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The Production, Characteristics and Utilization of Forage-Fed Beef

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INTRODUCTION

The future need for cereal grains and meat products is expected to increase. A world population of 6.5 to 7.0 billion is expected by the end of the century. As a result of population increase accompanied by greater per capita demand for agricultural products, increased world food needs are projected to range from 45 to 50% by 1985 and to over 100% by the year 2000 (Hodgson 1976, 1977).

Future demands for ruminant animal products (meat, milk and fiber) are expected to remain high, and less grain is likely to be available for cattle feeding (Hodgson, 1977). The feeding of cereal grains to farm livestock has also raised public concern in recent years. Therefore, increased demands will be placed upon forages to replace the digestible energy lost through reduced grain consumption by livestock. Pope and Schake (1975) reported that 86% of the dry matter required to produce carcass beef still comes from non-grain sources. Of the remaining 14%, which is grain or grain by-products, 1.5% is used for the breeding herd and 12.5% is used to finish cattle for slaughter.

Forages generally are grown on land not suitable for profitable grain crop production (Hodgson 1975, 1976, 1977). Worldwide, 3 billion hectares are in permanent grassland, this being nearly twice the area in cropland. Over 400 million ha of United States land is used for forage, pasture and range production. Missouri alone has 5.26 million ha of domestic and native pasture lands and 12,950 ha of rangeland (SCS-1978) which represent 28.8% of the total land area. The 5.35 million head of cattle and calves represent over $2.5 billion value on Missouri farms and over $1.3 billion in farm receipts (1980 Missouri Farm Facts). According to Soil Conservation Service estimates, Missouri's grasslands are producing only about 70% of their potential (SCS-1978).

The World Conference on Food Needs gave a high priority to research on increasing the utilization of forages (Research to meet U.S. and World Food Needs, Vol. I, Kansas City, MO. 1975). Regional committee NCA-6 in its projection of research needs for beef production from 1977 to 2000 A.D. indicated that more effective use of crop residues and forages is essential if beef cattle are to compete with other systems of food production. Increasing production of forages with improved feeding value, development of improved methods for rapidly determining the feeding value of forages, plus increased use of legumes in forage production programs were the three top priority research needs in forage research for the northeast (Forage Crops, Report of a NE Research Program Steering Committee, Report No. 1, November 1976).

It is increasingly apparent that we are becoming more highly dependent upon a dependable supply of all forms of forage as our main-line source of feed for ruminant livestock.

Research in recent years has dealt with production systems evaluating slaughter cattle after all forage feeding (forage-fed beef) or after periods of short term grain feeding (Chyba, 1973; Harrison *et al.*, 1978; Shinn *et al.*, 1976; and Meyer *et al.*, 1960). The production of forage-fed beef has not been without criticism. Seasonal variation of grass species can greatly influence rates of animal gain during the early spring and fall months with reduced rates of gain and carrying capacity during mid-summer and winter months (Roundtree *et al.*, 1974, and Burns *et al.*, 1973). Beef packers have traditionally discriminated against grass finished cattle, finding them less acceptable because of lowered dressing percentage, higher cooler shrinkage, and lower quality grade (Shroeder, et al., 1980) compared with grain-fed animals. Bowling *et al.* (1978) reported that grass finished beef exhibited lower flavor and tenderness scores than beef finished on grain diets. Short term feeding of grain to finishing cattle has the advantages of improving qualitative characteristics, lean color, dressing percentage, and retail acceptability compared to cattle finished on all-forage diets (Young and Kauffman, 1978). Supplementation of grain to grazing cattle has shown improvements in rates of gain, economic returns and consumer acceptability (Lake and Clanton, 1973; Chyba and Boren, 1976 and Coleman *et al.*, 1976).

Most researchers agree that grass-legume pastures are more productive than pure grass pastures fertilized with moderate rates of nitrogen. In recently published reviews on animal production from tall fescue (Spooner and McGuire, 1979; Van Kewen and Stuedeman, 1979), many examples were given showing that higher animal performance can be expected when legumes are included in pasture seedings of tall fescue. Likewise, tall fescue-legume mixtures many times produce greater yields of dry matter and have a more uniform distribution of herbage production over the season than for nitrogen fertilized fescue which is grown alone (Matches, 1979). Legumes can be expected to play a more important role in U.S. pastures in the future as we search for ways to increase red meat production from forages. Also, legumes provide an opportunity to conserve fossil fuels by reducing the need for nitrogen fertilizer on pastures.

There is an abundance of forage quality data reported in the literature, but in only a relatively few cases have attempts been made to relate herbage composition to animal performance under grazing conditions. Reid, *et al.* (1978) pointed out that for the Northeastern U.S. few studies have been designed to determine the nutritive value of forage species under grazing conditions, or to relate performance characteristics of grazing ruminants to changes in organic and inorganic components of the herbage. Such study is also lacking for the North Central region. However, the researcher is confronted with the problem of obtaining herbage samples representative of that consumed by grazing animal, and in measuring the amount of herbage consumed per animal per day. For example, in Oklahoma research with bermudagrass (Telford *et al.*, 1975), cows and calves that were fitted with esophageal cannula were found to select herbage higher in quality than the quality of hand clipped samples. Similarly, Coleman and Barth (1973) found differences in the quality of clipped samples and those collected from esophageal fistulated heifers. The fistula samples contained more crude protein, less acid detergent fiber and soluble carbohydrates than was observed in the available forage samples that were clipped. Use of esophageal fistulated animals appears to be desirable for grazing research, but seemingly, their availability is lacking in most grazing trials because of cost and possible health problems associated with the fistulas.

In only a few cases have researchers reported high correlations between sward quality measurements and animal gains. Duble *et al.* (1971), working with six warm-season grasses, have been more successful than many. In their experiments, average daily gains (ADG) of yearling crossbred heifers were significantly correlated ($r = .85$) with available forage when regressions were computed within the following ranges of in-vitro dry matter digestibility (IVDMD): >60%, 50-60%, and >50%. The ADG increased within each digestibility grouping as available forage increased up to a point above which ADG showed no further increase. This point shifted upward as digestibility decreased. The kg of available forage/ha at which ADG's did not increase were 500 kg for >60% IVDMD, 1000 kg for 50-60% IVDMD, and 1250 kg for <50% IVDMD. It was assumed that above these levels of available forage, forage quality was the predominant factor affecting animal performance; whereas, below these levels, forage availability had an overriding influence. The authors also examined relationships with other quality components besides IVDMD, but they will not be discussed here.

A more complete knowledge of forage quality trends will provide a basis for developing improved forage systems to meet the nutritional requirements of different classes of livestock (Kaiser *et al.*, 1974; Vartha *et al.*, 1977). Concurrently consideration should be given to the qualitative characteristics of meat produced by the animals. Several researchers have investigated the influence of diet on beef flavor. The literature is not conclusive as to the effect forages have on beef flavor. Some reports indicate an improvement in flavor of forage-fed beef (Oltjen *et al.* 1971; Cross and Dinius 1978), and other reports indicate forage-fed beef was less desirable than grain-finished beef (Bowling *et al.* 1978; Brown *et al.* 1979; Wanderstock and Miller, 1948).

The main objectives of the present investigation were to (1) evaluate pastures containing grass or a combination of grass and legume in terms of beef cattle gains and composition; (2) measure the rate and efficiency of cattle gains using production systems varying in the amount of total body weight gain produced on pasture, corn silage or corn grain; (3) determine if the beef produced under the above systems has the characteristics acceptable to the consumer and the industry; and (4) determine price-cost relationships for the various production systems.

MATERIALS AND METHODS

Four production system experiments were replicated each year for the years of 1977, 1978 and 1979, with a total of 352 steers. Each year during mid-October, Hereford-Angus crossbred steer calves weighing approximately 204 kg were purchased from area producers and transported to the Beef Research Center. Upon arrival, steers were weighed, wormed, vaccinated, treated for warbles and lice, eartagged and hot branded. After a two-week recovery and adjustment, all steers were transported to the Low Level Radiation Laboratory where body composition was determined by measuring ^{40}K (Clark, *et al.* 1976). Steers were allocated to the different systems and to treatments within systems by initial weight and body composition (table 1). Initial and final weights were taken after a 16-hour overnight shrink without feed or water, while interm 28-day weights were taken without overnight shrink in all but System III, where all cattle weights were shrunk weights.

An outline of the four production systems, the thirteen treatments comprising the production systems and projected slaughter weights for each treatment are presented in Table 1. The actual slaughter weights deviated some from the projected slaughter weights due to weighing intervals, slaughter schedule and in the case of System III, drought conditions which reduced forage availability.

System I - Drylot Feeding

This system consisted of three treatments of drylot feeding of steers using either a corn silage diet alone or corn silage diet followed by a corn grain finishing diet (table 2). Steers assigned to Treatment 1 were fed a corn silage diet until an average live weight of 367 kg was achieved and then slaughtered. Steers assigned to Treatment 2 were fed corn silage until they reached an average live weight of 367 kg and then were switched to a corn grain finishing diet. These steers were fed to a slaughter

TABLE 1. EXPERIMENTAL DESIGN

System	Treat-ment	Description	Projected slaughter weight, kg
I (Drylot Feeding)	1	corn silage only	363
	2	corn silage ➧ corn grain	431
	3	corn silage ➧ corn grain	477
II (Self-feeding corn on pasture)	4	winter backgrounding ➧ fescue: N➧ self-feeding corn on pasture	431
	5	winter backgrounding➧ tall fescue:red clover ➧ self-feeding corn on pasture	431
	6	winter backgrounding ➧ fescue:N ➧ self-feeding corn on pasture	477
	7	winter backgrounding ➧ tall fescue:red clover ➧ self-feeding corn on pasture	477
III (Slaughter after pasture grazing)	8	winter backgrounding ➧ tall fescue:N	363
	9	winter backgrounding ➧ tall fescue:red clover	363
	10	winter backgrounding ➧ tall fescue: birdsfoot trefoil	363
IV (Drylot feeding after pasture grazing)	11	winter backgrounding ➧ tall fescue:N ➧ drylot corn grain	477
	12	winter backgrounding ➧ tall fescue:red clover ➧ drylot corn grain	477
	13	winter backgrounding ➧ tall fescue: birdsfoot trefoil ➧ drylot corn grain	477

TABLE 2. COMPOSITION OF DIETS FOR STEERS FED IN DRYLOT[a]

Ingredient	International feed No.	Corn silage	Corn grain
		%	
Corn silage	3-08-154	87.6	25.9
Yellow corn (whole shell)	4-02-930	8.0	71.2
Soybean meal (44%)	5-04-604	1.6	1.0
Urea		1.6	.8
Calcium carbonate	6-01-069	.5	.4
Dicalcium phosphate	6-01-080	.2	.2
Trace mineralized salt		.4	.3
Monensin sodium (per head daily) (Elanco Products, Eli Lilly & Co.)		250 mg	250 mg

[a]Dry matter basis.

weight of 431 kg. Steers from Treatment 3 were managed similarly to steers from Treatment 2, except the end-point average slaughter weight was 477 kilograms. All animals were fed once a day with a truck mounted mixer. Feed intake, rate and efficiency of gain data were collected.

System II - Backgrounding, Pasture, Corn on Pasture

This system included three phases: a) fall and winter backgrounding, b) spring to mid-summer grazing of tall fescue *(Festuca arundinacea* Schreb) or tall fescue plus red clover *(Trifolium pratense* L) pastures, and c) self-feeding of corn on pasture from mid-summer until slaughter. One-half of the steers were slaughtered at an average weight of 431 kg and one-half at 477 kg weight.

Each fall, after weighing and assignment to treatments, all steers were backgrounded as one group from late October until the middle of April. Stockpiled Kentucky 31 tall fescue pastures were utilized until snow cover or forage availability prevented grazing. Generally from January until the beginning of the grazing period, tall fescue hay and limited amounts of cracked corn were fed to allow between .23 and .45 kg per day gain.

Summer pastures consisted of straight Kentucky 31 tall fescue fertilized with nitrogen and Kentucky 31 tall fescue interseeded with Kenstar red clover. Pastures of 2.02 ha size were arranged in a randomized complete block design with two replications.

Seeding method, initial and annual fertilization, and pasture measurements were the same as described for System III which follows.

Nine steers grazed each pasture from mid-April until the first week of July (approximately 85 days), after which time cracked corn was fed at increasing amounts until *ad libitum* intakes were reached. After *ad libitum* intakes were achieved, a self-feeder with a capacity of 1.81 metric tons cracked corn was placed in each pasture. When live body weight of all steers averaged 431 kg, nine of the steers from the fescue pastures (Treatment 4) and nine of the steers from the fescue plus red clover pastures (Treatment 5) were randomly selected (five from one replication and four from the other) and slaughtered. The other one-half of the steers were slaughtered when average weight reached 477 kg (Treatments 6-fescue and 7-fescue plus red clover).

System III - Backgrounding - Pasture

This system was designed to evaluate pasture performance of steers which had been winter backgrounded, and then allowed to graze tall fescue, tall fescue plus red clover, or tall fescue plus birdsfoot trefoil ('Empire', *Lotus corniculatus* L). The winter background phase for these animals was the same as described for System II animals.

In mid-April each year the steers were wormed. Six tester steers were assigned to each pasture. Pastures were 2.4 ha in size.

Pastures were rotationally grazed in a two paddock rotation in 1977 and in a four paddock rotation in 1978 and 1979. Extra steers were used to maintain the desired levels of pasture utilization among treatments. Adjustments in animal number were made only 1 to 4 times per season.

Cattle were weighed at aproximately 28-day intervals following 16 hours confinement in holding pens without feed or water. Cattle had access to trace mineral salt in all pastures. Movable cattle shades were present in each pasture. The grazing periods were 160, 158 and 165 days for 1977, 1978 and 1979, respectively.

Gain per hectare was computed from the performance of the tester animals similar to Method III proposed by Mott and Lucas (1952) except that a metabolic animal unit (MAU) rather than an effective feed unit basis of computation was used. Tester days were computed as follows:

$$\text{Tester Day/ha} = \frac{\text{Total MAU days of grazing/ha}}{\text{average tester MAU size}}$$

Where $1000^{3/4}$ live body weight equals one MAU, then gain/ha = Tester days/ha X Tester average daily gain

Pasture Seedings and Fertilization Used for System III Grazing

Four-year-old established pastures of Kentucky 31 tall fescue at the University of Missouri Agronomy Research Center were interseeded with Empire birdsfoot trefoil and Kenstar red clover on March 23-24, 1977. Legumes were interseeded into the tall fescue sod with a John Deere Powr-Till Seeder[1] at rates of 7.8 kg/ha of birdsfoot trefoil and 9.0 kg/ha of red clover. Red clover was seeded again into all pastures on March 1, 1979 by broadcasting seed on top of the surface and allowing freezing and thawing to work seed into the soil. Similarly, some pastures of birdsfoot trefoil were partially reseeded each year to improve trefoil stands.

Prior to seeding legumes in 1977, all pastures received a broadcast application of 6731 kg/ha of agricultural limestone, 30 kg/ha of P and 56 kg/ha of K. Soil tests indicated that no additional phosphate or potash was needed in 1978. In April 1979, 15 kg/ha of P and 56 kg/ha of K were applied to all pastures.

Only the tall fescue pastures without legumes were fertilized with nitrogen. The annual fertilization rate was 84 kg/ha applied in early spring (March-April) and an additional 57 kg/ha in August. Because of severe summer drought and expected termination of grazing in September, the August 1979 application of nitrogen was not made.

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[1]Mention of a trademark or proprietary product does not constitute a guarantee or warranty of the product by the U.S. Department of Agriculture or the University of Missouri and does not imply its approval to the exclusion of other products that may also be suitable.

Pasture Sward Measurement

Botanical Compositions. Herbage samples for botanical analysis were taken from pastures one to three times a season. Grab samples, cut to ground level were taken randomly over a pasture, composited and mixed, and a 400 to 600 g subsample taken for hand separation into component species. The percent composition is reported on a dry weight basis.

Plant Stands. Stands of tall fescue and legumes were determined three times each growing season. A ten-pin point quadrat was used to estimate plant frequency. Twenty frames (200 points) were taken randomly over the pasture, and only plants touching the pins at ground level were recorded. Plant species not tall fescue, red clover, or birdsfoot trefoil, were recorded and are reported as "other." Stands are reported as the percentage of total pin hits.

Herbage Bulk-Height. A disk meter consisting of a circular aluminum disk of 0.2 m^2 area which slides freely on a centrally located graduated rod was used to estimate bulk-height of the herbage. The disk weighed approximately 2.5 kg. As described by Vartha and Matches (1977), bulk height was determined by dropping the disk from a height of 80 cm above ground level and recording its resting height on the graduated slide rod. Values were read to the nearest centimeter. Twenty-five randomly located readings per pasture were recorded at approximately weekly intervals over the growing season.

Calibrations to estimate yield of herbage were made several times a season. From 15 to 30 disk readings representing the range of readings for that sampling date were recorded, and the herbage in a 0.2 m^2 area below the disk plate harvested to nearly ground level. The herbage sample was dried, and then dry matter yield (Y) and disk reading (X) matched for linear regression analysis. The resulting regression equations were intended for use in estimating yield of dry matter per ha based upon the average bulk-height value for a pasture.

Herbage Samples for Laboratory Analysis. Throughout the grazing season, herbage samples were obtained at approximately two-week intervals. Samples were taken by plucking the upper 1/3 to 1/2 of the standing forage. These samples were taken randomly over an entire paddock being grazed and/or in a fresh paddock which animals were to move into during the week of sampling. Samples were composited and a subsample of 400 to 600 g dried at 55 C in a forced air drier. Dried samples were ground to pass through a 1 mm screen and then held in sealed plastic bags at room temperature until analyzed.

Laboratory Analyses. In-vitro dry matter digestibility (IVDMD) was determined by the method of Tilley and Terry (1963) but modified for direct acidification as described by Marten and Barnes (1979). Neutral detergent fiber (NDF) and acid detergent fiber (ADF) were determined by the procedures outlined by Goering and Van Soest (1970); crude protein by the AOAC methods (1980); calcium (Ca), phosphorus (P), potassium (K), and magnesium (Mg) were also determined by appropriate analytical procedures (Horwitz; 1975; and Wall and Gehrke, 1974).

System IV - Backgrounding, Pasture and Drylot Feeding

This system was designed to evaluate drylot performance of half of the steers from System III. These steers had previously grazed either: a) straight tall fescue (Treatment 11), b) tall fescue plus red clover (Treatment 12) or c) fescue plus birdsfoot trefoil (Treatment 13) pastures. No corn was fed during the pasture phases. Upon arrival at the Beef Research Center, steers were adapted to the corn grain finishing diet (table 2) and were fed until an average live weight of 477 kg was achieved. Steers were fed once per day with a truck mounted mixer. Feed intake, rate and efficiency of gain data were collected.

CARCASS COMPOSITION AND QUALITY

Animals were slaughtered at the University abattoir or at a local commercial facility and transported to the University for evaluation. After a 48 hour chill the USDA carcass quality and yield grades were determined (USDA 1975). Each component of the quality and yield grades was recorded for analysis. These factors were: area of the *longissimus* muscle at the 12th rib as measured with a grid, fat thickness over the *longissimus* muscle at the 12th rib, carcass weight, estimated percentage of kidney, heart and pelvic fat and the marbling score. The maturity score was recorded but was not analyzed since all carcasses were within the A maturity.

The equations of Hedrick and Krause (1975) were used to predict the retail cuts from the primal cuts and total retail cuts from the carcass as percentages of carcass weights. The equations were: Percent retail cuts from primal cuts = 59.68 − 8.14 (fat thickness in inches) − .566 percent kidney, heart, and pelvic fat) + .696 (area of *longissimus* muscle in square inches) − .0120 (carcass weight in pounds). Percent total retail cuts = 74.22 − 9.17 (fat thickness in inches) − 1.173 (percent kidney, heart, and pelvic fat) + .795 (area of *longissimus* muscle in square inches) − .0125 (carcass weight in pounds).

Specific gravity was also determined to provide an additional indicator of carcass composition. One-half of each carcass was quartered. The quarters were then placed one at a time in a tank of water and their weight in water recorded. The temperature of the water was equal to the carcass temperature. Specific gravity was calculated from the formula: Specific gravity = weight in air ÷ (weight in air - weight in water). Percent carcass fat was calculated from the formula of Riley (1969). The formula was: Percent carcass fat = 518 - 462.9 (specific gravity).

Carcass Fabrication. The right hindquarter of each carcass was then aged for an additional eight days at 2 to 4 C (total of 10 days). After aging, the shortloin and top round *(semimembranosus)* were removed for further testing. Two 2.5-cm steaks were removed from the anterior portion of the shortloin for color evaluation. The remaining shortloin and top round were labeled and placed in frozen storage (-18 C) until used.

Color Evaluation. The two steaks, described above, were trimmed and residual bone and fat on the cut surface was removed to simulate a commercial retail cutting operation. The steaks were then placed in foam meat trays (W. R. Grace and Company) and wrapped with transparent film (Goodyear Prime Wrap). The steaks were then placed in a retail display case at 0 to 2 C under 100 foot candles of fluorescent light. The steaks were allowed one hour bloom time before the color evaluation. For the second and third years color was also evaluated after three days of display.

