EFFECT OF DIFFERENT PLANES OF NUTRITION

ON FEEDLOT PERFORMANCE AND BODY SIZE OF

FATTENING STEER CALVES

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1956

Submitted to the faculty of the Graduate School of the
Oklahoma State University of Agriculture and
Applied Science in partial fulfillment
of the requirements for the degree of
MASTER OF SCIENCE
May, 1961

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## ACKNOWLEDGMENT

The author wishes to express his appreciation to Dr. L. S. Pope of the Animal Husbandry Department for his guidance during the course of this study and in the preparation of this thesis.

Grateful acknowledgment is also extended to Dr. R. L. Henrickson for his invaluable assistance in obtaining the necessary carcass information.

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# INTRODUCTION

Recent studies indicate a change in consumer preference toward smaller, leaner cuts of beef with less fat. To better meet consumer demands, many feeders fatten weanling calves for market at 12 to 18 months of age. Calves are commonly full-fed, and, as a result, often have considerable fatness at time of slaughter.

Little information is available concerning the effects of different planes of nutrition on the feedlot performance of weanling calves. The majority of reports on the effect of nutritional levels have involved sheep and swine or, in a few instances, goats or poultry, and hence are not applicable to cattle. Furthermore, investigations concerning beef animals have, in most cases, employed rather extreme planes of nutrition and/or have been conducted over a 2 to 4 year period. Both factors tend to make the findings inapplicable to common feedlot practices.

Thus, information is needed on the extent to which body composition can be altered by moderately different levels of feeding. Also, the efficiency of conversion of ration constituents into body components merits investigation. Further, the quantity of fat necessary to produce beef of acceptable quality needs to be determined.

Four feeding trials were conducted at the Stillwater station to study the performance of individually-fed steer calves subjected to different planes of nutrition. Data were collected on rate of gain and feed efficiency, carcass merit, and body and carcass measurements. Steers on different nutritional planes were fed for the same total feedlot gain and also, in one trial, for the same length of time.

## REVIEW OF LITERATURE

### Early Studies

For some time it has been established that rate of gain and feed efficiency, carcass composition, and body measurements can be affected by nutritional treatment. As early as 1849, Lawes and Gilbert reported in Rothamstead Memoirs (according to Haecker, 1920) the chemical analysis of "a fat calf 9 or 10 weeks old,... a half-fat ox about 4 years old,... and a moderately fat ox about 4 years old." An inverse relationship between fat and water content was observed. Jordan (1895) conducted an elegant experiment with 4 Shorthorn steer calves, studying the effect of widely differing nutritive ratios on rate of growth and body composition. After 15 months of feeding, the pair of steers on the ration richer in protein (Nutritive ratio 1:5.2) had gained 221 pounds more than those on a ration containing a 1:9.7 nutritive ratio. However, after 25 months, the ration containing the wider nutritive ratio produced more favorable gains. Waters (1908) demonstrated the differential retardation of lean, fat and bone by extremely low planes of nutrition in steers. Skeletal growth continued although lean and fat tissues were extremely retarded. The length of the period of growth of normal beef steers is about 6 years. A low plane of nutrition was found to lengthen this period to as much as 9 years by Hogan (1929). Both severity of underfeeding and length of the period of underfeeding affected the eventual mature size. Eckles and

Swett (1918) noted similar effects with dairy cattle but commented on the strong tendency for animals to recover from retarded growth if the nutritional plane became more favorable later on.

In extensive experiments at Minnesota, Haecker (1916, 1920) studied the changes in body composition of steers at different stages of growth, as correlated with the feed requirements per cwt. gain from 100 pounds to 1200 pounds and 2 years of age. At younger ages, efficiency of feed conversion was much greater than when cattle approached maturity. Composition of early gains was primarily protein and minerals, whereas older steers had large deposits of fat.

Missouri workers have conducted extensive tests using rather extreme planes of nutrition. Trowbridge et al. (1918, 1919) studied the effects of full-feeding, supermaintenance (0.5 pound gain/day), maintenance, and submaintenance (-0.5 pound gain/day) with yearling steers to demonstrate a "saving" in nutrients at the lower feeding levels. Body measurements such as height at withers, depth and width of chest, width of hips and heart and paunch girths were markedly affected by the treatments imposed, but only after at least 3 months on test. When beef steers were fed from birth to 4 years of age for (1) maximum fattening, (2) maximum growth or (3) retarded growth, wide differences in live animal measurements were noted. At 4 years, however, height at withers was the same for all groups, and several other measurements were approaching equal values among treatments (Moulton et al., 1921, 1922a, 1922b). The ratio of carcass to live weight decreased to 8 1/2 months of age and then increased to a maximum at 3 to 4 years. Stomach and liver size were retarded by the low planes of nutrition. In contrast, Edinger (1925) observed similar weights of the empty internal organs when steers of varying fatness were slaughtered.

