conf., pp. 11-23.

Van Soest, P. J. 1973. Revised estimates of the net energy values of feeds. Cornell Nutr. Conf., pp. 11-23.

Van Soest, P. J., and R. H. Wine. 1967. Use of detergents in the analysis of fibrous feeds. IV. Determination of plant cell-wall constituents. J. Assoc. Off. Analytical Chem. 50:50.

Vetter, R. L. 1973. Evaluation of chemical and nutritional properties of crop residues. Nebr. Crop Residue Sym.

Vetter, R. L., and W. F. Wedin. 1964. Regular corn silage vs. corn silage plus hay in finishing cattle rations. Iowa State Exp. Sta. Rep.

Warncke, D., D. Christenson and R. Lucas. 1976. Fertilizer recommendations for vegetable and field crops. Mich. Ext. Bull. E-550.

Washko, J. B., and W. L. Kjelgaard. 1966. Double row corn planting can increase silage yields. Science for the Farmer. Penn. Ag. Expt. Sta. 13(3):7.

Welch, L. F. 1969. Effect on N, P and K on the percent and yield of oil in corn. Agron. J. 61:890.

Wells, D. M., G. F. Meenaghan, R. C. Albin, E. A. Coulman and W. Brug. 1972. Characteristics of wastes from southwest beef cattle feedlots. Cornell Ag. Waste Mgmt. Conf.

Wurster, M. 1972. The stover concept. Profit in Stalks Handbook 9.

Young, L. G., G. A. Branaman and R. J. Deans. 1962. Influence of rate of grain feeding on gain and carcass characteristics of calves. J. Anim. Sci. 21:621.