Color was evaluated according to the method of Bala *et al.* (1979). Values for "L" (measure of total light reflected), "a" (measure of redness), and "b" (measure of yellowness) were recorded from a Color Difference Meter (Hunter Lab Model D25D2). The meter was standardized against Hunter Standard Tile number C233955 which was wrapped with Goodyear Prime Wrap. The standard values were L = 67.6, a = 22.7 and b = 9.8. Care was taken while making the color measurements to insure that no air bubbles were present between the meat surface and film wrap in the area being evaluated.

Sensory Panel Evaluation

Facilities. The sensory testing was conducted in an air-conditioned room. The panelists were seated in individual booths with pass through doors for serving samples. The panelists were provided with a cup of room temperature water for rinsing between samples and an expectoration cup. The room was illuminated with red light to minimize any differences in sample appearance.

Panel Composition. The panel consisted of six people. Prior to the beginning each year of the loin steak panels and round roast panels, training sessions were held to familiarize the panelists with the test procedure and meat samples to be evaluated. Training involved evaluation of samples individually followed by a group discussion of the samples served and how they were scored.

Preparation of Samples. Prior to cooking, all steaks and roasts were given a coded number. Steaks, 2.5 cm thick, were removed from the short loin, immediately posterior to the steaks used for color evaluation. Steaks were thawed (wrapped)in a 2 to 4 C cooler to an internal temperature of 2 to 4 C. "Modified broiling" was the cooking method employed in preparing the steaks. The steaks were placed on a wire rack in an aluminum pan and cooked in a 177 C gas oven (Wimco Isothermic) with forced air to an internal temperature of 70 C.

Top round roasts were prepared as described above except the oven temperature was 149 C and forced air was not used.

Presentation of Samples. The external fat and bone were removed from loin steaks. The steaks were then placed in a plexiglass sample sizer and sectioned in 1.3 cm^3 pieces. The samples were then placed in paper souffle cups and presented to the panelists. The order of presentation of the samples was randomized. The panelists were instructed to evaluate the samples for juiciness, flavor, tenderness and overall acceptability on an eight-point rating scale as described by the American Meat Science Association (1978).

A 2.5 cm thick slice was removed from the anterior end of each roast and discarded. Another 2.5 cm thick slice was removed, sectioned, and served as outlined above.

Warner-Bratzler Shear Determination. A 3.8 cm loin steak from each short loin was cooked as described above for steaks used for sensory evaluation. After cooking, steaks were allowed to cool to room temperature. Three 1.3 cm cores were removed from the *longissimus* muscle using a drill press unit. The cores were sheared with a Warner-Bratzler shear device.

An additional 3.8 cm thick section was removed from the top round roasts adjacent to the slice used for sensory and sheared as described for the loin steaks.

IDENTIFICATION OF VOLATILE COMPOUNDS IN FAT

After the completion of the first year of the investigation, it was apparent that steaks and roasts from grass-fed animals (Treatments 8, 9, 10) were rated less desirable for all sensory attributes, especially flavor, compared to all other treatments by the sensory panel. Subcutaneous fat samples were obtained from the short loins of Treatments 6, 8 and 11 and analyzed for volatile compounds. Preparation of the fat samples from the short loins involved melting the samples at 177 C in covered pyrex beakers. The melted fat was then placed in tightly capped test tubes and held frozen until analyzed. Six hundred milligram samples of beef fat were analyzed by gas-liquid chromatography-mass spectrometry, using a direct sampling procedure (Legendre *et al.*, 1979). The volatiles from the beef fat were removed by heating in the direct sampler for 20 minutes at 180 C followed by gas-liquid chromatography on 7% Poly MPE on Tenax GC (80-100 Mesh). Detection was by a Hewlett-Packard Quadropole Mass-Spectrometer (Model No. 5930-A) interfaced to the gas-liquid chromatograph with a silicone separator. The data system was an Incos/Finnigan 2300. All other procedures were the same as those described by Legendre *et al.* (1979).

STATISTICAL ANALYSES

Performance parameters of animals were evaluated for the three years by analysis of variance and Duncan's multiple range test (Steele and Torrie, 1960). Data are reported as least squares means for the various parameters. Analyses contained the main effects of year, treatment and the interaction term.

Pasture treatments were arranged in a randomized complete block design with three replications. For analyses over years, a split-plot over time as described by Steele and Torrie (1960) was used. Simple correlation and regression were made according to Snedecor and Cochran (1979). The maximum R^2 improvement (MAXR) procedure as described by Helwig and Council (1979) was used to determine the combination of variables in multiple regressions which yield the maximum coefficient of determination (R^2).

Carcass and sensory data were analyzed using a repeated measurement design as described by Gill and Hafs (1971). Means were separated by least significant difference (Snedecor and Cochran. 1979).

The data were analyzed for each of the three years and for three years combined. Rather than present the data for each of the three years, we chose to present in tabular form the combined data of three years and when differences were observed between years, these are presented in the discussion.

ECONOMIC ANALYSES

Economic evaluations of the 13 treatments were made as outlined by Jacobs (1981). The factors considered in the evaluations are contained in Table 77. The dollar values used in making the comparisons were market quotations for feeder and slaughter cattle from USDA Market News Report and quotations for carcasses and by-products from The National Provisioner for the week of July 27, 1981.

RESULTS AND DISCUSSION

Live Animal Performance

System I. All steers assigned to this system were initially fed a corn silage diet until an average live weight of 381 kg was attained. At that time steers assigned to Treatment 1 were slaughtered. The period of corn silage feeding was an average of 203 days and daily gain was .73 kg per day with no significant difference ($P>.05$) between years (table 3). Daily gain and days fed respectively for steers during 1977 were .79 kg and 210 days; for 1978, .72 kg and 196 days; and for 1979, .71 kg and 203 days. Efficiency of gain (DM/unit gain) for all years was 7.82. Average efficiency for 1977 was 7.10; for 1978, 8.09 and for 1979, 7.36.

TABLE 3. DRYLOT PERFORMANCE OF STEERS FOR SYSTEM I (3 YR SUMMARY)

	Treatment				
	1	2		3	
Item	Silage Only	Silage	Corn	Silage	Corn
No. animals	29	29		29	
Initial wt, kg	221	220		223	
Final wt, kg	381	438		486	
Avg. gain/steer (kg)	160	141	77	151	112
Daily gain, kg	.78[a]	.70[b]	1.12	.75[a]	1.10
Days fed	205	201	69	201	102
DM/unit gain	7.32	8.08	7.32	8.04	7.89

[ab]Means with different superscripts are significantly different, (P<.05), (for corn silage phase).

Within treatments, gains for steers assigned to Treatment 2 were less (P<.05) than for the other two treatments, which were not different (P>.05), (.70 vs. .78 and .75 kg/day for Treatments 2, 1 and 3 respectively). Although there was a statistical difference, no biological difference could be determined since steers were of similar initial weight, similar breeding, similar body composition and were fed the same diet as steers assigned to Treatments 1 or 3. This gain difference was significant (due to 1977 performance) when averaging three years data, but was not different (P>.05) for the years 1978 or 1979.

The average slaughter weight across years from Treatment 1 was 381 kg. Average slaughter weights among years were similar (P>.05), with steers from 1977 weighing 376 kg, from 1978 weighing 377 kg, and from 1978 weighing 388 kg.

Steers assigned to Treatment 2 were fed the corn grain finishing diet for an additional 69 days after the corn silage feeding phase. This additional time was required for the steers to achieve a final average live body weight of 438 kg. Daily gains averaged 1.12 kg for the three years which was 0.42 kg/day faster than during the corn silage phase. Daily gains and days fed respectively for 1977 were .98 kg, 69 days; for 1978, 1.13 kg and 51 days; and for 1979, 1.25 kg and 86 days. Overall efficiency of gain when fed the corn grain finishing diet for the three years was 7.32 which was approximately 10.4% better than when fed the corn silage diet (8.08). Because steers assigned to Treatment 2 were slaughtered after reaching a pre-determined body weight, no statistical comparison was made with steers from Treatment 3, which were fed for an additional period of time and to a heavier body weight. The three-year average slaughter weight for Treatment 2 steers was 438 kg, with steers from the 1977 replication weighing 427 kg; from 1978, 414 kg; and from 1979, 472 kg (P<.05). Steers from 1979 weighed more at slaughter than did steers from 1977 or 1978 which were similar (P>.05).

Steers from Treatment 3 were fed the corn grain finishing diet for an additional 102 days after corn silage feeding. Daily gain averaged over the three years was only slightly slower (1.8%) than that for steers from Treatment 2, which were fed for fewer days. This would suggest that these steers were continuing to grow almost as rapidly as steers slaughtered at a lighter body weight. Daily gains, feed efficiency, and days fed, respectively, for 1977 were 1.02, 7.45 and 95; for 1978 were 1.09, 8.36 and 107; and for 1979 were 1.18, 7.87 and 105. The average slaughter weight for these steers was 486 kg with steers from 1977 weighing 479 kg, from 1978 weighing 480 kg, and from 1979 weighing 500 kg (P>.05).

Winter Backgrounding. This section describes the winter performance for steers assigned to Systems II and III. Steers were allowed to graze stockpiled tall fescue pastures and when necessary, the steers were supplemented with fescue hay and limited amounts of cracked corn. This program of winter feeding lasted until the middle of April, which was an average of 152 days.

Average daily gains for the three years were .32 kg. Gains were not different for 1977 or 1978 (.33 vs. .39 kg per day, respectively), but were less (P<.05) for 1979 (.24 kg). The winter of 1979 was much colder and wetter, especially during February, then the previous two winters, and it was believed that this may have partially caused the slower growth rate.

Spring and Summer Grazing (System II). Each year, during mid-April, steers assigned to System II were allotted to either nitrogen fertilized Kentucky 31 tall fescue pastures or to tall fescue pastures interseeded with Kenstar red clover. Steers grazed respective pastures for an average of 87 days, after which time *ad libitum* corn was fed. Three year daily gains were 15% faster for steers grazing tall fescue: red clover pastures compared to steers grazing nitrogen fertilized tall fescue pastures (.68 vs. .59 kg, respectively) but the differences were not significant (table 4). Within years, rate of gain of steers grazing fescue - red clover pastures was numerically greater, (P>.05) than gain of steers grazing nitrogen fertilized fescue pastures. For 1977, steer gains on tall fescue-red clover were 8.6% greater, for 1978 were 9.8% greater and for 1979 were 48.1% greater than for steers grazing nitrogen fertilized tall fescue. There was no significant year x treatment interaction (P>.05), but, a significant year effect was measured with steers from 1979 having the poorest combined average daily gains (.34 kg) and steers from 1978 having the best daily gains (.97 kg), an almost three-fold difference.

Because the nutritional quality of tall fescue usually decreases during July in Missouri, additional energy feedstuffs are necessary to maintain acceptable animal growth. After 87 days of grazing, cracked corn plus monensin was fed *ad libitum* to all steers. When live weight of all steers

TABLE 4. PASTURE PERFORMANCE OF STEERS FOR SYSTEM II (3 YR AVERAGE)

	Treatment			
	4	6	5	6
Item	Fescue		Fescue:Red Clover	
No. animals	28	27	26	26
Initial wt, kg	274	273	271	274
Final wt, kg	464	488	476	494
Days on:				
pasture	87		87	
pasture + corn	154	175	154	175
Daily gain on:				
pasture, kg	.59		.68	
pasture + corn, kg	1.10	1.06	1.10	1.05
Total gain on:				
pasture, kg	51		59	
pasture + corn, kg	169	186	169	184
Corn consumed/day, kg	6.57	6.72	6.66	6.97
Total corn, kg/steer	1012	1176	1026	1220

averaged at least 431 kg, 18 steers were randomly selected and slaughtered. Nine of the steers were from nitrogen fertilized tall fescue pastures (Treatment 4) and nine were from tall fescue-red clover pastures (Treatment 5). There were no differences among years (P>.05) in gain for steers fed corn in self feeders on N fertilized tall fescue (Treatment 4) or tall fescue—red clover (Treatment 5) pastures. However, steers from Treatment 5 averaged 12 kg more at slaughter (P>.05). Within years, gains were not significant, and there was no year x treatment interaction (P>.05). The consumption of cracked corn did not appear to be greater for one treatment vs. another (6.57 vs. 6.72 kg/day for N fertilized fescue vs. fescue-red clover) but the consumption was less (P<.05) for 1977 compared to the following two years which were not different (P>.05).

Each year the remaining 18 steers were fed cracked corn for an average additional 21 days or until body weight reached approximately 476 kg. No differences (P>.05) in daily gain (entire corn feeding period) or corn consumption were measured when comparing steers assigned to nitrogen fertilized tall fescue (Treatment 6) or to tall fescue-red clover pastures (Treatment 7). Daily gains and corn consumption, respectively, for Treatment 6 were 1.06 and 6.72 kg and for Treatment 7 were 1.05 and 6.97 kg. There was a year effect (P<.05) with steers from 1977 gaining at a slower rate and requiring more days (.79 kg/day gain and 225 days) to slaughter than steers from 1978 or 1979 (average of 1.19 kg/day gain and 150 days). Again there was no year x treatment interaction (P>.05) for

TABLE 5. AVERAGE DAILY GAINS OF STEERS, TOTAL BEEF PRODUCTION AND OTHER MEASUREMENTS ON THREE TYPES OF PASTURES FOR SYSTEM III (3 YR. SUMMARY)

	Pastures		
Item	Tall Fescue	Tall Fescue & Red Clover	Tall Fescue & Birdsfoot Trefoil
Initial wt, kg	241	242	240
Ending wt, kg	304	320	322
Days of grazing	161	161	161
Tester steer days/ha	569	462	415
Liveweight gain/ha, kg	219	225	211
Daily gain, kg	0.38	0.49	0.51
Gain/steer, kg	62	78	82

LSD .05 Tester steer days/ha = 24.
LSD .05 Tester ADG = 0.06.
LSD .05 Liveweight gain/ha = not significant.

gain or consumption of corn for steers fed to a heavier slaughter weight. Although steers slaughtered at a heavier body weight (Treatments 6 and 7) weighed more than steers slaughtered at a lighter weight (Treatments 4 or 5), combined average daily gains were not different (P>.05), (1.10 vs. 1.06, for N fertilized fescue vs. fescue-red clover, respectively. Corn consumption was only slightly greater on a per day basis for the heavier steers (6.85 kg) than for the steers slaughtered at a lighter weight (6.62 kg).

Spring and Summer Grazing (System III) Over the three years, there was a range of from 158 to 165 calendar days of grazing with an average of 161 days (table 5).

The three year averages for pasture production (table 5) reveal several interesting trends. Average initial steer weights were the same among pasture treatments, but ending weights reflected the influence of pasture type on animal performance. Steers on the tall fescue-legume pastures gained from 16 to 28 kg more than steers on straight tall fescue. However, steer days of grazing per ha for fescue alone were 569 as compared to 462 on tall fescue-red clover and 415 on tall fescue-birdsfoot trefoil. Both average daily gain of steers and pasture carrying capacity as determined by steer days/ha were significantly influenced by pasture type (table 5); however, there were no differences among pasture types for animal gain/ha. Thus, the tall fescue alone pasture yielded more animal days of grazing, but the fescue-legume pasture compensated with higher ADG so that the resulting gains/ha were nearly the same (P>.05). Over years, ADG's on the legume pastures averaged 31% greater than ADG's on tall fescue alone that was fertilized annually with up to 141 kg N/ha.

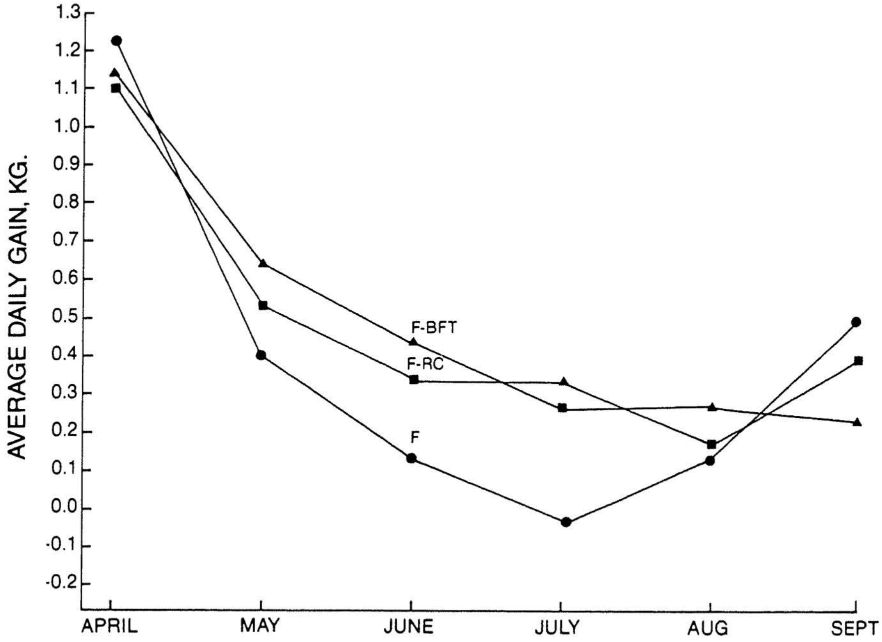

Figure 1. Monthly trends in average daily gains of steers on pastures of tall fescue (F), tall fescue-red clover (F-RC), and tall fescue-birdsfoot trefoil (F-BFT) averaged over three years for System III.

The seasonal trends (average for three years) show that ADG's on tall fescue (figure 1) were below those of the legumes from May until August, but April ADG's were similar for all three pasture types. In September, gains on tall fescue were nearly 0.25 kg greater than those on tall fescue-birdsfoot trefoil and about 0.1 kg higher than cattle gain on tall fescue-red clover.

In the first two years, the tall fescue-red clover pastures had more steer days/ha and more gain/ha, but the same ADG as tall fescue-birdsfoot trefoil. In the last year, the ADG on tall fescue-red clover was similar to the straight tall fescue. This shift was probably due to an early drought which caused much of the red clover to die by early summer.

Animal Heat Stress. During periods of high temperatures, especially if accompanied by drought, animals on the N fertilized fescue showed considerably more heat stress than cattle on the tall fescue-legume pastures. Animals on the straight fescue seemed to spend more time under shades, they had much mud covering their bodies, were slower in losing their winter hair coat and appeared much less thrifty than cattle on the tall fescue-legume pastures. During periods of heat stress, the mud under the shades of the nitrogen fertilized tall fescue was estimated at 10 to 30

TABLE 6. DRYLOT PERFORMANCE OF STEERS FOR SYSTEM 4 (3 YR AVERAGE)

	Treatment[a]		
Item	11	12	13
No. animals	26	27	27
Days fed	123	123	123
Initial wt, kg	303	320	320
Final wt, kg	494	496	505
Avg. gain steer, kg	191	176	185
Daily gain, kg	1.58[b]	1.45[c]	1.52[b]
DM/unit gain	6.61[b]	7.18[c]	6.87[b]

[a]Steers for treatment 11 previously grazed tall fescue; treatment 12 grazed tall fescue and red clover; and treatment 13 grazed tall fescue and birdsfoot trefoil pastures for approximately 160 days prior to entering drylot.
[bc]Values with different superscripts are significantly different ($P<.05$).

cm deep and was kept in a wet plastic condition with moisture from urinations (figure 2). In comparison, mud under the tall fescue-legume pasture shades was generally not more than 5 cm deep and was much less plastic. These conditions appeared in each of the three seasons of grazing.

We believe that nitrogen fertilizer may intensify the effects of an unidentified anti-quality factor which is present in Kentucky 31 tall fescue. These conditions did not appear in the tall fescue-birdsfoot trefoil pastures in 1977, and there was essentially no contribution of trefoil to the diet this first season after seeding. Thus, we feel justified in suggesting that nitrogen fertilizer may intensify poor animal performance on tall fescue pastures during the hotter portions of the summer.

Drylot Feeding of Yearling Steers (System IV). Daily gains and feed efficiencies were better ($P<.05$) for steers which had previously grazed nitrogen fertilized tall fescue (Treatment 11) and tall fescue-birdsfoot trefoil (Treatment 13) pastures compared with steers which had previously grazed tall fescue-red clover pastures (Treatment 12), Table 6. Three year average daily gains and feed efficiencies, respectively, for Treatment 11 were 1.58 and 6.61, for Treatment 12 were 1.45 and 7.18, and for Treatment 13 were 1.52 and 6.87. A significant year effect ($P<.05$) was measured with daily gains from 1979 (1.78 kg) being greater than for 1978 (1.39 kg) or 1977 (1.38 kg), which were not different ($P>.05$). No year x treatment interaction ($P>.05$) was measured, with the steers from Treatments 11 and 13 consistently gaining more than steers from Treatment 12.