In general, these early studies indicate the effect of relatively severe treatments (particularly undernutrition) imposed from shortly after birth until the animal approaches maturity. While such extreme treatments have produced striking changes in carcass composition and have greatly expanded our knowledge, they are far from applicable to most feedlot operations today. More recent investigations, while still not of a practical nature in many cases, furnish information that is more readily applied to the present situation. Because of the multiple effects due to varying nutritional planes, the following review is divided into 3 parts, involving effect of plane of nutrition on (1) rate of gain and feed efficiency, (2) carcass merit and (3) body and carcass measurements.

## Effect of Plane of Nutrition on Rate of Gain and Feed Efficiency

It soon became obvious to early investigators that average daily gains were nearly always influenced by plane of nutrition. Perhaps the experiments most widely referred to are the classical studies by McMeekan (1940a, 1940b, 1940c). His studies with swine involved 4 feeding levels imposed from shortly after birth to 200 pounds live weight. The 4 treatments were:

(1) High plane throughout.

(2) High plane to 16 weeks of age followed by low plane.

(3) Low plane to 16 weeks of age followed by high plane.

(4) Low plane throughout.

Feed consumption was regulated so that the animals in each group developed according to predetermined growth curves. The results indicated that high plane pigs were less efficient (in terms of pounds of meal per pound of gain) than "High-Low" pigs (5.05 vs. 4.28 lbs. feed/lb. gain). Conversely, "Low-High" animals had the lowest efficiency (5.61 lbs) followed by pigs on the low plane throughout (5.19 lbs). McMeekan interpreted these differences as reflections of differential growth of body tissues. Restricting the animal when fat was the most rapidly growing tissue proved economical, calorie-wise, since the conversion of feed into fat is an expensive process. The same argument explains the poor performance of the "Low-High" group. It is readily seen that although long-term retardation of growth results in poor feed conversion, short-term retardation may actually improve feed efficiency.

The treatment design employed by McMeekan has been utilized by many investigators in modified forms. The trials reported in this thesis are based on this type of treatment arrangement. Winters et al. (1949) reported that the moderate group (Lot IV) was the most efficient, particularly when differences in maintenance requirements were considered. This merely suggests that lean carcasses are produced from less feed than fatter ones. This study was with swine also, but does not necessarily conflict directly with McMeekan's work since there were differences in starting time and, of course, in genetic material.

In other work with swine, restricting the feed intake from 100 to 170 pounds resulted in slower rates of gain and better economy of feed conversion (Shorrock, 1940). Brugman (1950) observed that limiting the feed intake to 70 percent of full feed increased length of time to reach

150 pounds by as much as 77 days. Lucas and Calder (1956) noted that pigs on "Very High-Restricted" and "Very Low - Very Low" planes were 11 to 12 and 63-88 days older, respectively, at slaughter than those on a "Very High - Very High" level. The VL - VL treatment resulted in a loss of 4 to 14 percent in feed conversion efficiency from that of the other groups. In later studies (Lucas et al., 1960), pigs on high (H-H) and low (L-L) planes of nutrition made 11 to 13 percent and 22 to 26 percent slower gains than pigs on a very high (VH-VH) plane from 8 weeks to 200 pounds. Feed conversion efficiencies were approximately equal. When swine on a VH plane to 100 pounds were subjected to (1) very high, (2) restricted or (3) low levels to 200 pounds, groups (2) and (3) made 18 percent and 36 percent slower gains, but were only 0 percent to 5 percent less efficient, respectively, when compared to the VH group. Similar results were reported by Merkel et al. (1958a) who observed decreases in average daily gains but essentially no differences in TDN per cwt. gain when fibrous feeds were incorporated in a swine ration to reduce the energy intake.

Thus the effects of varying the plane of nutrition on rate of gain appears to be marked, with average daily gain varying directly with plane of nutrition. The results are not as clear-cut, however, in terms of efficiency of feed conversion. Generally, restricted feeding from weaning or from 100 pounds live weight to market weight has not affected this trait as much as has restriction imposed shortly after birth.