It may be hypothesized that part of the improvment in performance for steers that previously grazed nitrogen fertilized tall fescue or tall fescue-birdsfoot trefoil pastures may be compensatory gain. This assump-

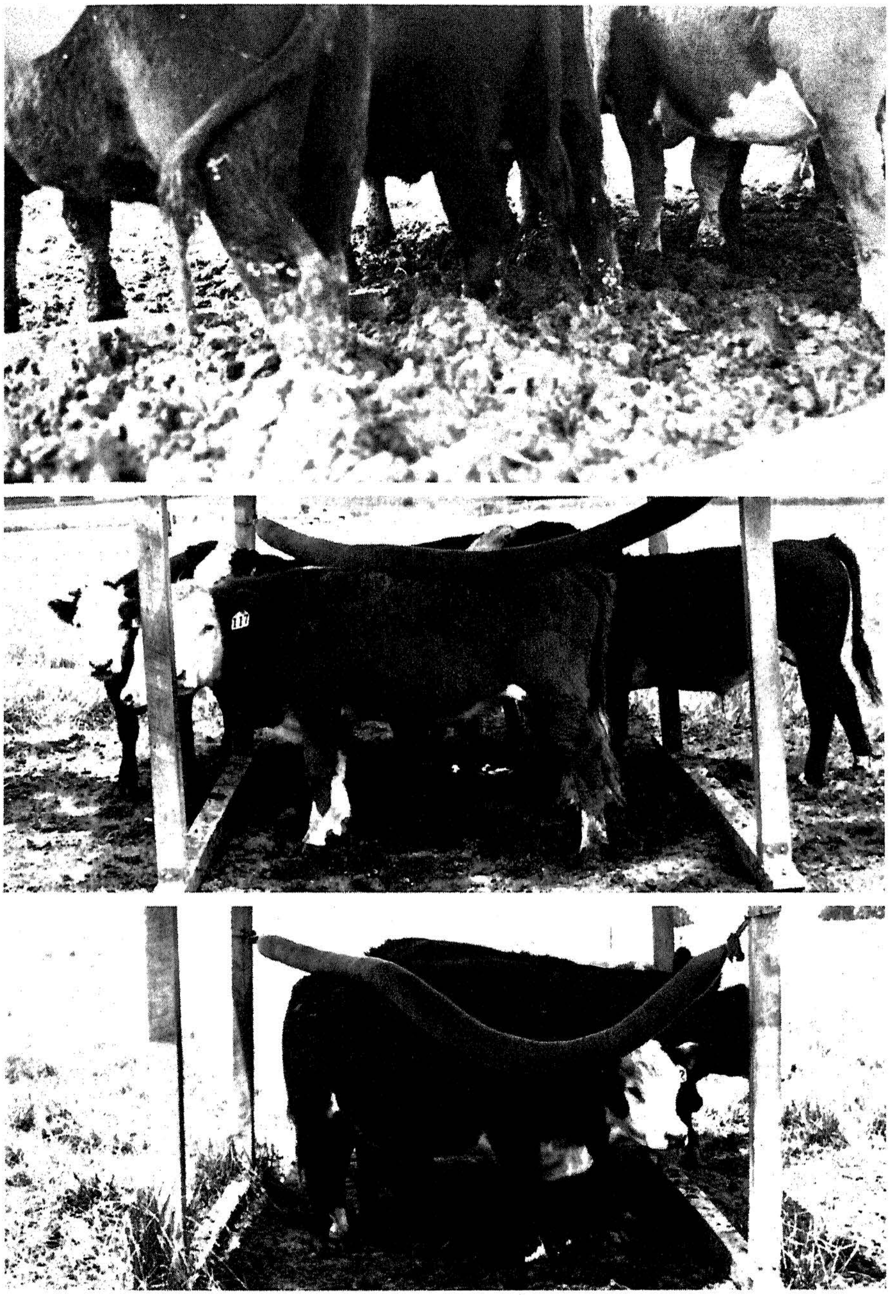

Figure 2. Example of the general appearance and "heat stress" of cattle that grazed nitrogen fertilized tall fescue (top) and general appearance and lack of "heat stress" of cattle that grazed fescue-red clover (middle) and fescue-birdsfoot-trefoil (bottom).

tion is based on similar initial weights among animals at the start of the winter backgrounding grazing phase and the lighter weight of steers entering dry lot at the end of the summer grazing period. Treatment 11 steers weighed an average of 17 kg less than steers from Treatments 12 or 13 (303 kg vs. 320 and 320 kg. respectively) when entering the feedlot. This trend was the same for all three years. The average slaughter weight for all steers was 498 kg, which required an average of 123 days of corn grain feeding. Although steers from Treatment 11 weighed less when entering the feedlot, final average slaughter weights for the three treatments were similar (P>.05) further suggesting compensatory gain. Slaughter weight for steers assigned to Treatment 11 was 494 kg, from Treatment 12 was 496 kg and from Treatment 13 was 505 kg.

Table 7 contains the total days required to reach the desired slaughter weights and the overall average daily gains. Steers assigned to System I, which were consuming corn silage alone or silage followed by corn grain, required fewer days and gained more rapidly overall than did steers from any of the other systems. Feeding rations with greater amounts of digestible energy and balanced for crude protein, steers from System I required an average of 259 days to reach slaughter weights between 381 and 486 kg compared with steers from System II, which required 403 days to reach slaughter weights between 464 and 494 kg or with steers from System IV which required 437 days to reach an average slaughter weight of 498 kg. Clanton (1978) suggested that the nitrogen content of forage during its rapid growth phase is too high in relation to its energy content. The high moisture content of irrigated pasture forage has been cited as a factor that reduces dry matter intake. However Lake *et al.* (1974) have shown that any impairment of weight gains was due more to the imbalance of the nitrogen and energy in the forage than reduced dry matter intake.

When performance of steers from Treatment 1 (System I) was compared to steers from System III, System III steers required an additional 109 days of pasture to reach similar slaughter weights. Overall gains for steers from Treatment 1 were .78 kg/day (205 days) compared with steers from System III which gained an average of .30 kg/day (314 days). These results are similar to those reported by Bowling *et al.* (1978); and Purchas and Davies (1974).

Comparing performance of steers from System II to that of steers from System IV it was observed that an endpoint slaughter weight could be achieved approximately 35 days sooner by switching animals to an increased energy intake after the nutritional value of pastures decreased to maintenance level in July rather than allowing steers to continue to graze from the months of July through October and then placing steers on a high corn diet in the feedlot. This difference has certain economic implications for the beef cattle producer. It would seem that a reduced rate of return would occur for the producer who allowed animals to have slower

TABLE 7. DAYS REQUIRED FOR EACH MANAGEMENT PHASE AND OVERALL DAILY GAIN FOR DIFFERENT TREATMENTS

		Management phase							
System	Treat-ment	Winter back-ground	Pasture	Pasture + corn	Corn silage	Corn grain	Total days	Total gain, kg	Average daily gain, kg
1	1				205		205	160	.78
	2				201	69	270	218	.81
	3				201	102	303	263	.87
2	4	151	87	154			392	241	.61
	5	151	87	154			392	251	.64
	6	151	87	175			413	269	.65
	7	151	87	175			413	274	.66
3	8	153	161				314	82	.26
	9	153	161				314	96	.31
	10	153	161				314	103	.33
4	11	153	161			123	437	272	.62
	12	153	161			123	437	271	.62
	13	153	161			123	437	286	.65

rates of gain during the summer when consuming only grass (especially poor quality grass) compared to the owner who supplemented corn or additional energy feedstuffs. The supplementation of corn during this period will allow for increased carrying capacity of pastures compared to non-supplementation (Mott *et al.*, 1968). Lake *et al.* (1974) concluded that supplements of 1.35 kg corn daily to steers receiving fresh clipped forage increased dry matter digestibility of the total diet over that of steers receiving fresh forage alone or supplemented with .45 kg corn. Steers that have been supplemented with limited amounts of corn on pasture require fewer feeding days in the feedlot (possibly due to increased body weight) than non-supplemented steers (Clanton, 1977).

There does, however, appear to be an economic opportunity based on these data for the feedlot producer who purchases steers managed similarly to System III and feeds them high energy diets and takes advantage of any compensatory gain. Rate of gain in the feedlot for steers from Treatments 11, 12 or 13 was faster when fed corn grain than for steers fed corn on pasture (Treatments 4, 5, 6 or 7) or corn only in the feedlot (Treatments 1, 2 or 3).

Table 8 contains a comparison of weight gain by phase for the 13 different treatments within the four systems. Evaluation of gains for System I revealed that steers from Treatment 1 gained 160 kg when fed corn silage (100% of gain) but steers from Treatment 2 gained 142 kg when fed corn silage which was 65% of total gain with 35% of total gain produced during the corn grain finishing phase (76 kg). Steers from Treatment 3 produced 57% of their gain (150 kg) during the corn silage phase and 43% of their gain (113 kg) when fed the corn finishing diet. With additional corn grain feeding, total days of feeding are understandably increased, but so is final live and carcass weight, quality grade and carcass dressing percentage (See section on carcass characteristics).

Steers assigned to System II (Treatments 4, 5, 6 and 7) were backgrounded for approximately 150 days on poor quality fescue and then allowed to graze spring pastures for approximately 87 days. This 237 plus days of grazing accounted for between 33 to 38% of total weight gain. However 62 to 71% of total gain was produced when corn grain was self-fed on pasture. This required 154 to 175 days of corn feeding until desired slaughter weights were achieved. Another way of stating this; approximately 87 kg of gain was produced during winter and spring grazing, while 172 kg was produced during the time when corn grain was offered in self feeders on pasture. These results are in agreement with those reported by Perry *et al.* (1971, 1972) and Peacock *et al.* (1964). Coleman *et al.* (1976) in a similar study reported that supplementation of energy and protein to grazing steers increased dressing percent, fat cover, the loin eye area and correspondingly decreased carcass yield grade.

Steers from System II reached a desired slaughter weight approxi-

TABLE 8. WEIGHT GAIN BY MANAGEMENT PHASE FOR DIFFERENT TREATMENTS

						Weight Gain by Phase of Experiment, kg				
System	Treatment	Initial wt, kg	Final wt, kg	Total gain kg	Total days	Winter background	Pasture	Pasture + Corn	Corn silage	Corn grain
1	1	221	381	160	205				160 (100)[a]	
	2	220	438	218	270				142 (65)	76 (35)
	3	223	486	263	303				150 (57)	113 (43)
2	4	223	464	241	392	51 (21)	31 (13)	159 (66)		
	5	225	476	251	392	52 (21)	43 (17)	156 (62)		
	6	219	488	269	413	46 (17)	32 (12)	190 (71)		
	7	220	494	274	413	55 (20)	36 (13)	184 (67)		
3	8	222	304	82	314	20 (24)	62 (76)			
	9	225	320	95	314	17 (18)	78 (82)			
	10	219	322	103	314	21 (21)	82 (79)			
4	11	222	494	272	437	16 (6)	62 (23)			194 (71)
	12	225	496	271	437	15 (6)	78 (29)			178 (66)
	13	219	505	286	437	17 (6)	82 (29)			187 (65)

[a]Percentage of total gain

mately 35 days sooner than did steers from System IV. The percentage of total weight gained when fed corn in the feedlot for steers from System IV was similar to that of steers from System II, which were fed corn on pasture (67% vs. 66.5%, respectively). As indicated, performance for System IV steers in the feedlot was felt to be partially compensatory in nature and that the forage quality in the late summer and early fall months probably was inadequate to sustain desired rates of animal gain.

Total days required to attain a desired slaughter weight is only one input that a producer should consider in selecting a production program. Another important input to consider is the amount and cost of supplemental feed (especially corn) per animal and efficiency of grain utilization. Table 9 presents the total amount of corn fed per steer and also efficiency of gain for the entire experimental period as well as for the period of time when corn was fed. The least amount of corn fed was for steers from Treatment 1 which consumed an estimated 605 kg and were slaughtered at 381 kg. The greatest quantity of corn fed was for steers from Treatment 3 which consumed 1370 kg and were slaughtered at 486 kg. Steers assigned to the various pasture treatments consumed intermediate amounts of corn (1201 to 1244 kg). Comparing the three systems and recognizing the differing slaughter weights and days fed corn, it was observed that steers from System I consumed an average of 1012 kg of corn, which was 232 kg less than for steers from System II, and was 189 kg less than that for steers from System IV. Corn fed/gain ratio for total days on experiment for steers from Treatment 1 was better than that of steers from Treatment 3 (3.78 vs. 5.21). The efficiency was slightly better for steers from Treatments 11, 12, and 13 compared to steers from Treatments 2, 4, 5, 6 or 7 (4.35 vs. 4.81). When the three systems were compared, steers from System IV had a better efficiency than steers from Systems I or II (4.35 vs. 4.62 and 4.81, respectively).

Further comparison of the three systems revealed that an average of 214 kg of gain was produced from System I, 223 kg was produced from System II and 202 kg was produced from System IV. When grain/gain efficiency for the period during which corn was fed was compared and not the total days on feed, steers from Treatment 12 had the poorest efficiency (6.21). Efficiency for steers from Treatment 2 was 4.87, which was 78% as efficient as that from Treatment 1. The comparison of the remaining treatments resulted in efficiencies ranging from 5.21 (Treatment 3) to 5.91 (Treatment 13). When the different systems were compared, steers from System I had an overall efficiency of 4.62 which was 21% better than System II, and 29% better than System IV.

Carcass Quality and Composition

Live animal and carcass data are presented in subsequent tables in which the 13 treatments are compared for the three years combined, and

TABLE 9. COMPARISON OF GRAIN TO GAIN EFFICIENCIES FOR THE DIFFERENT TREATMENTS

System	Treatment	Slaughter wt, kg	Total corn consumed, kg	Total gain, kg	Gain when corn fed, kg	*Total corn*[b] / Total gain	*Total corn*[c] / Gain when corn fed
1	1	381	605[a]	160	160	3.78	3.78
	2	438	1062	218	218	4.87	4.87
	3	486	1370	263	263	5.21	5.21
Ave.		435	1012	214	214	4.62	4.62
2	4	464	1148[d]	241	210	4.76	5.47
	5	476	1161[d]	251	208	4.63	5.58
	6	488	1312[d]	269	236	4.88	5.56
	7	494	1356[d]	274	239	4.95	5.67
Ave.		481	1244[d]	259	223	4.81	5.57
3	8	304	136[d]	82	-	-	-
	9	320	136[d]	95	-	-	-
	10	322	136[d]	103	-	-	-
Ave.		315	136[d]	93			
4	11	494	1199[d]	272	210	4.41	5.71
	12	496	1199[d]	271	193	4.42	6.21
	13	505	1206[d]	286	204	4.22	5.91
Ave.		498	1201[d]	276	202	4.35	5.94

[a]Assuming corn silage contains 50% corn grain on a dry basis.
[b]Efficiency for total days on experiment.
[c]Efficiency for days only when corn was fed.
[d]Includes corn fed during winter backgrounding

TABLE 10. LEAST SQUARES MEANS FOR LIVE WEIGHT, CARCASS WEIGHT AND DRESSING PERCENTAGE OF STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treatment number	Live weight, kg	Carcass weight kg	Dressing %
	1	381.6^{f}	208.7^{d}	54.7^{f}
	2	440.4^{e}	268.6^{c}	61.0^{ab}
	3	488.3^{bc}	301.7^{a}	61.8^{a}
I		435.9^{Y}	259.0^{Y}	59.1^{Y}
	4	464.4^{d}	271.4^{bc}	58.5^{e}
	5	476.9^{cd}	279.6^{b}	58.6^{e}
	6	488.4^{bc}	293.6^{a}	60.1^{bc}
	7	495.0^{ab}	298.0^{a}	60.2^{bc}
II		480.4^{X}	285.0^{X}	59.3^{Y}
	8	296.3^{h}	156.6^{f}	52.8^{g}
	9	315.3^{g}	167.8^{e}	53.2^{g}
	10	320.9^{g}	168.1^{e}	52.4^{g}
III		310.8^{Z}	164.2^{Z}	52.8^{Z}
	11	495.5^{ab}	293.0^{a}	59.1^{de}
	12	497.2^{ab}	296.5^{a}	59.6^{cd}
	13	506.3^{a}	300.8^{a}	59.4^{cde}
IV		499.7^{W}	296.8^{W}	59.4^{Y}

[a,b,c,d,e,f,g,h]Means within the same column for nutritional treatment bearing different superscripts are different ($P<.05$).

[W,X,Y,Z]Means within the same column for management system bearing different superscripts are different ($P<.05$).

on the basis of the four production systems. Due to the large number of comparisons the following discussion will emphasize the main differences or similarities among treatments and production systems and conclusions to be made from the data.

The live weights of the animals at time of slaughter followed a predictable pattern (table 10). The silage-fed and short grain-fed animals (Treatments 1 and 2) and the grass-fed animals (Treatments 8, 9, and 10) had the lowest slaughter weights. With the exception of these treatments all other feeding treatments produced animals with an average slaughter weight over 454 kilograms.

Animals on fescue (Treatment 8) in all years had lower live weights at slaughter than animals grazed on fescue overseeded with red clover or birdsfoot trefoil (Treatments 9 and 10). Overseeding with red clover or birdsfoot trefoil resulted in increased gains during the grazing phase and the weight gain advantage tended to extend through the feedlot feeding phase (Treatments 12 and 13 compared to 11). The improved live weight gains of steers on fescue-legume pastures compared to straight fescue can be attributed to the improved nutritional quality of the legume-containing pastures.

In the first two years animals from production Systems I and III were lighter (P<.05) in weight than the animals from Systems II and IV while live weights of animals from Systems II and IV did not differ (P>.05). In the third year only System I and II animals were statistically the same. In the combined average of all three years live weights at slaughter for all systems were different (P<.05).

Carcass weight data are presented in Table 10. The treatments that produced the heaviest live weights also produced the heaviest carcass weights. All treatments, with the exception of 1, 8, 9 and 10 produced carcasses of acceptable weight for the current retail trade. Carcass weights for the four production systems (table 10) followed a similar pattern as did live weights.

Dressing percentages were highly dependent on feeding regimen (table 10). The lighter weight and forage-fed animals of Treatments 1, 8, 9 and 10 had lower dressing percentages compared to all other treatments which were grain-fed. Treatments 4 and 5 (short grain-fed on pasture) were generally intermediate while the other longer grain-fed treatments (2, 3, 6, 7, 11, 12 and 13) had higher dressing percentages.

Dressing percentages for the four production systems are presented in table 10. While there were statistical differences within each year, in the combined three-year average only System III animals had significantly lower dressing percentages.

The energy levels of the feeding treatments and length of time on *ad libitum* grain feed influenced marbling scores (table 11). Animals from treatments with the highest plane of nutrition produced carcasses with the highest marbling scores. Only Treatments 8, 9 and 10 produced carcasses with drastically lower marbling scores. Comparison of Treatments 1, 2 and 3 shows that silage-fed animals (1) had less marbling than animals grain-fed following the silage feeding phase and that animals fed grain for a longer period of time (3) had more marbling than animals fed grain for a shorter period of time (2). Although the differences were not significant, Treatments 4 and 6 (grain-fed on fescue pasture) had approximately 1⁄3 degree less marbling than Treatments 5 and 7 (grain-fed on fescue-red clover pasture). When the three grass-fed treatments (8, 9, 10) are compared, Treatment 8 had the lowest marbling score. However, this slight advantage in marbling did not exist when comparable grass-fed treatments were subsequently finished in dry lot (Treatment 11 compared to Treatments 12 and 13). Carcasses from production System III had lower (P<.05) marbling scores than carcasses from the other production systems (table 11).

USDA quality grade is closely associated with marbling score. Data

TABLE 11. LEAST SQUARES MEANS FOR CARCASS QUALITY AND YIELD GRADES OF STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treat. No.	Marbling score[h]	USDA quality grade[i]	Fat thickness 12th rib c,	Longissimus muscle area 12th rib cm^2	Kidney, pelvic, & heart fat,%	USDA Yield grade
	1	10.8^{e}	7.6^{e}	0.56^{f}	59.2^{e}	1.8^{d}	2.2^{e}
	2	13.8^{bc}	9.8^{bc}	1.14^{de}	69.6^{abcd}	2.4^{c}	2.8^{d}
	3	15.6^{a}	10.5^{a}	1.42^{ab}	72.4^{a}	3.0^{a}	3.4^{b}
I		13.5^{Y}	9.3^{Y}	1.04^{Y}	66.8^{Y}	2.4^{Y}	2.8^{Y}
	4	12.6^{d}	9.2^{d}	1.24^{cde}	66.8^{d}	2.7^{b}	3.2^{bc}
	5	13.2^{cd}	9.4^{cd}	1.24^{cde}	67.0^{d}	2.5^{bc}	3.2^{bc}
	6	13.8^{bc}	9.9^{abc}	1.45^{ab}	67.4^{cd}	3.0^{a}	3.6^{a}
	7	14.8^{ab}	10.2^{ab}	1.50^{a}	68.7^{bcd}	3.0^{a}	3.6^{a}
II		13.6^{Y}	9.7^{X}	1.35^{X}	67.4^{Y}	2.8^{X}	3.4^{W}
	8	5.9^{g}	4.6^{g}	0.18^{g}	48.1^{g}	0.8^{e}	1.8^{f}
	9	7.1^{f}	5.3^{f}	0.20^{g}	52.1^{f}	0.9^{e}	1.7^{f}
	10	6.5^{fg}	5.2^{fg}	0.23^{g}	51.2^{f}	1.0^{e}	1.8^{f}
III		6.5^{Z}	5.0^{Z}	0.20^{Z}	50.5^{Z}	0.9^{Z}	1.8^{Z}
	11	13.9^{bc}	9.9^{abc}	1.09^{e}	70.5^{abc}	2.3^{c}	3.0^{c}
	12	13.3^{cd}	9.7^{bcd}	1.29^{bcd}	69.8^{abcd}	2.4^{c}	3.3^{b}
	13	13.2^{cd}	9.5^{cd}	1.32^{bc}	71.0^{ab}	2.4^{c}	3.3^{b}
IV		13.5^{Y}	9.7^{X}	1.24^{X}	70.4^{X}	2.4^{Y}	3.2^{X}

[a,b,c,d,e,f,g]Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).

[W,X,Y,Z]Means within the same column for management system bearing different superscripts are different (P<.05).

[h]Score of 6 = practically devoid+; 7 = traces−; 8 = traces; 9 = traces+; 10 = slight−; 11 = slight; 12 = slight+; 13 = small−; 14 = small and 15 = small+.

[i]Score of 4 = Standard−; 5 = Standard; 6 = Standard+; 7 = Good−; 8 = Good; 9 = Good+; and 10 = Choice−.

presented in Table 11 show that with the exception of carcasses from animals on Treatments 1, 8, 9 and 10, all treatments produced USDA high Good to low Choice carcasses. Treatment 1 carcasses were graded as USDA low Good while carcasses from Treatments 8, 9 and 10 were graded as USDA low to average Standard. Obviously, Treatments 8, 9 and 10 did not provide the energy necessary to fatten animals sufficiently to grade above the Standard grade. Treatment 1 animals were chronologically of younger age than all other animals. Carcasses from animals on production Systems 1, 2 and 4 produced USDA high Good to low Choice carcasses while carcasses from Production System III graded average Standard (table 11).

The primary reason System I carcasses graded lower ($P<.05$) than carcasses from animals on Systems II and IV was the lower quality grade of carcasses from Treatment 1.

Carcasses from animals on the high energy grain diets had greater external fat covering than carcasses from animals on the lower energy level diets (table 11). In Treatments 1 through 10 the external fat thickness was directly related to the energy level of the diet and the period of time on *ad libitum* grain feed. Although not always significantly different, Treatment 11 carcasses (fescue pasture during grazing phase) consistently had less fat thickness than carcasses from Treatments 12 and 13 (fescue-legume pasture during the grazing phase). Correspondingly, Treatment 8 carcasses had less fat thickness than carcasses from Treatments 9 and 10. The thinner fat cover of Treatment 8 carcasses indicates these animals were on a lower nutritional plane than animals on Treatments 9 or 10. Further, when animals on straight fescue were placed on grain *ad libitum* (Treatment 11) these animals had less fat cover at slaughter than animals on fescue-red clover and fescue-trefoil followed by grain feeding (Treatments 12 and 13, respectively).

Ribeye areas for carcasses of the 13 treatments are presented in Table 11. Carcasses from Treatments 8, 9 and 10 had smaller ribeyes than carcasses from all other treatments ($P<.05$). Since Treatments 8, 9 and 10 were similar except for legumes in Treatments 9 and 10, it is interesting to note that carcasses from animals on Treatment 8 (straight fescue) in the three-year average had smaller ribeyes than carcasses from animals on Treatments 9 (fescue-red clover) and 10 (fescue-trefoil). However, when animals on these treatments during the grazing phase were subsequently placed in dry lot and fed *ad libitum,* animals on Treatment 11 (fescue during the grazing phase) had comparable size ribeyes at slaughter as did animals on Treatments 12 and 13 (fescue-red clover and fescue-trefoil during the grazing phase, respectively). These observations indicate compensatory growth was greater during the finishing phase for animals on Treatment 11 compared to animals on Treatments 12 and 13. Average ribeye areas of Treatments 4, 5, 6 and 7 for the three years combined were similar. The longer period of time on *ad libitum* grain and heavier carcass weight (table 10) for Treatments 5 and 7 compared to Treatments 4 and 6 did not increase ribeye area but did increase fat thickness (table 11).

Carcasses from Treatments 6 and 7 (combined years) had the larger yield grade number (lowest cutability) and those from Treatments 8, 9 and 10 had the lowest yield grade number (highest cutability) (table 11). The ranking in yield grade number for combined years was as follows: Treatments 6 and 7 > 3, 12, and 13 > 4, 5 and 11 > 2 > 1 > 8, 9 and 10. The main factor contributing to differences in yield grade was differences in the amount of fat in subcutaneous and kidney, pelvic and heart deposits.

Yield grade number was higher ($P<.05$) for carcasses from System II

TABLE 12. LEAST SQUARES MEANS FOR YIELD OF RETAIL CUTS AND FAT OF BEEF CARCASSES AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treatment number	Primal retail cuts %[h] carcass	Total retail cuts % carcass	Carcass fat %[i]	Total retail cuts % Live wt.
	1	58.7^{b}	72.6^{b}	26.7^{e}	39.69^{bcd}
	2	55.1^{c}	68.5^{c}	28.1^{e}	41.77^{a}
	3	53.3^{fg}	66.8^{e}	30.6^{d}	41.27^{a}
I		55.7^{Y}	69.3^{X}	28.6^{X}	40.91^{Z}
	4	54.3^{de}	67.4^{de}	34.5^{b}	39.44^{cde}
	5	54.1^{de}	67.4^{de}	34.4^{b}	39.50^{bcd}
	6	53.0^{g}	65.7^{f}	35.6^{ab}	39.49^{bcd}
	7	53.8^{g}	65.6^{f}	36.3^{a}	39.51^{bcd}
II		53.6^{Y}	66.6^{Z}	35.2^{Z}	39.48^{Y}
	8	59.7^{a}	74.3^{a}	20.1^{f}	39.23^{de}
	9	59.7^{a}	74.2^{a}	21.5^{f}	39.46^{cde}
	10	59.5^{a}	73.9^{a}	20.2^{f}	38.71^{e}
III		59.6^{Z}	74.1^{W}	20.4^{W}	39.13^{Y}
	11	54.7^{cd}	68.2^{cd}	32.6^{c}	40.29^{b}
	12	53.9^{ef}	67.2^{e}	32.5^{c}	40.06^{bc}
	13	53.8^{ef}	67.1^{e}	32.7^{c}	39.87^{bcd}
IV		54.1^{Y}	67.5^{Y}	32.6^{Y}	40.07^{Z}

[a,b,c,d,e,f,g]Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).

[W,X,Y,Z]Means within the same column for management system bearing different superscripts are different (P<.05).

[h]Retail cuts from the round, loin, rib and chuck.

[i]Carcass fat determined by specific gravity.

(table 11). This system contained the higher yield grade number carcasses from Treatments 6 and 7. System III carcasses had yield grades which were significantly lower in number than all other systems.

Treatments 1, 8, 9, and 10 produced the highest cutability carcasses (table 12). The higher retail yields of carcasses from these treatments is attributed to less fat deposition in carcasses from these nutritional treatments. The ranking of treatments on the basis of yield of retail cuts from the round, loin, rib and chuck was as follows: 8, 9 and 10 > 1 > 2, 11 > 4, 5, 12, 13 > 3, 6, 7. Total yield of retail cuts expressed as a percentage of live weight instead of carcass weight revealed that carcasses from the grass-fed treatments (Treatments 8, 9 and 10) generally had a lower yield of total retail cuts than carcasses from the other feeding treatments.

Carcasses from Treatments 2 and 3 had the highest yield of retail cuts on a live weight basis compared to all other treatments. The slightly lower yield from System III animals (Treatments 8, 9 and 10) was due to lower dressing percentages of these animals compared to animals of the other systems. Even though System II animals had high dressing percentages (table 10) their greater amounts of kidney, heart, and pelvic fat and external fat caused them to have a lower retail yield when expressed as a percentage of carcass weight or live weight than the other three systems.

The calculated percent fat from the specific gravity values (table 12) support the yield grade data. Nutritional treatments which had the highest cutability carcasses also had the lowest percentage of fat.

Treatments 8, 9 and 10 produced the highest cutability carcasses. However, their low USDA quality grade and small muscle size would make these carcasses undesirable for production of steaks and roasts. All other treatments produced carcasses which could be easily utilized for fabrication into steaks and roasts. The low dressing percentage for Treatments 8, 9 and 10 would increase the per animal slaughtering and processing costs as compared to carcasses from treatments with higher dressing percentages. The same would also be true for Treatment 1, although not to the extent as carcasses from the grass-fed treatments.

The results presented here are in general agreement with previous research. Meyer *et al.* (1960), Bayne *et al.* (1969), Dubé *et al.* (1971), McCampbell *et al.* (1972), Oltjen *et al.* (1972), Purchas and Davies (1974), Shinn *et al.* (1976), Bowling *et al.* (1978), Harrison *et al.* (1978), Skelly *et al.* (1978) and Schroeder *et al.* (1980) have all shown that cattle on a high energy nutritional regimen will have carcasses of higher USDA quality grade and of lower cutability than carcasses from animals on a lower energy nutritional regimen. Animals on low energy nutritional regimens generally have lower dressing percentages, lower carcass weights and smaller ribeye areas than animals on high energy nutritional regimens. The extent to which each carcass trait is affected has varied among the studies reviewed because of differences in animal background, feeding regimen, length of time on feed and animal age.

Color Evaluation

Loin steaks removed from each carcass were used to objectively measure the effects of animal feeding regimen on color stability during retail display. Hunter Color Difference Meter "L" values (average of three years) for the *longissimus* muscle of loin steaks measured at the beginning of retail display are presented in Table 13. Steaks from animals on Treatment 1 had the highest "L" values. Treatment 1 animals were chronologically youngest at time of slaughter. The muscle of animals from this treatment would be expected to have light red color and this is substantiated by the high "L" values. Also, loin steaks from animals on

TABLE 13. LEAST SQUARES MEANS FOR HUNTER COLOR DIFFERENCE METER VALUES FROM LOIN STEAKS OF STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treatment number	Hunter color difference meter values		
		"L	"a"	"b"
	1	30.9[a]	13.8[f]	7.6[e]
	2	29.4[b]	17.5[c]	10.3[a]
	3	29.2[bc]	17.6[c]	9.5[b]
I		29.7[X]	16.5[Y]	9.3[Y]
	4	28.4[cd]	18.0[bc]	10.0[ab]
	5	29.6[b]	15.8[d]	9.8[ab]
	6	28.8[bcd]	19.0[ab]	10.3[a]
	7	28.3[d]	19.2[a]	10.0[a]
II		28.8[Y]	17.9[X]	10.0[X]
	8	25.3[f]	14.3[ef]	7.9[de]
	9	26.4[ef]	14.8[def]	8.6[c]
	10	26.9[e]	15.1[de]	8.4[cd]
III		26.3[Z]	14.7[Z]	8.3[Z]
	11	28.8[bcd]	17.6[c]	10.1[a]
	12	28.4[cd]	17.7[c]	10.1[a]
	13	28.2[d]	17.9[bc]	9.8[ab]
IV		28.5[Y]	17.8[X]	10.0[X]

[a,b,c,d,e,f]Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).

[X,Y,Z]Means within the same column for management system bearing different superscripts are different (P<.05).

Treatments 2 and 3, the next youngest, had high "L" values. The "L" values from Treatments 1, 2, and 3 when combined (Production System I) were higher than that of the other three production systems, further confirming that the loin muscles of carcasses from System I were lighter red in color.

Steaks from the grass-fed animals (Treatments 8, 9 and 10, System III) had the lowest "L" values. These low values were not due to the animals' age since they were intermediate in age among the treatments. The color of steaks from the other animal treatments (Systems II and IV) had similar "L" values and were intermediate and significantly different from values for Systems I and III.

The "a" values for loin steaks are presented in Table 13. Steaks from Treatment 1 animals, which had the lightest colored meat, also had the lowest amount of redness. The other silage treatments (Treatments 2 and 3), which had high "L" values, had intermediate "a" values indicating that there was a higher level of redness to their color. The dark color (low "L" values) of steaks from the grass-fed treatments was apparently not due to high amounts of red pigmentation. Steaks from animals fed grain had higher "a" values than steaks from animals which did not receive grain. Steaks from Systems II and IV animals had significantly higher "a" values than steaks from Systems I or III and System I was significantly higher than System III.

The "b" values, which measure yellowness, were lowest for steaks from Treatment 1, the youngest at time of slaughter, and Treatments 8, 9 and 10 (grass-fed). The addition of grain to the animals' diet resulted in increased "b" values (table 13).

The "a" and "b" values approach zero as the color becomes more grey. The "a" values for steaks from Treaments 1, 8, 9 and 10 are slightly higher than one-half the standard "a" value (22.7). This would indicate that these steaks were about an equal mixture of red and grey. The "b" values for steaks from these treatments were somewhat closer to the standard "b" value (9.8). However, these steaks still had a higher proportion of grey than did steaks from other treatments.

The higher marbling scores (table 11) of the steaks from animals fed grain could also affect the "L", "a", and "b" values. A dark colored muscle with a high degree of marbling could appear as lighter or redder in color.

Craig *et al.* (1959) compared color values of steaks from animals on differing feeding treatments. Steaks from the grass-fed animals had the lowest "a" and "b" values at all sampling times. They attributed the differences in color to differences in the fat and moisture content and not to differences in pigment content. Schroeder *et al.* (1980) and Kropf *et al.* (1975) reported that visual color scores were lowest for steaks from grass-fed animals.

Wheeling *et al.* (1975), Allen *et al.* (1976) and Schroeder *et al.* (1980) reported that steaks from forage-fed animals were darker in color at the beginning of retail display and had more discoloration during display than steaks from animals on high energy diets. However, Craig *et al.* (1959) reported that nutritional regimen had little effect on the discoloration of steaks during display. But they did note that steaks which were most desirable initially were also the most desirable at the end of the display period.

Sensory Panel and Warner-Bratzler Shear Evaluation

Loin steaks and top round roasts were evaluated by a six-member sensory panel for juiciness, flavor, tenderness, and overall acceptability. Warner-Bratzler shear values were recorded from loin steaks and round roasts as an objective measure of tenderness. Cooking losses were recorded for all steaks and roasts.

Loin Steaks. Steaks from all treatments were rated as being at least slightly desirable in juiciness (table 14). Juiciness scores varied among

TABLE 14. LEAST SQUARES MEANS FOR SENSORY PANEL SCORES AND WARNER—BRATZLER SHEAR VALUES OF LOIN STEAKS FROM STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treat. No.	Sensory panel scores[f]				Warner-Bratzler shear kg/1.3 cm
		Juiciness	Flavor	Tenderness	Overall accept-ability	
	1	6.0[ab]	6.5[abc]	6.3[a]	6.4[ab]	3.6[d]
	2	6.3[a]	6.5[ab]	6.5[a]	6.5[a]	3.6[d]
	3	6.1[ab]	6.3[abcd]	6.2[abc]	6.3[abcd]	3.6[d]
I		6.1[Z]	6.4[Z]	6.3[Z]	6.4[Z]	3.6[Z]
	4	6.0[abc]	6.1[d]	5.8[bc]	6.0[cd]	3.9[cd]
	5	5.9[bcd]	6.2[cd]	5.9[bc]	6.0[d]	4.0[cd]
	6	6.0[ab]	6.2[bcd]	5.8[c]	6.1[cd]	4.2[c]
	7	6.0[ab]	6.4[abcd]	5.7[c]	6.1[bcd]	4.1[cd]
II		6.0[Z]	6.2[Y]	5.8[Y]	6.0[Y]	4.0[Y]
	8	5.5[d]	5.1[e]	4.5[e]	5.0[e]	6.4[a]
	9	5.5[d]	5.1[e]	5.1[d]	5.1[e]	5.4[b]
	10	5.6[cd]	5.0[e]	5.1[d]	5.1[e]	5.5[b]
III		5.5[Y]	5.1[X]	4.9[X]	5.1[X]	5.7[X]
	11	6.1[ab]	6.5[ab]	6.2[ab]	6.4[abc]	3.8[cd]
	12	5.9[bcd]	6.4[abcd]	6.1[abc]	6.2[abcd]	3.7[cd]
	13	6.2[ab]	6.6[a]	6.2[ab]	6.4[ab]	3.9[cd]
IV		6.2[Z]	6.5[Z]	6.2[z]	6.3[Z]	3.8[YZ]

[a,b,c,d,e]Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).
[X,Y,Z]Means within the same column for management system bearing different superscripts are different (P<.05).
[f]Range of scores: 1 = extremely undesirable to 8 = extremely desirable.

years for some treatments. Steaks from Treatments 11, 12 and 13 were generally scored the highest for juiciness in year one while steaks from the grass-fed treatments of 8, 9 and 10 were scored the lowest. However, in year two steaks from Treatments 8, 9, 10, 11, 12 and 13 were similar in juiciness. In year three, Treatment 12 steaks were significantly lower in juiciness than steaks from Treatments 11 and 13 but were not different from Treatments 8, 9 and 10. Steaks from Treatments 4, 5, 6 and 7 were similar in juiciness.

Steaks from the silage-fed treatment, Treatment 1, were consistently rated high for juiciness scores. In year one steaks from all three silage treatments were statistically the same while in years two and three, Treatment 2 steaks were rated as being significantly higher than

Treatment 1 steaks. However, in the combined three-year average no significant (P>.05) difference was observed among the three treatments. Steaks from Treatment 1 were rated equal to or higher than treatments which had higher marbling scores and higher USDA quality grade.

Steaks from Systems I, II and IV were not significantly different in juiciness (table 14). In the combined average, System III steaks were significantly lower than the other three systems.

Within each year and in the combined average, steaks from Treatments 8, 9 and 10 had the lowest flavor scores (table 14). However, only in year three were steaks from these treatments rated as being unacceptable.

In the first year the ranking of the treatments for flavor was very similar to the juiciness ranking, suggesting that flavor was possibly related to juiciness. However, in the second year steaks from Treatments 2 and 13, which had low juiciness scores, were scored comparatively high for flavor.

Comparison of flavor of steaks on the basis of production systems (table 14) indicates that steaks from Systems I and IV were not significantly different for flavor and were ranked higher (P<.05) than steaks from Systems II and III. In System I, flavor of steaks from all treatments was similar. Silage feeding alone had no detrimental effect on flavor as compared to silage feeding followed by a corn diet. This similarity in flavor occurred even though carcasses from Treatment 1 had a significantly lower USDA quality grade and marbling score than Treatment 2 and 3 carcasses.

Steaks from System II were scored higher (P<.05) for flavor than steaks from Production System III but lower than those from Systems I and IV. Carcasses from System II had the same marbling score and a greater amount of external fat cover than carcasses from Systems I and IV. Since animals on Production System II were fed grain while still grazing on pasture, it appears that these animals still retained some of the flavor that is typical of animals fed on grass. Further studies were made of volatile compounds in the fat of the grass-fed and grain-fed on grass animals and these results will be presented later in this report.

Steaks from Treatment 8 were given the lowest tenderness scores in each of the three years and in the combined three-year average (table 14). This was the only animal treatment which produced steaks rated as being slightly tough. Steaks from Production Systems I and IV were rated higher (P<.05) for tenderness than steaks from either System II or III (table 14). Steaks from System III were rated lower (P<.05) than steaks from all other systems.

As expected, steaks from Treatments 8, 9 and 10 (System III) were given the lowest (P<.05) scores for acceptability. Also, steaks from Treatments 4, 5, 6 and 7 (System II) were given the next lowest (P<.05) scores. Steaks from Treatments 1, 2 and 3 (System I) and 11, 12 and 13

(System IV) were scored similar for acceptability.

Warner-Bratzler shear values (table 14) generally supported the tenderness ratings of the sensory panel. Steaks from Treatments 8, 9 and 10 (Production System III) generally had higher shear values than steaks from the other treatments. Steaks from the other treatments and systems in general had similar shear values. Sensory panelists were able to detect differences in tenderness. Even though shear values for steaks from System II were higher than for those of System IV, there was no significant difference (P>.05). System I had the lowest shear values but not significantly different from System IV.

Top Round Roasts. The variation in sensory panel juiciness scores for top round roasts between treatments was less than that of loin steaks. Sensory panel juiciness scores were not necessarily related to animal treatment, marbling score, or USDA quality grade (table 15). No discernible pattern was detected in the panel scores for juiciness of top round roasts for any of the treatments. There were very few significant differences in juiciness of round roasts between nutritional treatments and production systems.

Roasts from the grass-fed treatments (8, 9 and 10) were scored the lowest for flavor (similar to loin steaks) compared to all other treatments. These treatments were significantly lower (P<.05) than all other treatments, except for year one when Treatment 13 was not different from Treatments 9 and 10. In years two and three and in the combined average there were no significant differences in flavor among nutritional treatments except for the grass-fed treatments. Comparisons of flavor scores on the basis of production system indicates the flavor of top round roasts from Production System III was less desirable (P<.05) than that of roasts from the other three production systems (table 15).