In 1950, Brookes and Vincent (as reported by Hammond, 1955) and Brookes and Hodges (1959), in cattle experiments involving high, high-moderate, moderate-high and moderate treatments, noted results somewhat similar with those observed with swine. All groups were slaughtered at an estimated 57 percent dressing percentage. High and moderate-high level cattle reached this point in 2 years, high-moderates in 2 1/2 years and moderates in 3 1/2 years. Planes of nutrition were reversed, where indicated, at 8 months of age. The groups finishing on the high level of feeding, although the most rapid gainers, were least profitable because of the large amounts of expensive concentrated feeds required to produce gains. The most profitable group was the high-moderate because (according to the authors) the high plane of nutrition was supplied early in life when the potential for growth was high. By the time the moderate plane was introduced, the animals had reached a size where they could make good use of cheap bulky feeds.

Guilbert et al. (1944) also observed a high-moderate regime to be more profitable than a moderate-high treatment due to differences in amounts and kinds of feeds consumed. In this trial the latter group actually lost weight in the first phase and should be considered "low-high". Differences at slaughter were not great, however, which supports early work and later studies by Winchester et al. (1957), in which the ability of young beef cattle to survive on restricted intakes of protein and energy and to recover from these effects when feed is again abundant has been demonstrated. Calves restricted to maintenance allowances of protein or energy for 6 months and then fed for rapid gain took more time to reach the same slaughter grade but required essentially the same amounts of digestible nutrients per cwt. gain as twins liberally fed for rapid growth.

In general, effects of plane of nutrition on average daily gains and feed efficiencies of cattle have paralleled those observed with swine, but recent work in this area has been limited. Few reports of effects under feedlot conditions are available. Nelson (1945) stated that efficiency of feed utilization during fattening increases slightly to the Good grade (slightly lower grade for 2-year-olds, higher for yearlings) and Choice grade (calves). Beyond the average Good grade, efficiency drops rapidly; only 2 pounds of edible beef per 100 pounds of grain consumed vs. 6 pounds per 100 pounds before reaching average Good.

Western lambs were subjected to the following conditions by Weber et al. (1931): (1) Maintenance for 56 days, then 84 days on full feed, (2) full feeding for 84 days followed by 56 days of maintenance and (3) continuous full feeding for 140 days. Group 1 gained 7 pounds per head more on the 84 day full feeding period (after retardation) than did the second group when full-fed. Less grain, but more alfalfa, was needed to produce this increase. The authors state that from the standpoint of weight, finish and attractiveness, maintenance followed by full feeding was the most efficient method of prolonging the feeding period.

Extensive studies with sheep by Palsson and Verges (1952a) were patterned after McMeekan's swine studies. Lambs were reared on high and low planes of nutrition from the third month of fetal life to 41 weeks of age. Birth weights of twins, but not of singles, were decreased by the low plane. Throughout the test, wide differences in rate of gain, favoring the high group, were noted. Palsson and Verges (1952b) used H-H, H-L, L-H and L-L planes to study lamb development from the third month of fetal life to an estimated 30 pounds carcass weight. Treatments were changed, when indicated, after 6 weeks post-natal life. Slaughter ages were 9, 15, 15, and 41 weeks for the four levels, respectively. No feed efficiency values were reported. Average daily gains were markedly influenced by the levels of nutrition imposed.

Two studies by Wilson (1958, 1960) utilized HH, HL, LH and LL treatments to explore the nature of growth and development of dwarf goats. High plane kids reached the 33 pound final weight in 26 weeks, compared to 48 weeks for the low plane group. As has been observed with all other species studied, LH groups outgained HH groups during the second half of the trial. Similarly, in several species, animals frequently gain less on a HL regime during the second phase than those on LL treatments do. At slaughter, the ruminant stomachs of low plane kids were much larger than for kids on a high plane due to the functional requirements of kids on the different diets.

Three groups of chickens (A, B and C) were used to compare weight gains and feed efficiencies for different feeding patterns of a restricted ration by Osbourn and Wilson (1960). Group B (compensatory growth regime) showed a greater relative growth rate after re-alimentation than group A (milk restriction followed by _ad libitum_ feeding), due partially to an increase in appetite. Group C was used as a control and fed _ad libitum_. Efficiency of food conversion was essentially the same for groups B and C, with group A slightly more efficient than either B or C.

It appears from the foregoing discussion of the effects of different planes of nutrition on rate of gain and feed efficiency that many species, although they may differ widely in several respects, respond similarly to varied nutrient intakes. Daily gains were noticeably affected in every study reported, as was expected. Feed efficiencies, however, were often unchanged, and occasionally favored the lower plane. The high-moderate or high-low system was often found to be more efficient than the other treatments.

## Effect of Plane of Nutrition on Carcass Merit

Many of the carcass studies reported in the literature are rather extensive in scope. Primary emphasis for the articles reviewed herein will be the effect of plane of nutrition on live and carcass grades, yield and marbling scores.

Merkel et al. (1958b) observed lower carcass grades and dressing percentages by restricting TDN intake of swine with high fiber rations. Comparing HH and LH treatments, Brugman (1950) noted that the LH regime resulted in leaner, lower grading carcasses. No differences in yield were discernible. However, Shorrock (1940) found restricted feeding of bacon pigs to have little effect on carcass quality, except for a tendency toward production of slightly thinner backfat. Dressing percentages were essentially equal. Using HH, HL, LH and LL levels of feeding, Winters et al. (1949) observed backfat thickness values of 1.69, 1.45, 1.52 and 1.37 inches for the above treatments, respectively, and 2-3 percent lower yields for the last three groups when compared to the H-H plane. Lucas et al. (1960) and Lucas and Calder (1956) reported slightly less backfat but no differences in yield when pigs on a very high plane were restricted (moderately) or placed on a low plane.

Guilbert et al. (1944) were able to detect very little difference between treatment groups (HM and MH) with respect to either carcass grade or dressing percentage. Beef steers used were on range, supplemented with grain on the high plane of nutrition. Winchester et al. (1957)

observed that protein or energy restriction of calves for 6 months did not measurably influence carcass composition or merit, with 2 exceptions where both protein and energy were restricted.

A deterioration in both live and carcass grade was noted when full-fed lambs were held at constant weight, as well as a decreased dressing percentage (Weber et al., 1931). Lambs which had been held to maintenance for 56 days and then full-fed for 84 days produced "very desirable carcasses." Palsson and Verges (1952a) obtained a marked decrease in yield of lamb carcasses on a low plane of nutrition when compared to a high level. Carcass and live grades were not reported. The 4 treatments used by Palsson and Verges (1952b) produced 2 distinct kinds of lamb carcasses. The High-High and Low-High groups were similar in conformation and desirability, and appeared markedly superior to carcasses obtained from the High-Low and Low-Low groups. The degree of marbling in the Longissimus dorsi muscle appeared to be more dependent on age of the animal than on the plane of nutrition, being lowest in the High-High and highest in the Low-Low carcasses.

Wilson (1960) did not report dressing percentages or grades for dwarf goats. However, the dry matter content of the carcass increased among treatments in this order: LL, HL, LH and HH. Many characteristics could be compared in 2 groups; LL and HL vs. LH and HH. Thus, the predominant effect of reversing nutritional planes appears to be that associated with the level used in the second phase of the trial.

These studies on the effect of different planes of nutrition on carcass merit generally indicate a reduction in fat content when growth is retarded, which in turn reflects lowering of carcass grade (with some exceptions, as in the case of swine). Trends in dressing percentage frequently paralleled carcass grades. In most cases where differences in grade or yield were not observed, the designs of the trials were such that carcass differences would be minimized or at least reduced, i.e. removal from experiment at an estimated fatness, yield or carcass weight. Marbling score, however, appeared to be influenced as much by age differences as by plane of nutrition in some instances.

## Effect of Plane of Nutrition on Body and Carcass Measurements

As with carcass studies, no attempt has been made here to exhaust the literature, nor to include individual measurements which have little bearing on the trials reported herein. Rather, an effort has been made to present some of the general trends resulting from various planes of nutrition.

In both sheep and cattle, the normal age-changes in body proportions can be altered by controlling the growth curve of the animal. Waters (1908) noted that when steers were kept on maintenance and sub-maintenance rations for prolonged periods of time, changes in conformation occurred and the steers continued to grow in some dimensions. Although the steers were losing weight, they increased in height at withers. On the other hand, width measurements at hips and chest decreased. This regression toward a more juvenile form was established as being due to continued growth of long bones at the expense of body tissues (fat reserves). Guilbert et al. (1944) noted a relative increase in development of "thickness" dimensions on a high-moderate plane of nutrition, particularly in the later maturing loin and hindquarter regions. This indicates the influence of high levels of feeding during a period when the impulse for skeletal growth is still rather strong (as contrasted to a moderate-high regime).