While roasts from all treatments were given flavor scores of slightly acceptable or higher, it is readily apparent that the sensory panelists discriminated against roasts from the grass-fed treatments. The addition of grain to the diet, even while the animals were grazing on pasture significantly improved the flavor of top round roasts.

When sensory panel tenderness scores for top round roasts were compared on the basis of individual nutritional treatments within year or combined three-year average no consistent significant differences were observed among treatments (table 15). However, when the data were analayzed on the basis of production system, roasts from System III were scored less (P<.05) tender than those from the other three systems (table 15). In the combined average, roasts from all nutritional treatments and production systems were rated as slightly tender to tender.

Roasts from Treatments 8, 9 and 10 were given the lowest acceptability scores (table 15). Roasts from all other treatments in all three years and in the combined average were scored similar for acceptability. Roasts from

TABLE 15. LEAST SQUARES MEANS FOR SENSORY PANEL SCORES AND WARNER—BRATZLER SHEAR VALUES OF TOP ROUND ROASTS FROM STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

		Sensory panel scores^{e}				
System (See table 1)	Treat. No.	Juiciness	Flavor	Tenderness	Overall accept-ability	Warner-Bratzler shear kg/1.3 cm
	1	5.6^{ab}	6.3^{a}	5.8^{ab}	6.0^{a}	4.5^{abcd}
	2	5.4^{b}	6.3^{a}	5.9^{a}	6.1^{a}	4.5^{abcd}
	3	5.5^{ab}	6.3^{a}	5.9^{ab}	6.1^{a}	4.5^{abcd}
I		5.5^{Z}	6.3^{Z}	5.9^{Z}	6.1^{Z}	4.5^{Z}
	4	5.6^{ab}	6.3^{a}	5.8^{abc}	6.0^{a}	4.6^{ab}
	5	5.5^{ab}	6.2^{a}	5.5^{bcd}	5.9^{a}	4.7^{ab}
	6	5.6^{ab}	6.3^{a}	5.8^{abc}	6.0^{a}	4.5^{abcd}
	7	5.5^{ab}	6.2^{a}	5.9^{ab}	5.9^{a}	4.6^{abcd}
II		5.6^{Z}	6.2^{Z}	5.7^{Z}	6.0^{Z}	4.6^{Z}
	8	5.3^{b}	5.3^{b}	5.1^{d}	5.2^{b}	4.8^{a}
	9	5.5^{ab}	5.3^{bc}	5.4^{cd}	5.2^{b}	4.5^{abcd}
	10	5.2^{b}	5.0^{c}	5.4^{cd}	5.0^{b}	4.6^{abc}
III		5.3^{Y}	5.2^{Y}	5.3^{Y}	5.2^{Y}	4.6^{Z}
	11	5.4^{b}	6.2^{a}	6.0^{a}	6.0^{a}	4.1^{d}
	12	5.9^{a}	6.3^{a}	5.9^{ab}	6.2^{a}	4.4^{bcd}
	13	5.4^{b}	6.0^{a}	5.8^{abc}	5.9^{a}	4.2^{cd}
IV		5.6^{Z}	6.2^{Z}	5.9^{Z}	6.0^{Z}	4.3^{Y}

^{a,b,c,d}Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).

^{Y,Z}Means within the same column for management system bearing different superscripts are different (P<.05).

^{e}Range of scores: 1 = extremely undesirable to 8 = extremely desirable.

animals on System III were scored slightly acceptable but lower (P<.05) than those of the other three production systems (table 15).

Warner-Bratzler shear data from the roasts are presented in Table 15. The shear values indicate less difference in tenderness due to nutritional treatment than indicated by the sensory panelists, especially Treatments 8, 9 and 10. Also, there were no significant differences in shear values between Systems I, II and III. Roasts from System IV were more tender (P<.05) than those from the other three systems. The sensory panelists scored roasts from Systems I, II and IV more tender than those from System III.

Other workers (Gutowski *et al.*, 1979; Smith *et al.*, 1979) have reported similar results from the effect of animal feeding regimen on sensory attributes. These workers evaluated four feeding regimens (grass-, short-, long- and forage-fed). They reported no significant differences between grass- and short-fed animals for tenderness, juiciness, and flavor even though the grass-fed treatment was given lower scores. The grass-fed animals were scored significantly lower than the long-fed animals for tenderness and flavor. The long-fed treatment was rated significantly higher than all other treatments for tenderness, but was not significantly different from the forage-fed treatment for juiciness and flavor. This would be similar to a comparison between Systems I and IV in the present study which were not significantly different for any of the sensory panel parameters.

Wheeling *et al.* (1975) compared carcasses from forage-fed steers containing traces to slight marbling and another grain-fed group containing modest to moderate marbling. They found no differences among nutritional treatments in Warner-Bratzler shear value or sensory panel evaluation of flavor, tenderness or juiciness. Johnston *et al.* (1976) fed cattle to a low Choice slaughter end point on high energy and forage rations. Meat from the forage-fed cattle was rated by a sensory panel equal to or superior to that from the grain-fed cattle. Conversely, Bowling *et al.* (1976) reported that meat from grain-fed cattle was significantly more desirable in flavor and tenderness than that from forage-fed cattle of the same quality grade.

Shinn *et al.* (1976) and Leander *et al.* (1978) grazed cattle on fescue for 180 days then fed one group on a high energy ration for 56 days and another group for 112 days. They found that grain feeding increased flavor and tenderness scores and decreased Warner-Bratzler Shear values. There were no sensory differences between the short- and long-fed group and no differences between any of the groups for juiciness. There were large differences in slaughter weight, and quality grade increased from Standard to Good to high Good for grass-fed, 56-day and 112-day grain fed animals, respectively. Bidner (1975) reported that if feeding for a constant time or to a constant age resulted in large differences in final weight or quality grade, there would be detectable differences in palatability. Bidner (1975) also reported, as opposed to Bowling *et al.* (1976), that feeding to comparable weights and quality grades would cause little differences in palatability regardless of the type of diet.

Many of the differences detected by the sensory panelists can be explained through knowledge of the animals's age and carcass characteristics. The higher tenderness ratings for Treatments 1 and 2 in the present study are more a reflectance of the animal's age than of feeding regimen. These animals were slaughtered at a younger age than those on the other treatments.

A comparison of Systems III and IV (tables 14 and 15) reflects differences in feeding regimen. System IV animals were significantly more tender than System III animals. There were little age differences between these treatments so it would appear that high energy diets increased tenderness. Animals on a high energy diet had a greater external fat cover (table 11) than animals of similar age on a grass diet. Meyer *et al.* (1977) reported that lean carcasses are more susceptible to cold shortening effects. So the tenderness differences between these systems could be due in part to the amount of external fat cover and its effects on chill rate.

Still, other differences cannot be accounted for by the animal's age or carcass characteristics. System II animals had significantly less tender loin steaks than animals on Systems I and IV (table 14). System II animals were slaughtered at a younger age than System IV and had a greater external fat cover than System I cattle. System II animals were fed while still grazing on pasture while Systems I and IV were confined to dry lot. Whether the increased physical activity of the grazing animals had any effect on tenderness is not known.

Moody (1976) reported that juiciness scores and marbling levels are positively correlated. As previously noted in the present study, juiciness had little relationship to marbling. Moody (1976) also reported that higher marbling levels are associated with more desirable flavor. Again, in the present study this was not generally true. Feeding animals a grass diet appeared to have a greater effect on flavor than the marbling level. System III animals, which were given the lowest flavor scores also had the lowest marbling scores. However, System II animals which did not differ in marbling from Systems I and IV were given significantly lower flavor scores for the loin steaks (table 14).

Cooking Losses

Total cooking losses from the loin steaks are presented in Table 16. The lowest cooking losses were generally observed for steaks from Treatments 8, 9 and 10 (System III), and the silage-fed treatments (1, 2 and 3) of System I. Higher cooking losses were also observed for steaks from the animals fed in dry lot (System IV) compared to steaks from animals fed grain on grass (System II). Kropf *et al.* (1975) reported that steaks from grass-fed cattle had higher cooking losses than steaks from short- and long-fed grain finished cattle. Wheeling *et al.* (1975) noted that steaks from forage-fed cattle had lower cooking losses than steaks from grain-finished cattle even when there was no difference in quality grade. Gutowski *et al.* (1979) and Smith *et al.* (1979) reported less cooking losses for loin steaks from grass-fed animals compared to long-fed animals.

No consistent differences were observed for cooking losses of roasts which could be associated with nutritional treatment of the animals (table 16). The least cooking losses were observed for roasts from System I. No significant differences were observed in cooking losses for roasts from animals on Production Systems II, III and IV.

TABLE 16. LEAST SQUARES MEANS FOR PERCENT COOKING LOSS OF LOIN STEAKS AND TOP ROUND ROASTS FROM STEERS AS INFLUENCED BY NUTRITIONAL TREATMENT

System (See table 1)	Treatment number	Cooking loss, %	
		Loin steaks	Round roasts
	1	21.10^{de}	32.02^{bc}
	2	22.48^{cd}	30.55^{c}
	3	21.42^{de}	31.86^{bc}
I		21.65^{X}	31.53^{Z}
	4	22.65^{cd}	32.63^{b}
	5	23.70^{bc}	32.82^{ab}
	6	25.12^{ab}	32.33^{b}
	7	24.74^{ab}	32.05^{bc}
II		24.05^{Y}	32.44^{Y}
	8	21.07^{de}	33.13^{ab}
	9	20.47^{e}	31.69^{bc}
	10	20.69^{e}	33.06^{ab}
III		20.75^{Z}	32.62^{Y}
	11	24.92^{ab}	34.39^{a}
	12	25.66^{a}	31.84^{bc}
	13	25.70^{a}	32.63^{b}
IV		25.46^{W}	32.93^{Y}

[a,b,c]Means within the same column for nutritional treatment bearing different superscripts are different (P<.05).
[W,X,Y,Z]Means within the same column for management system bearing different superscripts are different (P<.05).

Beef Fat Volatiles

Subcutaneous fat samples of animals from three treatments were analyzed for volatile compounds. The nutritional treatments were: (1) fescue pasture (Treatment 8); (2) grain *ad libitum* on fescue pasture (Treatment 6) and (3) fescue pasture followed by *ad libitum* grain in dry lot (Treatment 11). Thirty-six volatile compounds were identified by gas-liquid chromatography-mass spectrometry using the direct sampling procedure (table 17). A large number of the volatiles identified were classed as carbonyl compounds. Herz and Chang (1970) reported carbonyls arise principally from lipids and thus are found in the volatiles of fat or fatty meat.

The overall profiles of the mass spectrometer (MS) total ion chromatograms of the beef fat from steers fed three nutritional regimens were distinctly different. The MS total ion chromatogram of beef fat volatiles from steers fed exclusively on fescue pasture is illustrated in Figure 3, from steers fed grain *ad libitum* on fescue pasture in Figure 4, and from

TABLE 17. VOLATILE COMPOUNDS FROM BEEF FAT

Compound No.[a]	Compound name
1	Acetaldehyde
2	Pentane
3	Acetone
4	Trimethylamine
5	Propanal
6	Methylene chloride
7	Acetic acid
8	Hexane
9	Butanal
10	Chloroform
11	Benzene
12	Heptane
13	Pentanal
14	Methyl methacrolate
15	Octane
16	Toluene
17	Hexanal
18	Nonane
19	Heptanal
20	Dimethylpyrazine
21	Octanal
22	Dichlorobenzene
23	Monanal
24	Methyl benzaldehyde
25	Unknown
26	Unknown
27	Naphthalene
28	2,4 decadienal
29	Undecane
30	4-methyl-4-hepten-3-one
31	γ-lactone
32	C-12-methyl ketone
33	Octadecane
34	Δ-Decalactone
35	Diethylphthalate
36	Δ-Dodecalactone
37	Δ-Tetradecalactone
38	Δ-Hexadecalactone

[a]The compound number corresponds to numbers on peaks in figures 3, 4 and 5.

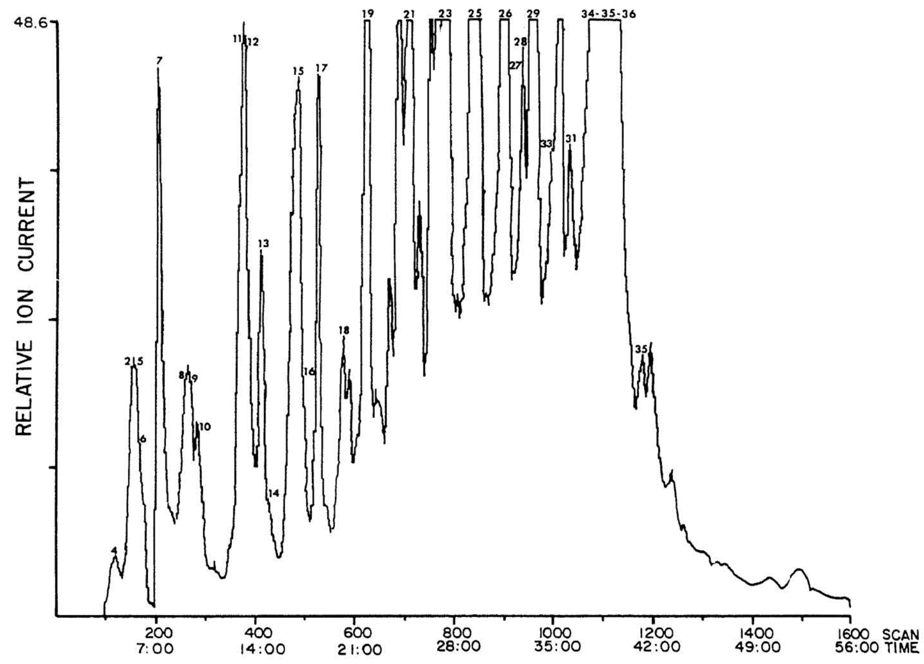

Figure 3. Volatile compounds from subcutaneous fat of fescue pasture-fed cattle (Treatment 8). (See table 17 for nomenclature of compounds corresponding to numbers on peaks).

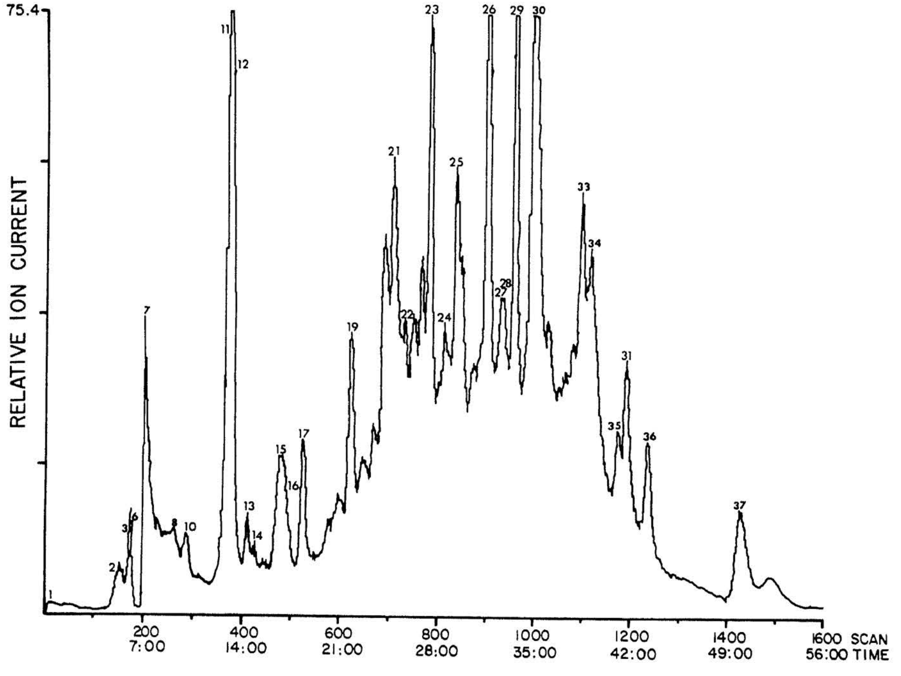

Figure 4. Volatile compounds from subcutaneous fat of cattle fed grain *ad libitum* on fescue pasture (Treatment 6). (See table 17 for nomenclature of compounds corresponding to numbers on peaks).

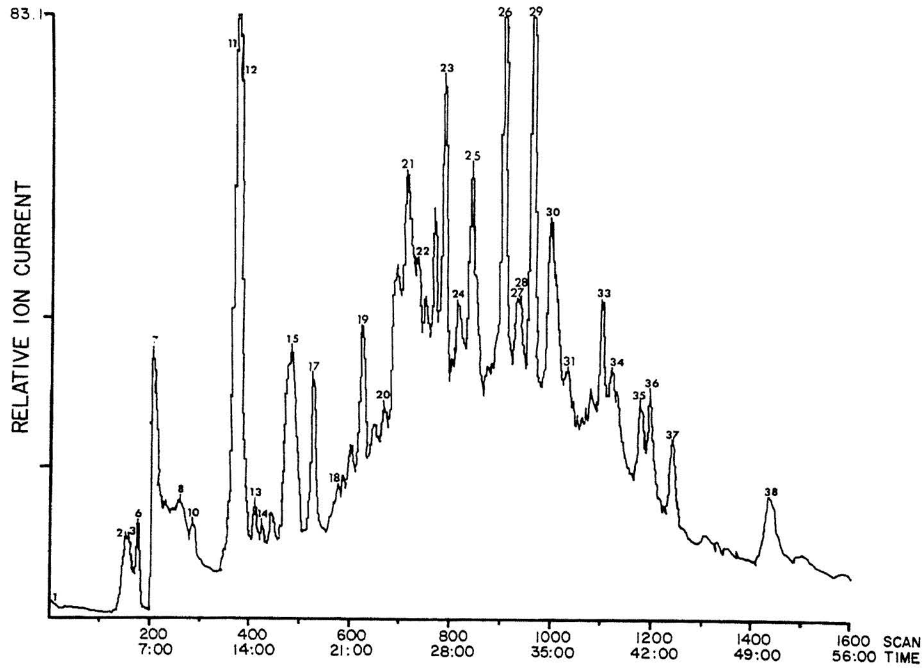

Figure 5. Volatile compounds from subcutaneous fat of cattle fed grain *ad libitum* in dry lot following fescue pasture (Treatment 11). (See table 17 for nomenclature of compounds corresponding to numbers on peaks).

steers fed grain *ad libitum* in dry lot following fescue pasture in Figure 5. There was considerable quantitative difference in the volatiles from fat of animals on the three nutritional regimens as measured by the mass spectrometer ion responses.

The GLC-MS ion profiles revealed that fat of fescue-fed steers contained the most total volatiles, followed by fat from steers fed grain on fescue pasture and steers fed grain in dry lot following fescue pasture. Three different peak areas were selected to numerically compare the volatile concentration from beef fat samples of animals on the three nutritional regimens (total peaks, 1100 scan position and 800-1000 scan position). The fat from fescue-fed steers had the highest average total volatile concentration (1447.5) followed by fat from steers fed grain on pasture (875.7) and the lowest being fat from steers fed in dry lot following pasture (825.3).

The peak located at the 1100 scan number position on the MS total ion chromatogram was much larger in area for the fat from fescue-fed steers than that of fat from animals on the other two nutritional treatments. The volatile concentration for the 1100 scan number peak was highest for the fat from the fescue-fed steers (139.0), intermediate for the steers fed grain on pasture (34.5) and lowest for steers fed in dry lot following pasture (28.5).

The peak located at the 1100 scan position on the MS total ion chromatogram was much larger in area for the fat from fescue-fed steers than that of fat from animals on the other two nutritional treatments. The volatile concentration for the 1100 scan position for the fat from fescue-fed steers was identified as being composed of Δ-decalactone (34), diethylphthalate (35) and Δ-dodecalactone (36) and Δ-tetradecalactone. It also contained a high molecular weight hydrocarbon, probably octadecane (33) which could be responsible for much of the undesirable flavor. Of the nine lactones identified by Leibich *et al.* (1972) most were present in the beef fat drippings and were absent from the concentrate of lean meat. The 1100 scan peak from the MS total ion chromatograms of fat from steers fed in dry lot following pasture and steers fed grain on pasture was composed of a C-12-methyl ketone (33) and Δ-decalactone (34).

The peak areas located between the 800 to 1000 scan position were also selected to compare volatile concentrations. The selected area (800-1000 scan) was comprised of four major peaks and appeared larger in area from the fescue-fed steers than the other two nutritional treatments. The volatile concentration for the four peak area (800-1000 scan) was highest for the fat from fescue-fed steers (86.6), intermediate for the steers fed grain on pasture (62.4) and lowest for steers fed in dry lot following fescue pasture (46.5).

In all three MS total ion chromatograms two of the peaks (25 and 26) were not identified. The remaining two peak areas were comprised of naphthalene (27), 2,4-decadienal (28) and undecane (29).

The peak located at the 1100 scan position comprised 9.4 percent of the average total volatiles for the fescue-fed steers. The 1100 scan peak comprised only 3.9 percent and 3.5 percent of the average total volatiles for the steers fed grain on pasture and steers fed in dry lot following pasture, respectively. The four-peak area located at the 800-1000 scan position comprised 7.1 percent of the average total volatiles from steers fed grain on pasture, 5.9 percent from fescue-fed steers and 5.6 percent from steers fed in dry lot following pasture.