McMeekan (1940a, 1940b, 1940c) has described changes in body and carcass measurements in detail. Those parts which are least developed at birth exhibit the greatest impulse to grow at a time when they can be influenced by nutritional treatment. In general, leg measurements (particularly toward the extremities) increase relatively less than those of the trunk. Length growth is related to bone development, and thickness growth to an increase in muscle and fat, which occurs at a more rapid rate during the later ages. In swine, length of leg, length of body, length of carcass and depth of chest showed the greatest differences among treatments at 16 weeks of age. At slaughter weight (200 pounds) the heavier-boned treatment groups (Low-Low and High-Low) yielded the longest pigs, as measured by body and carcass length and length of leg.

Brugman (1950) observed increases in body length and decreases in width of shoulder, width of loin, width of ham and depth of body when low plane pigs were compared to high, which is in line with the expected trend. None of the values approached significance, however.

Steers of shorter height at withers and length of body, and larger heart girth and width of shoulder, tend to have slightly higher slaughter and carcass grades (Cook _et al_., 1951) and therefore may reflect higher levels of feedings. According to Kohli _et al_. (1951), circumference of foreflank is more indicative of average daily gain, efficiency of feed utilization, and age at slaughter than are height at withers, height to floor of chest, width at shoulders and length of body.

It appears from the foregoing discussion that plane of nutrition can markedly affect the development of the skeleton and, to a larger extent, fleshing measurements if the feeding levels used differ widely. Under more practical conditions, these relationships are more difficult to determine with precision. Heart girth has been most closely related to plane of nutrition of the live animal dimensions studied. Other width and depth of body measurements also show some promise.

## EXPERIMENTAL

A series of three trials was initiated in December, 1956, at the experimental feeding pens located at Stillwater. A total of 64 weanling Hereford steer calves from the experiment station herd at Fort Reno was used. A fourth trial was also conducted in 1959-60 with 24 similar calves from the same herd.

### Trials I, II and III

The experimental design used in Trials I, II and III is shown in Table I.

TABLE I. DESIGN OF EXPERIMENT (TRIALS I, II AND III)

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Phase I (200 lb. gain) | High | High | Moderate | Moderate |
| Phase II (200 lb. gain) | High | Moderate | High | Moderate |
| Numbers of steers used | | | | |
| Trial I (1956-57) | 4 | 4 | 4 | 4 |
| Trial II (1957-58) | 5[1] | 5[1] | 5[1] | 5[1] |
| Trial III (1958-59) | 6 | 6 | 6 | 4[2] |
| Total | 15 | 15 | 15 | 13 |

[1]One steer was removed from each treatment group in Trial II: One steer died due to bloat; another was removed because of a throat injury; and two were removed because of poor performance.

[2]Two steers were removed from the MM group in Trial III because of chronic bloat and poor performance.

The 4 treatments employed each year were: HH--Full-fed to gain rapidly for 400 pounds total feedlot gain; HM--Full-fed to gain rapidly for 200 pounds, then fed to gain moderately for the remaining 200 pounds feedlot gain; MH--Fed to gain moderately for the first 200 pounds, then full-fed to gain rapidly for 200 pounds; MM--Fed to gain moderately for 400 pounds total feedlot gain.

In the first trial, 16 steers from related sires were used; 8 calves by sire 1-03 and 4 by each of 2 half-brother bulls, 09 and 11. In the second experiment, 24 steers were used sired by 2 pairs of half-brother bulls (6 each by bulls D-95 and D-84, 8 by 4-68 and 4 by 4-50). Sixteen calves sired by half-brothers 5-23 and 5-85 (8 by each) and 8 steers by 2 other related bulls (469 and 5-26, 4 by each) comprised the 24 head used in the third trial. However, due to an error in identity of the calves, one steer sired by 5-85 was sold prior to allotment and since no more progeny of the above sires were available, a calf sired by bull 5-16 (a half-brother) was substituted.

The above sire groupings were utilized in allotment to the treatment groups, along with shrunk weight of the calves (16 hours off feed and water), feeder grade, age of calf, and treatment and age of dam insofar as possible. A 2-3 week adjustment period preceded each trial to allow the steers to adapt to the experimental rations and the change in environment.

In all tests, the calves were individually fed in stanchioned stalls, twice daily. Between feedings the calves were allowed the freedom of the pen (8 steers per lot) and had access to water and a mineral mixture of 2 parts salt and 1 part steamed bonemeal, free choice. Stanchion time consisted of 1 1/2 - 2 hours per feeding. Any feed refused was weighed back and recorded.

The steers in the first three trials were kept on experiment until it was estimated (by shrunk weights) that they had gained a total of 400 pounds. This has approximated the gain made by weanling steers in achieving a low choice slaughter grade in previous trials at this station. To achieve this, calves on the high plane of nutrition were fed approximately 2 pounds of rolled milo per cwt. daily (which is about the amount of grain consumed by steers when self-fed a fattening-type ration) and calves fed at the moderate plane received one-half this amount, or approximately 1 pound of milo per cwt. per day. In addition, each steer was offered 1.5 pounds of cottonseed meal and 1.0 pounds of dehydrated alfalfa pellets daily, plus approximately 0.75 pounds (high plane groups) and 1.5 pounds (moderately-fed groups) of cottonseed hulls per cwt. per day. It was hoped that use of these rations would result in gains in excess of 2.0 pounds per day for the high lots and from 1.3 to 1.5 pounds per day for the moderate-fed groups. The average percent composition of feeds used in formulating these rations is shown in Table II, while the estimated chemical composition values, as well as TDN and net energy values, are given in Table III.

TABLE II. AVERAGE PERCENT COMPOSITION OF RATIONS (TRIALS I, II and III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Rolled milo | 65.5 | 49.9 | 54.9 | 40.4 |
| Cottonseed meal | 6.8 | 8.1 | 7.8 | 8.7 |
| Dehydrated alfalfa pellets | 5.1 | 5.6 | 5.4 | 5.8 |
| Cottonseed hulls | 22.6 | 36.4 | 31.8 | 45.1 |

[1]Percent composition for individual trials is shown in Appendix Table XX.

TABLE III. ESTIMATED PERCENT CHEMICAL COMPOSITION OF RATIONS (TRIALS I, II and III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Dry matter | 89.9 | 89.6 | 90.0 | 90.4 |
| Ash | 2.9 | 3.1 | 3.0 | 3.2 |
| Crude protein | 11.7 | 11.2 | 11.4 | 10.8 |
| Ether extract | 2.7 | 2.5 | 2.5 | 2.3 |
| Crude fiber | 13.7 | 19.8 | 17.7 | 23.6 |
| N-free extract | 58.9 | 53.7 | 55.3 | 50.5 |
| TDN[2] (lb) | 69.5 | 64.4 | 66.0 | 61.2 |
| Net energy[2] (therms) | 64.8 | 57.8 | 60.1 | 53.5 |

[1]Composition was estimated by chemical analysis of ration components.

[2]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

Average composition of rations for individual trials are presented in Appendix Table XX.

All cattle were shrunk and weighed periodically (at 21-28 day intervals) throughout each trial. Individual animals were weighed more frequently as they approached 200 pounds gain (Phase I of trial) or slaughter weight at the end of Phase II (400 pounds feedlot gain). Feed allowances were adjusted for every 50 pounds increase in body weight.

Live animal measurements were taken at the beginning, half-way point, and termination of each test. These included height at withers, length of body, heart girth, width of shoulder, width of loin and width of round. Other data included individual feed records, average daily gains and length of time required to reach slaughter weight.

As each steer was removed from experiment for slaughter at the Meats Laboratory, a live slaughter grade was determined by a committee of 3-5 representatives of the Animal Husbandry department. A similar committee was employed to evaluate the carcasses in terms of grade and marbling score. Dressing percentages were obtained, and at time of slaughter, the 4 compartments of the ruminant stomach were weighed, emptied, and reweighed to obtain an estimate of fill. In addition, the following carcass measurements were taken: carcass length, length of leg, circumference of round (first 2 years only), length of loin, depth of body, width of shoulder and width of round. Reference points for these measurements are presented in Appendix Table XIX.

## Trial IV

The 24 calves utilized in the fourth test were by 5 different sires; 6 each were progeny of D-95, 5-85 and 6-44, and bulls 6-05 and 6-09 sired 3 steers each. Sires 5-85 and 6-44 were half-brothers, as were bulls 6-05 and 6-09. Trial IV differed from the previous experiments in that only 3 treatments were employed, as follows:

1. High -- Full-fed to gain rapidly for 350 pounds total feedlot gain.
2. Moderate I -- Fed to gain moderately and removed from test at the same time as the high group.
3. Moderate II -- Fed to gain moderately for 350 pounds total feedlot gain.

Allotment of cattle, method of feeding and handling, and collection of data were essentially the same as described for earlier trials. The ration was changed, however, by the addition of sorghum silage and a decrease in cottonseed hull content. It was hoped that this would provide a more palatable mixture and result in a greater feed intake of the high level calves. The percent composition and estimated chemical composition are shown in Tables IV and V, respectively. Estimated TDN and net energy values are also included in the latter table.