Fat from fescue-fed animals was highest in volatile concentration for total volatiles, for the 1100 scan peak and for the 800-1000 scan peak area. The steers fed in dry lot following pasture were lowest for all three comparisons and the steers fed grain on pasture were intermediate between the two. Though the 1100 scan peak comprised the highest percent (9.4) of total volatiles for the fescue-fed steers compared to the other two nutritional treatments, the four-peak area (800-1000 scan) from fescue-fed steers comprised a smaller percentage (5.9) of total volatiles than the steers fed grain on pasture (7.1 percent).

A greater percentage of the total volatiles of fat from fescue-fed steers was comprised of compounds in a higher boiling fraction (higher molecular weight) than the volatiles of the fat from animals on the other two nutritional treatments. Thus, a greater percentage of the total volatiles from the fescue-fed steers would be concentrated at the 1100 scan peak position (higher temperature) than the 800-1000 scan peak area (lower temperature). The reverse is true for volatiles of fat from steers fed grain on pasture and steers fed in dry lot following pasture. Their greater volatile concentration would be at the 800-1000 scan peak area rather than at the 1100 scan peak position.

Nutritional regimen affected the volatile concentration between treatments and meat palatability as previously described. The nutritional treatment effect on the volatile concentration may be linked to the nutritional treatment effects on meat palatability, especially flavor. The fescue-fed animals had the highest total volatiles and were especially higher in volatiles in the peak located at the 1100 scan peak position. The 1100 scan peak was much larger in the fescue-fed steers than in the steers fed in dry lot following pasture or steers fed grain on pasture and may be associated with the undesirable flavor for beef from fescue-fed steers. The trend of decreasing total volatiles and volatile concentration at the 1100 scan number peak position from fescue-fed steers (highest) to steers fed grain on pasture (intermediate) to steers fed in dry lot following pasture (lowest) is associated with an inverse trend for flavor scores. The beef from fescue-fed steers was rated the least desirable in flavor (lowest), followed by steers fed grain on pasture (intermediate) and steers fed in drylot following pasture being rated the most desirable in flavor (highest).

The information related to greater quantities of volatiles in the fat of fescue-fed animals which were associated with less desirable flavor, compared to grain-fed animals could be useful to plant breeders in the future. It may be possible to eliminate or minimize these volatile compounds through plant breeding.

Digestibility and Chemical Composition of Herbage - (System II)

There were no significant differences (P>.05) among years for IVDMD, CP, ADF, P, K or Mg. However, there were differences (P<.05) among years for NDF and Ca. The seasonal percentage NDF from 1979 was higher (P<.05) (69.29) than from years 1977 (65.39) or 1978 (63.82) which were not different (P>.05). Average calcium seasonal concentration was greatest during 1978 (.58) (P<.05) compared to 1977 and 1979, which were not different (.52 and .52, respectively).

There were no seasonal differences (P>.05) between fescue and fescue-red clover pastures for IVDMD, CP, NDF, ADF, or K. However, P and K seasonal values were greater for fescue-red clover forage than for fescue forage alone. Mg values were greater for fescue forage than for fescue-red clover forage. Generally, as the season progressed from spring into summer, there were decreases in IVDMD, CP, K, P and increase in percent NDF, ADF, Mg and Ca (figures 6 and 7). The lowest percentages for IVDMD and CP were during July and August with increases generally measured from the end of August through the first of October.

Botanical Composition and Stands - (System III)

Average botanical values for each year are given in Table 18. Tall fescue pastures were composed nearly entirely of tall fescue each year. Birdsfoot trefoil contributed essentially nothing to the botanical composition in 1977, about 5% in 1978, and 10% in 1979. Red clover exhibited the opposite trend, averaging about 18% red clover in 1977 and 7% in 1978 and 1979. In 1979, red clover contributed very little to the total sward until September. This occurred because most of the new red clover seedlings died in June because of drought, but the few plants surviving made good growth in the fall.

Stand does not indicate the productivity of plants present, but it does indicate whether grass or legume plants were present. Like botanical composition, stands of the legumes were quite variable within a year and over years (table 19). Although birdsfoot trefoil plants were present in 1977, these plants made little growth the first year since growth consisted of only one to four stems for most of the season. In the following year, the trefoil plants consisted of many stems, and plants were very robust.

As suggested earlier, lower ADG's of steers on tall fescue-red clover in 1979 were probably related to the lower contribution of red clover to the total sward, especially from June through August. However, cattle gains

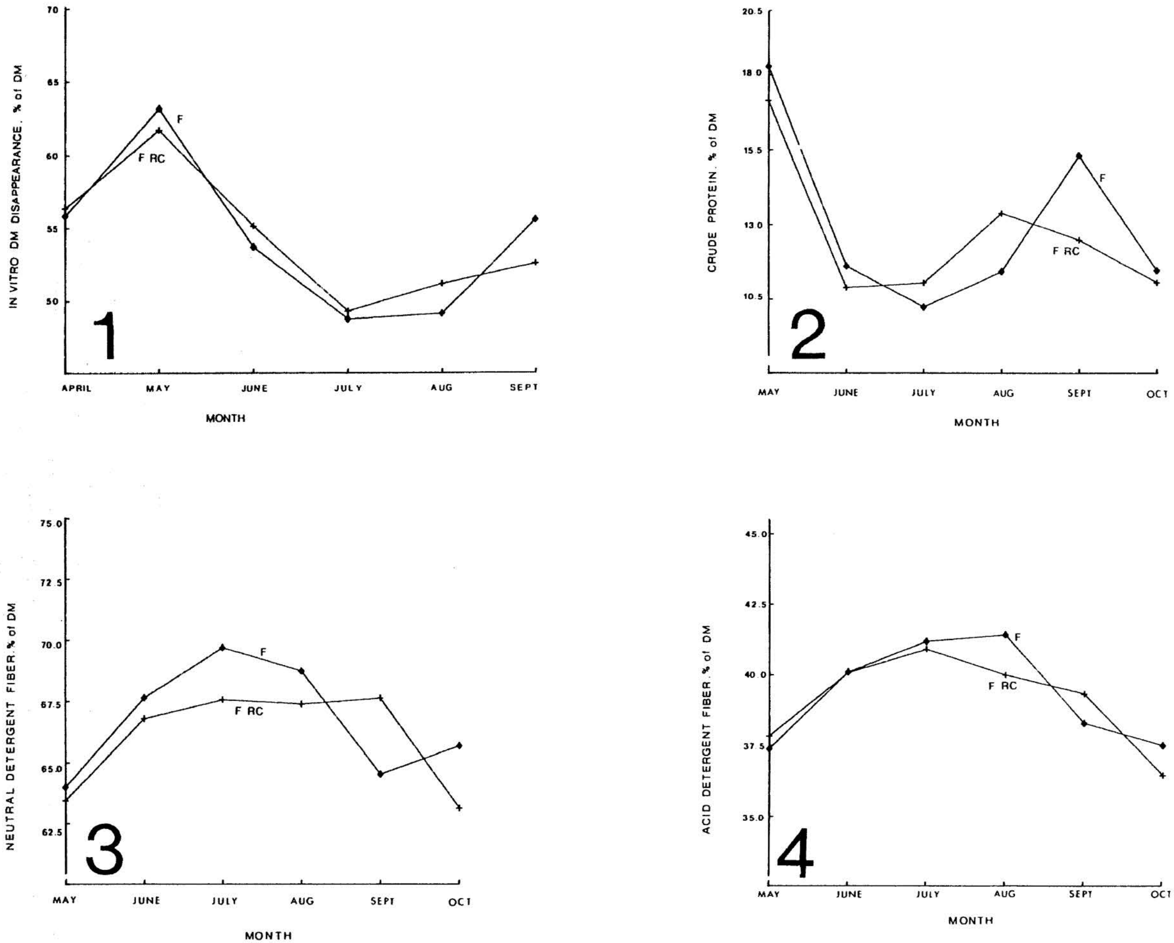

Figure 6. Monthly trends for *in vitro* dry matter disappearance (1), crude protein (2), neutral detergent fiber (3), and acid detergent fiber (4) for tall fescue (F) and tall fescue:red clover (F:RC) averaged over three years for System II.

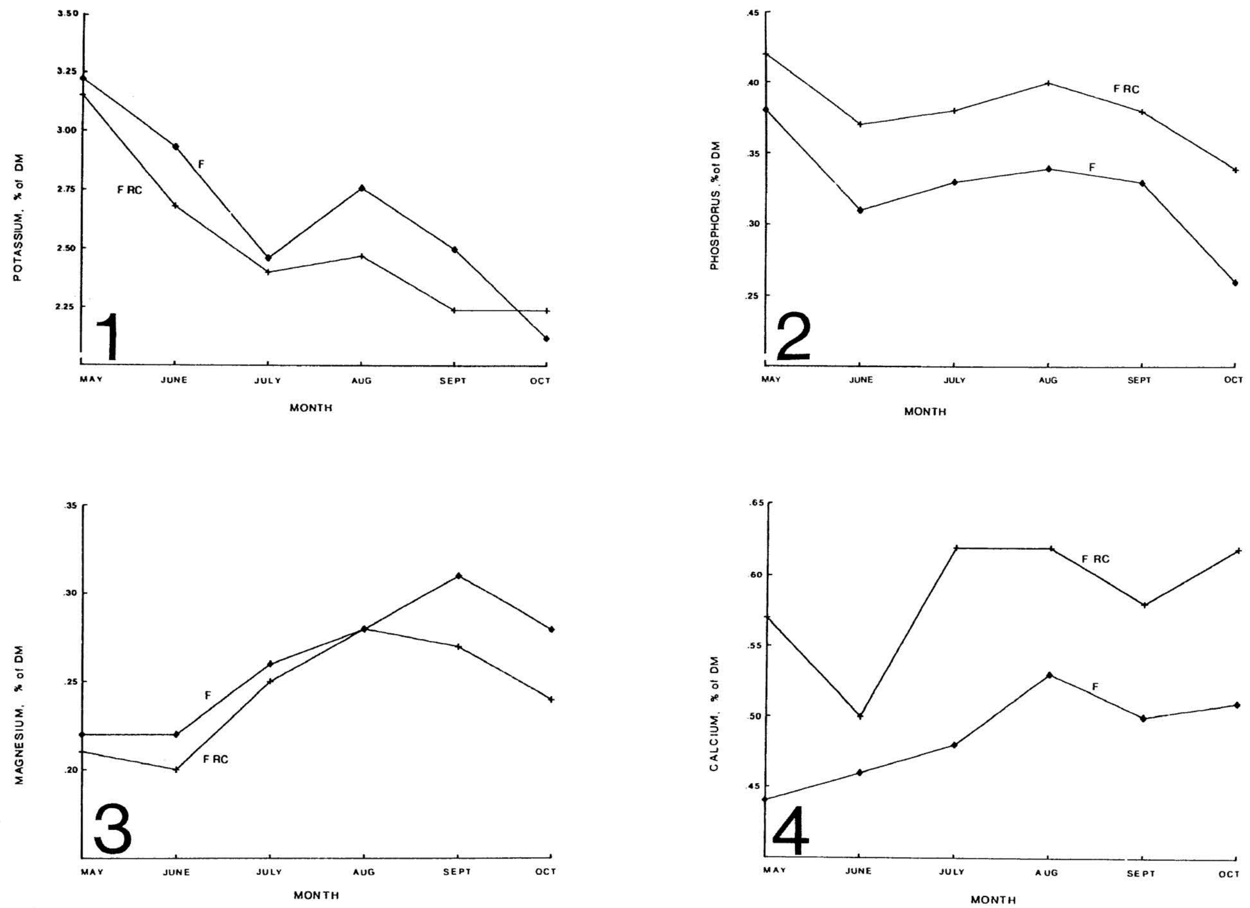

Figure 7. Monthly trends for potassium (1), phosphorus (2), magnesium (3), and calcium (4) for tall fescue (F) and tall fescue:red clover (F:RC) averaged over three years for System II.

TABLE 18. BOTANICAL COMPOSITION OF PASTURES AS DETERMINED BY HAND SEPARATION AND REPORTED ON A DRY WEIGHT BASIS.

	Tall Fescue	Tall Fescue Birdsfoot Trefoil		Tall Fescue Red Clover	
	Grass	Grass	Legume	Grass	Legume
	%	%		%	
1977					
June 13	100.0	79.6[a]	trace	85.8	14.2
Aug 8	100.0	—	—	85.0	15.0
Sept 23	100.0	—	—	76.8	23.2
Average	100.0	79.6	trace	82.5	17.5
1978					
May 2	100.0	97.1	2.9	97.3	2.7
June 2	100.0	94.6	5.4	88.3	11.7
July 25	100.0	93.9	6.1	92.6	7.4
Average	100.0	95.2	4.8	92.7	7.3
1979					
June 7	100.0	86.1	13.9	97.7	2.3
July 10	100.0	89.2	10.8	96.2	3.8
Sept 5	100.0	93.1	6.9	84.4	15.6
Average	100.0	89.5	10.5	92.8	7.2

[a]The remaining 20.4% of the botanical composition was annual legumes (red clover) and annual weeds. Following the June sampling, pastures consisted nearly entirely of tall fescue.

increased in the last two periods, and this would correspond to increases in red clover to the botanical composition.

Herbage Bulk-Height - (System III)

Herbage bulk-heights, as determined with the disk meter, are governed by the height of sward, its density (number of stems/unit area) and the toughness of the herbage. Any one of these factors alone or in combination with others will influence the reading obtained.

Our intent in using the disk meter was to estimate forage availability over the grazing season. However, the relationship between meter reading and available dry matter were so erratic ($r = 0.29$ to 0.92) that we have little confidence in the yield estimates. Therefore, forage availability data are not presented. We attribute most of the failure to obtain high correlation coefficients (r) between meter reading and dry matter yield to changes in the toughness of the herbage during the season.

Herbage toughness may be an indirect measure of forage quality; therefore, herbage bulk-heights were correlated with animal performance and forage quality components. These relationships are discussed later.

TABLE 19. PLANT STANDS OF PASTURES ESTIMATED WITH A TEN-PIN POINT QUADRAT.

Sampling Dates	Tall Fescue Grass	Tall Fescue Other	Tall Fescue Birdsfoot Trefoil Grass	Tall Fescue Birdsfoot Trefoil Legume	Tall Fescue Birdsfoot Trefoil Other	Tall Fescue Red Clover Grass	Tall Fescue Red Clover Legume	Tall Fescue Red Clover Other
	%		%			%		
1977								
June 3	97.4	2.6	80.3	18.8	0.9	64.1	34.9	1.0
July 26	99.8	0.2	85.5	13.8	0.7	63.9	35.6	0.5
Oct 14	99.1	0.8	92.6	6.6	0.8	76.5	23.3	0.1
Average	98.8	1.2	86.1	13.1	0.8	68.2	31.3	0.5
1978								
May 30	100.0	0.0	79.3	16.6	4.2	74.6	24.7	0.7
Aug 21	100.0	0.0	78.5	17.0	4.5	82.1	17.9	0.0
Nov 8	99.0	1.0	77.6	19.3	3.1	75.1	24.9	0.0
Average	99.7	0.3	78.5	17.6	3.9	77.3	22.5	0.2
1979								
June 5	100.0	0.0	81.5	18.4	0.0	84.0	15.3	0.7
July 29	99.7	0.3	91.0	8.7	0.3	94.2	5.8	0.0
Oct 1	100.0	0.0	99.0	1.0	0.0	99.8	0.2	0.0
Average	99.9	0.1	90.5	9.4	0.1	92.7	7.1	0.2

Digestibility and Chemical Composition of Herbage - (System III)

There were no significant differences (P>.05) in 1977 among pasture types for average seasonal levels of IVDMD, CP, NDF, ADF, P, K, Ca, and Mg; however, in 1978, differences occurred (P<.05) for CP, Ca and Mg and for P in 1979. Generally as the season progressed from spring into summer, there were decreases in percent IVDMD, P, Ca and increases in percent NDF, ADF and Mg (figures 8 and 9). Compared to June and July, herbage in August and September had higher levels of IVDMD, CP, P, K and Mg. These trends are similar to those reported by Reid *et al.* (1967) and Vartha *et al.* (1977). We do not know why the tall fescue-red clover herbage had a sizeable increase in Ca between June and July (figure 9). We suspect that dust may have collected on the pubescent stems of the red clover, and some of the increase in Ca was a result of contamination. Both tall fescue and birdsfoot trefoil are nearly glabrous, so contamination from dust was less likely to occur.

None of the minerals appeared to fall below minimum levels recommended by National Research Council—National Academy of Science (1970) feed standards for the size of beef steers used in this experiment.

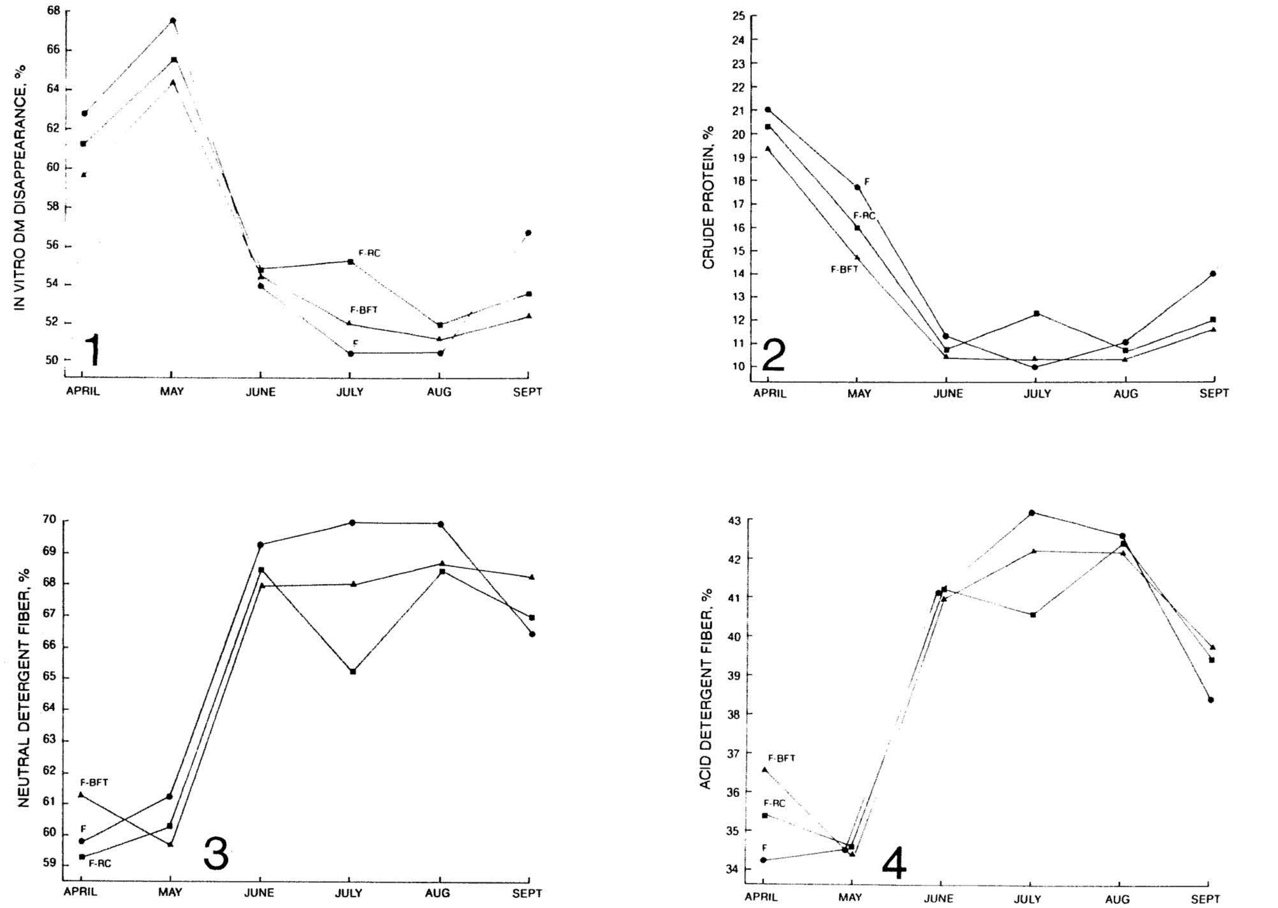

Figure 8. Monthly trends for *in vitro* dry matter disappearance (1), crude protein (2), neutral detergent fiber (3), and acid detergent fiber (4) for tall fescue (F), fescue-red clover (F-RC) and fescue-birdsfoot trefoil (F-BFT) averaged over three years for System III.