TABLE IV. AVERAGE PERCENT COMPOSITION OF RATIONS (TRIAL IV)

| Plane of Nutrition | High | Moderate I[1] | Moderate II[2] |
|---|---|---|---|
| Rolled milo | 52.4 | 26.7 | 29.4 |
| Cottonseed meal | 6.2 | 6.0 | 6.2 |
| Dehydrated alfalfa pellets | 4.2 | 4.0 | 4.9 |
| Cottonseed hulls | 8.5 | 16.0 | 18.1 |
| Sorghum silage | 28.8 | 47.2 | 41.5 |

[1]Moderate I steers were fed to gain moderately and removed from test at the same time as the High group.

[2]Moderate II steers were fed to gain moderately for 350 pounds total feedlot gain.

TABLE V. ESTIMATED PERCENT CHEMICAL COMPOSITION OF RATIONS (TRIAL IV)[1]

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Dry matter | 71.2 | 59.3 | 63.2 |
| Ash | 2.5 | 2.4 | 2.6 |
| Crude protein | 9.8 | 7.4 | 8.0 |
| Ether extract | 2.4 | 1.9 | 2.0 |
| Crude fiber | 8.7 | 12.7 | 13.6 |
| N-free extract | 47.7 | 34.8 | 37.2 |
| TDN (lb) | 57.0 | 42.8 | 45.5 |
| Net energy (therms) | 54.0 | 38.8 | 41.2 |

[1]Composition was calculated using values of Morrison (1956).

Data obtained were similar to those collected during the first 3 trials, except that only 2 sets of live animal measurements were taken (initial and final), and the contents of the stomachs were not determined, thus no estimate of fill was available.

## Statistical Analysis

The data in all 4 trials were analyzed according to methods described by Snedecor (1956). Outlines of the analyses used are presented in Appendix Tables XVII and XVIII. Orthogonal comparisons were made to compare differences among treatment groups.

# RESULTS AND DISCUSSION

Results of Trials I, II and III involving 4 different nutritional regimes are presented, followed by a discussion of Trial IV with 3 treatment groups. The results of the first 3 trials are discussed according to the effect of plane of nutrition on rate of gain and feed efficiency, carcass merit, and body and carcass measurements.

## Effect of Plane of Nutrition on Rate of Gain and Feed Efficiency

### Effect on Rate of Gain

Average weight gains for the 3 trials are presented in Table VI. Corresponding values for individual trials are shown in Appendix Table XXI. Data from animals which were removed due to illness, death loss or poor performance are not included in the averages shown. This involved 1 steer from treatment groups HH, HM and MH, and 3 steers from the MM group.

In each trial, average daily gains for the total period showed a similar trend. HH and MH groups tended to outgain the groups which terminated the test on a moderate plane of nutrition ($P < .10$, $P < .001$ and $P < .025$ for Trials I, II and III, respectively). Essentially the same trend and levels of significance were obtained for length of time on feed, as was to be expected since the experiments were designed so that all groups were fed to gain the same total amount. Thus, days on feed were inversely proportional to average daily gains.

TABLE VI. AVERAGE WEIGHT GAINS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIALS I, II AND III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Time on feed (days) | 211[2] | 251 | 221[2] | 261 |
| Av. weights (lb)[3] | | | | |
| Initial | 485 | 476 | 473 | 492 |
| Final | 874 | 856 | 863 | 882 |
| Av. daily gains (lb) | | | | |
| Phase I | 2.25[4] | 2.15[4] | 1.90 | 1.80 |
| Phase II | 1.62[2,5] | 1.17[5] | 1.74[2] | 1.36 |
| Total period | 1.88[2] | 1.54 | 1.79[2] | 1.55 |
| Total period minus fill[6] | 1.60[2] | 1.30 | 1.51[2] | 1.27 |

[1]Weight gains for individual trials are shown in Appendix Table XXI.

[2](HH + MH) significantly different from (HM + MM) at $P < .001$.

[3]Shrunk weights (16 hours off feed and water).

[4](HH + HM) significantly different from (MH + MM) at $P < .001$.

[5](HH + HM) significantly different from (MH + MM) at $P < .01$.

[6]Contents of rumen, reticulum, omasum and abomasum were determined at time of slaughter and deducted from live animal weight.

There were marked differences in rate of gain between years ($P < .001$). In 1956-57 all treatment groups were removed from test within a relatively short interval. Also, overall average daily gains decreased markedly from year to year (1.95 vs. 1.68 vs. 1.52 pounds per steer per day). Differences among trials in amount of total gain, quality of calves, weather conditions and daily nutrient intake may have contributed to this variation. Further, the first trial was conducted by a different investigator.