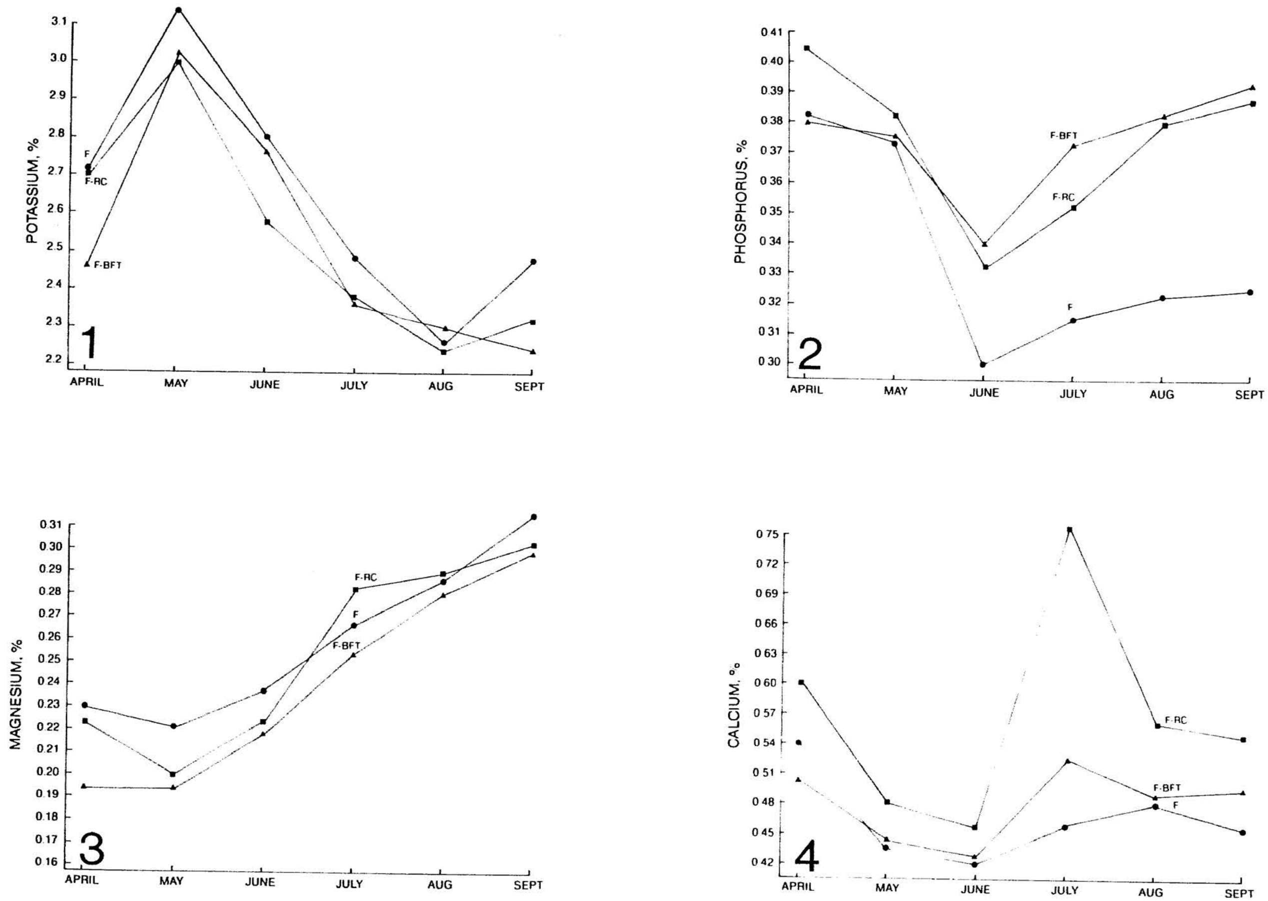

Figure 9. Monthly trends for potassium (1), phosphorus (2), magnesium (3), and calcium (4) for tall fescue (F), fescue-red clover (F-RC) and fescue-birdsfoot trefoil (F-BFT) averaged over three years for System III.

Relationships Between Sward Data and Steer ADG - (System III)

Simple Correlations: Sward data consisting of bulk-height, IVDMD, CP and mineral composition were examined in simple correlation matrixes (tables 20 and 21) and in multiple correlations for predicting steer ADG (tables (22, 23, 24 and 25).

For years and pasture types combined (table 19), CP, IVDMD, ADF, NDF, Mg and P were all significantly correlated ($P<.05$) with ADG of steers. Highest simple correlations were obtained with IVDMD ($r = 0.730$), NDF ($r = 0.710$), ADF (0.692), and CP ($r = 0.559$). Also, these components usually had the highest correlations with ADG within individual years and for pasture types (table 21). In some cases, K and Mg were also correlated with average daily gain.

As might be expected, ADF and NDF usually were significantly correlated ($P<.05$) with percent IVDMD, and r values ranged from −0.658 to −0.934. Correlations between CP and IVDMD ranged from $r = .0678$ to 0.884.

Multiple Regressions: Combinations of variables yielding maximum coefficients of determination (R^2) for the prediction of steer ADG are shown in tables 22 and 25. The R^2 values for pasture types and years combined ranged from 0.545 to 0.672, and the standard deviations (SD) from 0.267 to 0.368. Coefficients of determination and SDs were not improved by separating out pasture types in the case of tall fescue-red clover ($R^2 = 0.466$ to 0.599, SD = 0.286 to 0.312) and tall fescue-birdsfoot trefoil ($R^2 = 0.525$ to 0.656, SD = 0.253 to 0.282). However, in the case of tall fescue grown alone, the R^2 values ranged from 0.696 to 0.824 and SDs from 0.244 to 0.295.

TABLE 20. MATRIX OF CORRELATION COEFFICIENTS (r) OF FORAGE QUALITY MEASUREMENTS FOR YEARS AND PASTURE TYPES COMBINED[a]

	Mg	Ca	K	P	CP	IVDMD	ADF	NDF	DISK
					r[b]				
ADG	−0.398	0.065	0.538	0.303	0.559	0.730	−0.692	−0.710	−0.176
DISK	−0.194	0.038	0.252	−0.270	−0.210	0.056	0.288	0.102	
NDF	0.340	−0.210	−0.633	−0.433	−0.783	−0.826	0.867		
ADF	0.237	0.103	−0.634	−0.474	−0.809	−0.804			
IVDMD	−0.351	−0.009	0.762	0.309	0.779				
CP	−0.183	0.072	0.615	0.343					
P	0.041	0.056	0.231						
K	−0.371	−0.183							
Ca	0.208								

[a]n = 153
[b]Significant levels for correlation coefficients, .05 level = 0.185, .01 level = 0.207

TABLE 21. MATRIX OF CORRELATION COEFFICIENTS (r) OF FORAGE QUALITY MEASUREMENTS FOR PASTURE TYPE WITH YEARS COMBINED[a]

	Mg	Ca	K	P	CP	IVDMD	ADF	NDF	DISK
	r[b]								
Tall Fescue									
ADG	−0.257	0.321	0.635	0.582	0.664	0.834	−0.805	−0.800	−0.130
DISK	−0.395	−0.408	0.333	−0.112	−0.303	−0.008	0.246	0.130	
NDF	0.187	−0.379	−0.623	−0.700	−0.856	−0.892	0.944		
ADF	0.134	−0.365	−0.597	−0.695	−0.893	−0.900			
IVDMD	−0.239	0.235	0.708	0.610	0.812				
CP	−0.182	0.428	0.532	0.610					
P	−0.201	0.360	0.542						
K	−0.404	−0.075							
Ca	0.274								
Tall Fescue-Birdsfoot Trefoil									
ADG	−0.506	0.021	0.534	−0.033	0.574	0.705	−0.673	−0.725	−0.108
DISK	−0.235	0.044	0.148	−0.103	−0.336	0.080	0.370	0.126	
NDF	0.464	−0.092	−0.603	−0.203	−0.747	−0.806	0.897		
ADF	0.324	0.066	−0.573	−0.240	−0.775	−0.747			
IVDMD	−0.457	−0.100	0.723	0.084	0.724				
CP	−0.210	−0.018	0.585	0.268					
P	0.264	0.019	0.126						
K	−0.410	−0.340							
Ca	0.373								
Tall Fescue-Red Clover									
ADG	−0.441	−0.035	0.524	0.160	0.501	0.658	−0.592	−0.600	−0.211
DISK	−0.143	0.280	0.156	−0.334	−0.196	0.062	0.336	0.014	
NDF	0.360	−0.209	−0.738	−0.358	−0.809	−0.800	0.787		
ADF	0.285	0.291	−0.738	−0.578	−0.762	−0.742			
IVDMD	−0.436	−0.071	0.874	0.296	0.786				
CP	−0.273	0.044	0.720	0.401					
P	0.247	−0.218	0.270						
K	−0.401	−0.148							
Ca	0.217								

[a]n = 51

[b]Significance level for correlation coefficients, .05 level = 0.276, .01 level = 0.358

TABLE 22. REGRESSION EQUATIONS FOR PREDICTING STEER ADG FROM HERBAGE IN VITRO DRY MATTER DIGESTIBILITY (IVDMD), CRUDE PROTEIN (CP), BULK HEIGHT (DISK), ACID DETERGENT FIBER (ADF), NEUTRAL DETERGENT FIBER (NDF), CALCIUM (Ca), PHOSPHORUS (P), POTASSIUM (K), AND MAGNESIUM (Mg), AND COEFFICIENTS OF DETERMINATION (R^2) AND STANDARD DEVIATION (SD) FROM REGRESSION FOR ALL PASTURE TYPES OVER YEARS.

Step No.	Pasture type and years combine, n = 153 Regression Equation for Predicting Steer ADG (kg)	R^2	SD
1	− 2.320 + 0.050 IVDMD	0.545	0.308
2	− 2.034 + 0.050 IVDMD − 0.040 DISK	0.585	0.295
3	− 1.215 + 0.046 IVDMD − 0.048 DISK − 1.958 Mg	0.619	0.284
4	− 1.344 + 0.045 IVDMD − 0.050 DISK + 0.539 Ca − 2.283 Mg	0.635	0.279
5a	− 1.563 − 0.026 CP + 0.055 IVDMD − 0.060 DISK + 0.604 Ca − 2.243 Mg	0.647	0.275
5b	1.299 − 0.034 CP + 0.043 IVDMD − 0.051 DISK − 0.030 NDF − 1.571 Mg	0.650	0.274
6a	0.467 − 0.034 CP + 0.047 IVDMD − 0.055 DISK − 0.022 NDF + 0.390 Ca − 1.882 Mg	0.657	0.272
6b	0.713 − 0.039 CP + 0.043 IVDMD − 0.044 DISK − 0.041 ADF + 0.750 Ca − 2.194 Mg	0.668	0.268
7	0.451 − 0.043 CP + 0.040 IVDMD − 0.052 DISK − 0.037 ADF + 0.137 K + 0.836 Ca − 2.156 Mg	0.672	0.267
8	0.329 − 0.043 CP + 0.040 IVDMD − 0.051 DISK + 0.003 NDF − 0.040 ADF + 0.139 K + 0.874 Ca − 2.20 Mg	0.672	0.268
9	0.354 − 0.043 CP + 0.040 IVDMD − 0.052 DISK + 0.003 NDF − 0.040 ADF − 0.031 P + 0.139 K + 0.875 Ca − 2.195 Mg	0.672	0.268

TABLE 23. REGRESSION EQUATIONS FOR PREDICTING STEER ADG FROM HERBAGE IN VITRO DRY MATTER DIGESTIBILITY (IVDMD), CRUDE PROTEIN (CP), BULK HEIGHT (DISK), ACID DETERGENT FIBER (ADF), NEUTRAL DETERGENT FIBER (NDF), CALCIUM (Ca), PHOSPHORUS (P), POTASSIUM (K), AND MAGNESIUM (Mg), AND COEFFICIENTS OF DETERMINATION (R^2) AND STANDARD DEVIATION (SD) FROM REGRESSION FOR TALL FESCUE OVER YEARS.

Step	Pasture type and years combine, n = 51		
No.	Regression Equation for Predicting Steer ADG (kg)	R^2	SD
1	− 2.932 + 0.059 IVDMD	0.696	0.295
2	− 3.491 + 0.057 IVDMD + 1.493 Ca	0.712	0.290
3a	− 3.791 + 0.047 IVDMD + 0.228 K + 1.993 Ca	0.726	0.286
3b	− 2.697 + 0.048 IVDMD − 0.042 DISK + 0.292 K	0.730	0.284
4	− 2.905 − 0.036 CP + 0.060 IVDMD − 0.061 DISK + 0.342 K	0.746	0.279
5	− 3.965 − 0.050 CP + 0.060 IVDMD − 0.055 DISK + 0.432 K + 2.193 Ca	0.772	0.267
6	− 3.280 − 0.066 CP + 0.062 IVDMD − 0.074 DISK + 0.402 K + 2.873 Ca − 2.694 Mg	0.802	0.251
7	0.056 − 0.086 CP + 0.047 IVDMD − 0.062 DISK − 0.053 ADF + 0.367 K + 2.777 Ca − 2.858 Mg	0.817	0.244
8	0.841 − 0.089 CP + 0.045 IVDMD − 0.064 DISK − 0.064 ADF − 1.157 P + 0.416 K + 3.102 Ca − 3.061 Mg	0.822	0.244
9	1.676 − 0.090 CP + 0.043 IVDMD − 0.067 DISK − 0.018 NDF − 0.049 ADF − 1.264 P + 0.417 K + 2.953 Ca − 3.023 Mg	0.824	0.246

TABLE 24. REGRESSION EQUATIONS FOR PREDICTING STEER ADG FROM HERBAGE IN VITRO DRY MATTER DIGESTIBILITY (IVDMD), CRUDE PROTEIN (CP), BULK HEIGHT (DISK), ACID DETERGENT FIBER (ADF), NEUTRAL DETERGENT FIBER (NDF), CALCIUM (Ca), PHOSPHORUS (P), POTASSIUM (K), AND MAGNESIUM (Mg), AND COEFFICIENTS OF DETERMINATION (R^2) AND STANDARD DEVIATION (SD) FROM REGRESSION FOR TALL FESCUE-RED CLOVER OVER YEARS.

Step	Pasture type and years combine, n = 51		
No.	Regression Equation for Predicting Steer ADG (kg)	R^2	SD
1	− 1.933 + 0.043 IVDMD	0.466	0.312
2	− 1.662 + 0.044 IVDMD − 0.038 DISK	0.507	0.303
3	− 0.851 + 0.038 IVDMD − 0.046 DISK − 1.765 Mg	0.536	0.297
4	− 0.859 + 0.038 IVDMD − 0.055 DISK + 0.392 Ca − 2.194 Mg	0.556	0.294
5	− 1.094 − 0.036 CP + 0.052 IVDMD − 0.074 DISK + 0.536 Ca − 2.335 Mg	0.576	0.290
6	0.654 − 0.048 CP + 0.043 IVDMD − 0.059 DISK − 0.033 ADF + 0.695 Ca − 2.331 Mg	0.597	0.286
7	0.810 − 0.046 CP + 0.046 IVDMD − 0.054 DISK − 0.036 ADF − 0.091 K + 0.669 Ca − 2.285 Mg	0.598	0.289
8	1.018 − 0.046 CP + 0.046 IVDMD − 0.054 DISK − 0.039 ADF − 0.358 P − 0.100 K + 0.655 Ca − 2.139 Mg	0.599	0.292
9	0.748 − 0.044 CP + 0.046 IVDMD − 0.052 DISK + 0.006 NDF − 0.044 ADF − 0.316 P − 0.104 K + 0.727 Ca − 2.225 Mg	0.599	0.296

TABLE 25. REGRESSION EQUATIONS FOR PREDICTING STEER ADG FROM HERBAGE IN VITRO DRY MATTER DIGESTIBILITY (IVDMD), CRUDE PROTEIN (CP), BULK HEIGHT (DISK), ACID DETERGENT FIBER (ADF), NEUTRAL DETERGENT FIBER (NDF), CALCIUM (Ca), PHOSPHORUS (P), POTASSIUM (K), AND MAGNESIUM (Mg), AND COEFFICIENTS OF DETERMINATION (R^2) AND STANDARD DEVIATION (SD) FROM REGRESSION FOR TALL FESCUE-BIRDSFOOT TREFOIL OVER YEARS.

Step	Pasture type and years combine, n = 51		
No.	Regression Equation for Predicting Steer ADG (kg)	R^2	SD
1	5.083 – 0.069 NDF	0.525	0.282
2	2.055 + 0.023 IVDMD – 0.042 NDF	0.567	0.272
3	2.259 + 0.020 IVDMD – 0.038 NDF – 1.476 Mg	0.593	0.266
4a	1.729 + 0.025 IVDMD – 0.034 DISK – 0.028 NDF – 1.886 Mg	0.613	0.263
4b	– 1.128 + 0.038 IVDMD – 0.056 DISK + 1.505 Ca – 3.160 Mg	0.634	0.255
5	– 1.269 + 0.028 IVDMD – 0.061 DISK + 0.216 K + 1.882 Ca – 3.241 Mg	0.649	0.253
6	– 0.518 + 0.024 IVDMD – 0.050 DISK – 0.013 ADF + 0.191 K + 1.790 Ca – 3.127 Mg	0.652	0.254
7	– 0.504 – 0.015 CP + 0.028 IVDMD – 0.058 DISK – 0.016 ADF + 0.222 K + 1.884 Ca – 3.096 Mg	0.655	0.256
8	– 0.269 – 0.013 CP + 0.027 IVDMD – 0.055 DISK – 0.018 ADF – 0.351 P + 0.220 K + 1.838 Ca – 2.597 Mg	0.656	0.259
9	– 0.453 – 0.013 CP + 0.027 IVDMD – 0.054 DISK + 0.004 NDF – 0.022 ADF – 0.317 P + 0.224 K + 1.910 Ca – 3.046 Mg	0.656	0.262

The R^2 values were greater than anticipated, and we are encouraged that up to 80+% of the variation in ADG was accounted for in some cases by the forage quality components measured. Perhaps in the future, herbage quality measurements from clipping experiments may be used to project expected animal performance if grazed by steers. In our experiments, we did not have reliable estimates of the amount of herbage available for grazing. With the inclusion of herbage availability in predictive equations, we believe that R^2 values might improve substantially, and the previously mentioned technique of Duble *et al.* (1971) could be used to predict animal gains. Also, curvilinear regression equations might have improved the accuracy of prediction. For example, Rohweder *et al.* (1977) observed that improved predictions were achieved with curvilinear as compared to linear equations when using ADF and NDF as predictors of digestible dry matter and dry matter intake of grass and legume forages.

Economic Analysis

An economic comparison of the 13 treatments on a live animal basis is presented in Table 26 and on a carcass basis in Table 27. Live animal, carcass, feed and non-feed data were averaged for the three-year period. The sale receipts and purchase costs on a live animal basis and sale receipts on a carcass basis (carcass value includes hide and offal value) were computed using market quotations from USDA Market News Report and The National Provisioner for the week of July 27, 1981. Feed costs, non-feed costs and operating interest values were likewise chosen for the above similar period (Summary of individual costs are presented in table 25). The purchase costs of animals on Treatments 1, 2 and 3 were computed using average weights for each treatment, while the purchase cost of animals on Treatments 4-13 was based on an average initial weight of all animals on these treatments. No labor costs involved in feeding the animals were included.

Animals on Treatments 1, 2, 3, 5, 7, 11, 12 and 13 returned an average profit per animal ranging from \$10.44 to \$53.13 (table 26). While a net loss was observed for animals on Treatments 4, 6, 8, 9 and 10, ranging from \$9.50 to \$37.09 per animal. The treatments that had the greatest loss were the grass-fed treatments (Treatments 8, 9 and 10) and the two treatments that grazed and were finished on straight fescue (Treatments 4 and 6). Treatments 5 and 7 were the same as Treatments 4 and 6 except fescue pastures were interseeded with red clover for 5 and 7 and not for 4 and 6. The presence of legume in the pasture increased rates of gain and resulted in greater live animal return. Similarly when Treatments 8, 9 and 10 were compared, Treatment 8 (straight fescue) animals returned less per animal than Treatments 9 and 10 (fescue pasture interseeded with red clover and birdsfoot trefoil, respectively). These data indicate that the presence of

TABLE 26. ECONOMIC ANALYSIS OF BEEF CATTLE PRODUCTION BY TREATMENTS (LIVE ANIMAL BASIS)

Treatment	Sale Receipt	−	Purchase Cost[a]	+	Feed cost[b]	+	Non-feed cost[c]	+	Operating[d] Interest	=	Return/head, $
1	527.94		315.90		112.10		38		30.65		31.29
2	607.32		314.60		188.07		50		44.92		12.05
3	705.54		319.50		240.38		56		54.35		35.31
4	643.23		317.20		244.60		30		67.09		−15.66
5	676.62		317.20		245.36		30		67.15		16.91
6	691.02		317.20		275.50		32		75.82		−9.50
7	717.42		317.20		281.48		32		76.30		10.44
8	408.09		317.20		70.80		12		45.18		−37.09
9	429.44		317.20		70.80		12		45.18		−15.74
10	431.88		317.20		70.80		12		45.18		−13.30
11	717.42		317.20		250.69		34		77.85		37.68
12	720.06		317.20		250.69		34		77.85		37.68
13	733.26		317.20		251.05		34		77.88		53.13

[a]Purchase Cost = \$65.00/cwt. Costs for Treatments 1, 2 and 3 were determined on average weights of animals assigned to each treatment, while average weights were used for all animals assigned to Treatments 4-13.

[b]Feed Costs:
- Corn grain = 7.1¢/lb. dry basis.
- Corn silage = 3.6¢/lb. dry basis.
- Protein, salt, minerals & additives = 14¢/lb. dry basis.
- Summer pasture = \$6.00/month/steer
- Winter backgrounding (stock piled fescue) = \$6/month/steer.

[c]Non-feed costs:
- Pasture = 7.5¢/day.
- Feedlot = 18.5¢/day.

[d]Operating interest = Purchase cost + $\frac{\text{Feed cost + Non-feed cost}}{2}$ x % year owned x interest rate (assumed to be 14%)

TABLE 27. ECONOMIC ANALYSIS OF BEEF CATTLE PRODUCTION BY TREATMENTS (CARCASS BASIS)

Treatment	Carcass value[e], $	−	Purchase cost, $	+	Feed & Non-Feed costs & interest[f]	=	Return/head, $
1[a]	507.94		315.90		180.75		11.29
2[b]	646.52		314.60		282.99		48.93
3[c]	764.23		319.50		350.73		94.00
4[b]	654.06		317.20		341.69		−4.83
5[b]	677.18		317.20		342.51		17.48
6[c]	745.00		317.20		383.32		44.48
7[c]	756.95		317.20		389.78		49.97
8[d]	352.45		317.20		127.98		−92.73
9[d]	379.84		317.20		127.98		−65.34
10[d]	380.09		317.20		127.98		−65.09
11[c]	745.40		317.20		362.54		65.66
12[c]	751.96		317.20		362.54		72.22
13[c]	764.76		317.20		362.93		84.63

[a]Good; [b]Good +; [c]Choice−; [d]Standard quality grades.

[e]Value by quality grade for carcass ($/cwt).

Standard = $ 90.00
Good = $ 99.00
Good+ = $ 99.00
Choice− = $105.00

Offal value = $6.35/100 lb. live weight.

[f]See table 77 for data used in calculating total feed, non-feed and interest costs.

legumes in pasture will increase the returns per animal compared to straight fescue.

Comparison of the 13 treatments on a carcass basis (table 27) revealed that Treatments 4, 8, 9 and 10 returned a net loss of $4.83 to $92.73 per animal. While all other treatments returned a net profit ranging from $11.29 to $94.00 per animal.

Management System I (Treatments 1, 2 and 3) resulted in profits for each of the Treatments. This System of beef cattle production requires considerable capital investment for silage production and feed lot facilities. From the standpoint of utilization of the entire plant, the corn plant can be effectively used as silage for beef production. If this production system is available to a beef cattle producer, the returns presented in Table 26 show that finishing on grain after silage feeding (Treatments 2 and 3) resulted in greater returns per animal than silage alone (Treatment 1). The increased returns for Treatment 3 compared to Treatments 2 and 1 can be attributed to increased carcass value due to greater carcass weights and improved carcass quality grades. Also, cattle on Treatments 2 and 3 continued to make desirable rates of gain. Cattle on Treatment 3 attained near their maximum growth potential in near minimum time. The operating interest costs were less for this system of production than for Systems II and IV because of the shorter time period required to grow and finish the cattle.

Management System II (Treatments 4, 5, 6 and 7) offers possibilities for beef cattle producers who have pasture land. This system relies upon wintering cattle on stockpiled hay, early spring and summer grazing and corn self-fed while on pasture. No investment is required for feed lots and silage production. Data presented in Table 27 show the advantage of a legume interseeded in fescue pasture, compare Treatment 4 (fescue) and 5 (fescue-red clover) and 6 (fescue) and 7 (fescue-red clover). In both comparisons animals on straight fescue returned less than those on fescue-red clover, even though the animals were self-fed corn during the finishing phase.

Management System III (Treatments 8, 9 and 10) is not suitable for production of slaughter cattle. Neither fescue pasture of fescue interseeded with red clover or birdsfoot trefoil provides enough nutrients for young cattle to fatten sufficiently and produce desirable beef. However, Treatments 9 and 10 reflect a considerable advantage of legumes in fescue compared to straight fescue (Treatment 8). In these comparisons of Treatments 9 and 10 less loss was incurred than for Treatment 8.

Management System IV (Treatments 11, 12 and 13) offers a good potential for beef cattle production. Cattle are wintered on stockpiled hay, grazed during the summer and then finished on grain in drylot. In this system, maximum utilization of forages is employed to grow and develop cattle and during the final finishing period on grain maximum advantage of compensatory growth is achieved.

TABLE 28. LIMESTONE AND FERTILIZER COSTS FOR PASTURES

Item	Description of Cost Item	Cost/ha[a]
	Initial Costs for all Pastures	
Limestone	6.73 mt/ha @ $8.50/mt spread	$ 57.30
Fertilizer		
P	30 kg/ha @ $1.20/kg	36.00
K	56 kg/ha @ $0.345/kg	19.32
Spreading	$8.65/ha	8.65
	TOTAL	$121.17
	Maintenance all Pastures, 3rd year only	
Fertilizer		
P	15 kg/ha @ $1.20/kg	$ 8.00
K	56 kg/ha @ $0.345/kg	19.32
Spreading	$8.65/ha	8.65
	TOTAL	$ 45.97
	Costs for tall fescue Pastures	
Fertilizer		
N (1st year)	141 kg/ha @ $0.55/kg	$ 77.55
Spreading	$8.65/ha x 2	17.30
N (2nd year)	141 kg/ha @ $0.55/kg	72.55
Spreading	$8.65/ha x 2	17.30
N (3rd year)	84 kg/ha @ $0.55/kg	46.20
Spreading	$8.65/ha	8.65
	TOTAL	$244.55
	Average/year	81.52

[a]Fertilizer and spreading costs (August 1981) provided by commercial vendors located in Columbia, MO.

Pasture Production Costs

Costs of seed and fertilizer for the summer pasture phase of treatments 8 through 13 are given in Tables 28 through 30. Fertilization costs are itemized in Table 28 and seeding costs in Table 29. Total costs for the combined three years and the average yearly costs per ha and per steer month are summarized in Table 30.

In the three years of experimentation, seeding costs were lower for red clover (Treatments 9 and 12) than for birdsfoot trefoil (Treatments 10 and 13). This occurred because birdsfoot trefoil seed is more expensive, and two partial reseedings were needed to establish satisfactory stands. However, stands of trefoil were very good by the end of the third grazing season. The high cost of fertilizer for straight tall fescue (Treatments 8 and 11) is due to the high cost of nitrogen fertilizer. Actual total costs per ha

TABLE 29. COST OF INITIAL INTERSEEDING AND RESEEDING OF LEGUMES INTO A TALL FESCUE SOD

Item	Description of Cost Item	Cost/ha[a]
Item	Description of Cost Item	Cost/ha[a]
	Initial interseeding	
Red clover	Seed 9 kg/ha @ $3.09/kg	$ 27.81
Power-Til drill	$14.83/ha	14.83
	TOTAL	$ 42.64
Birdsfoot trefoil	Seed 7.8 kg/ha @ $1.58/kg	$ 59.12
Power-Til drill	$14.83/ha	14.83
	TOTAL	$ 73.95
	Reseeding	
Red clover (3rd year)	Seed 9 kg/ha @ $3.09/ha	$ 27.81
Broadcast seeding	$7.41/ha	7.41
	TOTAL	$ 35.22
Birdsfoot trefoil		
(2nd & 3rd years)	Seed 3.9 kg/ha @ $7.58/kg	$ 29.56
Broadcast seeding	$7.41/ha	7.41
	TOTAL	$ 36.97
	Total reseeding 2 seasons	$ 73.94

[a]Seed prices quoted August 1981 by commercial vendors located in Columbia, MO.
Costs of Power-Til operation and broadcast seeding obtained from Dr. E. M. Smith, Agricultural Engineer, Univ. of Kentucky, Lexington, KY.

were lowest ($81.66) for the fescue-red clover treatments (Treatments 9 and 12) and highest ($137.23) for nitrogen fertilized tall fescue (Treatments 8 and 11). The fescue-trefoil pasture costs were $105.00/ha (table 30). Costs per steer per month, based on carrying capacity of pastures, were $7.23, $5.30, and $7.59, respectively, for nitrogen fertilized fescue, fescue-red clover and fescue-trefoil.

Stands of birdsfoot trefoil by the end of the third year were very good and would not require additional reseedings. If the pasture experiment were projected to be grazed for 10 years, then average costs per steer month would decrease because the initial fertilizer costs would be averaged over the 10 years. We would anticipate that red clover would require reseeding every two years under normal conditions and that maintenance applications of P and K would be required every other year. Based upon the cost values used in this experiment with reseedings of red clover and

TABLE 30. THREE YEAR COSTS ($) OF FERTILIZATION AND SEEDING PER HECTARE FOR THE SUMMER PASTURE PHASE OF TREATMENTS 8 THROUGH 13

Treatment				Total cost	Average per year
	Fertilization, lime, P & K		Nitrogen		
	Initial	Maintenance			
8 & 11	121.17	45.97	244.55	411.69	137.23
9 & 12	121.17	45.97	0	167.14	55.71
10 & 13	121.17	45.97	0	167.14	55.71
	Seeding				
	Initial	Reseeding			
9 & 12	42.64	35.22		77.86	25.95
10 & 13	73.95	73.94		147.89	49.29
	Yearly costs/ha				
	Seed[a]	Fertilizer	Total	Cost/steer/month	
8 & 11	0	137.23	137.23	7.23	
9 & 12	25.95	55.71	81.66	5.30	
10 & 13	49.29	55.71	105.00	7.59	

[a]Legumes were intereseeded into an established tall fescue sod.

maintenance fertilizer made for years three, five, seven and nine, the projected average costs per year (over 10 years) and costs per steer month are estimated as follows:

Treatments	*Average costs/ha per year*	*Average cost per steer month*
8 & 11 (tall fescue)	$125.36	$6.61
9 & 12 (red clover)	44.59	2.90
10 & 13 (birdsfoot trefoil)	30.50	2.20

Two points are apparent; nitrogen fertilization is very expensive, and using a perennial legume which does not require reseeding will help to further reduce costs of summer pasture.

SUMMARY

Hereford-Angus crossbred steers were used to evaluate four beef cattle production systems, consisting of 13 dietary regimens, in terms of live animal performance, and quantitative and qualitative carcass characteristics. The experiments were replicated each year for the years 1977, 1978 and 1979, with a total of 352 steers. The dietary and management systems

investigated were intended to provide variation in grain and forage inputs and serve as a basis for determining the minimum amount of grain needed to produce acceptable beef.

Each year during October steer calves were purchased and after a two-week adjustment period, animals were uniformly allocated to the thirteen different treatments on the basis of live weight and body composition as determined by the whole body (^{40}K) counter technique. System I consisted of three treatments of drylot feeding of steers using either a corn silage diet alone or corn silage diet followed by a corn grain finishing diet. System II consisted of four treatments of winter backgrounding on stockpiled fescue, a spring and summer grazing period on either nitrogen fertilized tall fescue or tall fescue interseeded with red clover, followed by self-feeding of corn on pasture to slaughter. System III consisted of three treatments of winter backgrounding on stockpiled fescue following by spring and summer grazing on either nitrogen fertilized tall fescue, tall fescue-red clover or tall fescue-birdsfoot trefoil pastures until slaughter. System IV was the same as System III except the animals were placed in drylot after the grazing period and were fed corn grain diet until slaughter.

All steers assigned to System I (Treatments 1, 2 and 3) were fed corn silage diet for 203 days and gained .73 kg/d. Treatment 1 steers were slaughtered at the end of the grain period, weighing 381 kg. Treatment 2 steers were adapted to a higher energy corn grain diet and fed until a slaughter weight of 438 kg was reached (69 days). Daily gains averaged 1.12 kg for the three years. Steers assigned to Treatment 3 were fed the corn diet to a slaughter weight of 486 kg (102 days). The overall average slaughter weight for System I was 435 kg. The times required to reach slaughter weights of 381, 438 and 486 kg were 205, 270 and 303 days for Treatments 1, 2 and 3, respectively. Overall daily gains for the entire feeding period were .78, .81 and .87 kg, respectively. Consumption of corn was 605, 1062 and 1370 kg for Treatments 1, 2 and 3, respectively. It required between 3.78 (Treatment 1) and 5.21 kg (Treatment 3) of corn per kilogram of weight gain.

Steers assigned to Systems II, III and IV were winter-backgrounded from October until April (average of 159 d) on stockpiled tall fescue pastures and fescue hay. Normally .9 kg/day cracked corn was fed from January until April. Steers gained an average of .32 kg/day for the three years. After winter-backgrounding, steers assigned to System II were allowed to graze either nitrogen fertilized tall fescue or tall fescue interseeded with red clover pastures for 87 days. Daily gains were 15% faster (.68 vs .59 kg) for steers grazing fescue-red clover pastures compared to steers grazing nitrogen fertilized fescue pastures. This difference was considered to be of biological significance but was not statistically significant at the .05 level. Daily gains were not different between treatments when self-fed corn grain on pasture (average of 1.07 kg/d). One-half of the steers were slaughtered when body weight averaged 431 kg [Treatments 4 (fescue) and 5 (fescue-red clover)] and the remaining one-half were slaughtered at 477 kg [Treatments 6 (fescue) and 7 (fescue-red clover)]. Treatment 4 and 5 steers required 154 days of corn feeding to reach the designated final weights and 175 days were required for Treatment 6 and 7 steers. Overall, daily gains from purchase through slaughter were .61, .64, .65 and .66 kg for Treatments 4, 5, 6 and 7, respectively. Total weight gains produced were 241, 251, 269 and 274 kg for Treatments 4, 5, 6 and 7, respectively. Approximately 65% of the total gain was produced when corn was fed on pasture. Average steer slaughter weight was 481 kg for this system with total days required varying from 392 (Treatments 4 and 5) to 413 days (Treatments 6 and 7). Corn grain consumption was approximately 1150 kg/steer for Treatments 4 and 5 and approximately 1334 kg/steer for Treatments 6 and 7. It required between 4.63 and 4.95 kg of corn per steer per kilogram of gain.

The remaining steers not assigned to System II were assigned to System III. Steers on fescue-red clover or fescue-birdsfoot trefoil pastures gained from 16 to 28 kg more than steers on straight tall fescue. Slaughter weights were 296, 315 and 321 kg for treatments 8, 9 and 10, respectively. Length of grazing was from mid-April until October (average of 161 d). Steer days of grazing for fescue were 569 compared to 462 for fescue-red clover or 415 for fescue-birdsfoot trefoil pastures. The tall fescue pastures alone yielded more animal days of grazing, but the fescue-legume pastures compensated with higher daily gains so that the resulting gains/ha were nearly the same. Daily gains were 31% faster for steers grazing fescue-legume pastures compared to steers grazing nitrogen fertilized fescue pastures. It was observed that during period of high temperatures, animals on the straight fescue pastures showed more heat stress than animals on fescue-legume pastures.

One-half of System III steers were slaughtered directly off pasture while the remaining one-half were placed in the feed lot and fed corn grain finishing diet until slaughter weight averaged 477 kg. Daily gains and feed efficiency were greater ($P<.05$) for steers which had previously grazed N fertilized fescue (Treatment 11) and fescue-birdsfoot trefoil (Treatment 13) pastures compared to steers which had previously grazed fescue-red clover pastures (Treatment 12). Part of the improvement in performance may be compensatory growth. Average daily gains and DM/unit gain were 1.58, 6.61; 1.45, 7.18; and 1.52, 6.87 for Treatments 11, 12 and 13, respectively. Final slaughter weights were 494, 496 and 505 kg, respectively. Total days from purchase until slaughter were 437 for steers assigned to this system. Between 65 and 71% of the total weight gain was produced during the last 123 days when steers were fed the corn grain diet. Consumption of corn averaged between 1199 and 1206 kg/per steer for this system. Total gain produced by this system averaged 276 kg with final slaughter weight averaging 498 kg. It required an average of 4.35 kg of corn per kilogram of weight gain.

These data would support the idea that steers can be fed on a forage-based production system although requiring more days than a typical feedlot program (System I). The deferred feeding of corn on pasture (System II) allows the producer to take advantage of fall regrowth pastures and continue to own the steers to a heavier weight. Spring and summer grazing of fescue-legume pastures increased rate of gain but did not in this study increase carrying capacity compared to N fertilized fescue pastures. The practice of self-feeding corn on pasture has the advantage of reducing non-feed costs (feed trucks, forage storage and investments in buildings and other fixed facilities) that are incurred with a typical dry lot feeding system.

The dependence on a total forage finishing program does have certain inheritant problems. The major limitation may be to the producer who is paying interest on purchased animals which require significantly more days of ownership before a desired slaughter weight is achieved. Data from System II show that between 62 and 71% of the total gain produced occurred when corn was self-fed on pasture. Similar results were observed for System III. The total corn consumption was similar between Systems II and IV, with the only difference being in the number of days steers were allowed to graze pasture before the start of corn feeding.It might be questioned if the pastures alone contain enough TDN to provide a necessary rate of gain which will allow animals to reach desired slaughter weights and at the same time have an acceptable carcass.

Herbage from the pasture types did not differ greatly ($P>.05$) in their average seasonal values of percent IVDMD, CP, fiber components and minerals.There were some variations among pasture types within a season, particularly for Ca and P.

Significant ($P<.05$) correlations were found between steer average daily gain over the season and herbage levels of CP, IVDMD, ADF, NDF, Mg and P, but the highest correlation was only $r = 0.73$. Also, ADF, NDF and CP were significantly ($P<.05$) correlated with percent IVDMD.

Multiple regressions accounted for up to 80+% of the variation in steer ADG over the seasons. Factors most often appearing in multiple regression which maximized the coefficient of determination were in the ranked order of IVDMD, herbage bulk-height, Mg, Ca and CP.

All animals were slaughtered and USDA quality and yield grades and specific gravity of one-half of each carcass were determined. Steaks from the short loin were used for sensory analyses, Warner-Bratzler shear determinations and color evaluations. Top round roasts were used for shear and sensory analyses. Subcutaneous fat samples from animals on three treatments that grazed fescue pasture were analyzed by gas chromatography-mass spectrometry for volatile compounds to determine the relationship of volatile compounds to sensory panel flavor scores.

All treatments produced carcasses of acceptable weight for the current retail trade except the three all grass-fed treatments and the all corn silage treatment. Dressing percentages were highly dependent upon feeding regimen, grain-fed treatments having higher dressing percentages and grass-fed and silage-fed treatments the lowest dressing percentages. Animals from treatments with the highest plane of nutrition (grain-fed) produced carcasses with the higher marbling scores, higher carcass quality grades but lower carcass yield grades. The calculated percent fat from the specific gravity values indicated that the nutritional treatments which had the highest cutability carcasses also had the lowest percentage of fat.

Carcasses from animals on fescue pasture compared to those on fescue-legume pastures weighed less, had smaller ribeyes, less fat thickness and graded lower. However, when comparable animals that grazed fescue were placed in the feed lot and finished on corn grain, these animals exhibited greater compensatory growth than animals that grazed fescue-legume pastures and later finished in dry lot.

The color of the *longissimus* muscle from the silage-fed animals was the lightest red (higher Hunter color difference meter "L" values), that of the grass-fed the darkest red and the color of muscle from animals self-fed grain on grass or finished on grain in dry lot was intermediate in redness to that of the silage-fed and grass-fed animals.

Sensory evaluations revealed that loin steaks and top round roasts from animals on the grass-fed treatments were rated less desirable in tenderness, flavor and overall acceptability than samples from the other treatments. Essentially no differences in tenderness were observed between any of the other treatments, including silage-fed, grain on grass or grain in dry lot treatments. Silage-fed animals produced steaks and roasts equally as acceptable in tenderness and other sensory characteristics as animals finished on grain in dry lot or on pasture, even though the quality grade was lower. Steaks and roasts from animals that received *ad libitum* grain on pasture had some of the less desirable flavor that was characteristic of samples from the grass-fed animals. However, the addition of grain to the diet while the animals were grazing on pasture improved the flavor of meat compared to that of all grass-fed animals.

The greatest quantity of volatiles was detected from the fat of the animals fed exclusively on fescue pasture and the least amount from those finished on grain in dry lot following fescue pasture. Fat from steers fed grain on pasture had higher total volatile concentration than the dry lot fed animals, but considerably less than the fescue-fed animals. The nutritional treatment effect on the higher molecular weight compounds was associated with meat palatability, especially flavor.

Management Systems I and IV returned a net profit for all of the Treatments indicating that feeding corn silage in dry lot followed by grain (System I) and winter backgrounding and summer pasture followed by grain in dry lot (System IV) can be profitable and desirable methods for beef production. System II returned a net profit when animals were self-fed corn on pasture to the heavier weight and when the fescue pasture contained red clover. System III resulted in losses for all treatments because of the lower carcass weights and grades. However, this System when followed by finishing on grain in dry lot (System IV) was desirable and profitable.

In all treatments where cattle grazed fescue pastures containing a legume, advantages for the legume were noted in terms of animal performance and monetary return.

In terms of pasture production costs for the three year period of this investigation, the preferred pasture combination was fescue-red clover. However, when the production costs were projected over a ten year period both fescue-red clover and fescue-birdsfoot trefoil would be preferred over straight tall fescue.

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