Much of the difference in significance noted between Trial I and Trials II and III in total average daily gains can be attributed to differences in fill, estimated by determining the contents of the four compartments of the ruminant stomach at time of slaughter. When average daily gains were calculated using live weight minus fill, differences between calves finishing on a moderate level and on a high feeding regime were significant for each year ($P < .05$ or less).

The 3-year average shows the above comparison, HH and MH vs. HM and MM, to be highly significant ($P < .001$) for both total average daily gain and total average daily gain minus fill. The pronounced influence of the plane of nutrition employed in the second phase on overall performance has been observed by several other investigators (Hammond, 1955; Brookes and Hodges, 1959; Guilbert et al., 1944; Weber et al., 1931; and Wilson, 1952, 1958, 1960).

As would be expected, feedlot gains in Phase I each year reflected the plane of nutrition imposed. Comparisons between the high groups and moderate groups were highly significant ($P < .025$ or $P < .01$). In Trial III, however, significance was also obtained for HH and MH vs. HM and MM treatments ($P < .05$), apparently as a result of the poor performance of the MM group. The 3-year average for Phase I reflects the expected results, with full-fed steers outgaining the moderate groups ($P < .001$).

In Phase II, steers full-fed (HH and MH) were significantly faster gainers, in each test, than those on a moderate level of nutrition ($P < .05$ or less). Moderates converted to a high plane gained more rapidly than HH steers, while the HM group made lower average daily gains than the MM group, in each trial. This observation may reflect differences in the maintenance requirements due to the plane of nutrition to which the steers were subjected in Phase I. Many workers have observed a similar pattern

(Winters et al., 1949; Lucas and Calder, 1956; Winchester et al., 1957; Weber et al., 1931 and Wilson, 1952, 1956 and 1958). The same argument can be applied to the significantly lower daily gains of the HH and HM groups in Phase II of Trials I and II ($P < .05$ and $P < .01$, respectively). The above effect was also observed in the 3-year average ($P < .01$).

Effect on Feed Efficiency

Previous studies have not shown as unanimous agreement on effects of different nutritional planes on feed efficiency as on rate of gain. Average daily feed consumption and calculated TDN and net energy intakes for the trials reported herein are presented in Table VII, while Appendix Table XXII contains corresponding values for the individual trials. Feed intake in the second and third trials was lower than in the first trial, as reflected by decreased rate of gain. The reason for the decreased feed consumption is not apparent.

TABLE VII. AVERAGE POUNDS OF FEED, TDN, AND THERMS OF NET ENERGY CONSUMED PER DAY BY STEERS ON DIFFERENT PLANES OF NUTRITION (TRIALS I, II AND III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Rolled milo | 12.4 | 8.5 | 9.7 | 6.8 |
| Cottonseed meal | 1.3 | 1.4 | 1.4 | 1.5 |
| Dehydrated alfalfa pellets | 1.0 | 1.0 | 1.0 | 1.0 |
| Cottonseed hulls | 4.3 | 6.2 | 5.6 | 7.5 |
| Total | 18.9 | 17.0 | 17.7 | 16.7 |
| TDN[2] | 13.1 | 11.0 | 11.7 | 10.2 |
| Net energy[2] | 12.2 | 9.8 | 10.6 | 8.9 |

[1]Corresponding values for individual trials are shown in Appendix Table XXII.

[2]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

Full-fed calves (HH) consumed less milo than was anticipated, eating 12.4 pounds instead of an estimated consumption of 13.8 pounds per head daily. Also, difficulty was encountered with MM steers in obtaining expected consumption of cottonseed hulls which resulted in less total feed intake than was hoped for, particularly in Trial III. For the 3 trials, the HH steers consumed an average of 5.6 pounds more milo, 3.2 pounds less hulls and 2.2 pounds more total feed than the MM group. HM and MH groups were intermediate, the latter averaging 1.2 pounds more milo, 0.6 pound less hulls, and 0.7 pound more total feed than the HM group.

Average TDN and net energy intakes per steer per day show relatively greater differences among treatments than total feed. This is due to the TDN and net energy contents of the rations, which varied as much as 8.3 percent in TDN and 11.3 percent in net energy (Table III, Experimental). The greater range in net energy content among rations is primarily the result of differences in cottonseed hull content, since the net energy system assigns roughages a much lower value than the TDN system of feed evaluation. In each of the 3 trials, amounts of TDN (lb) and net energy (therms) consumed per day decreased in the following order: HH, MH, HM and MM. This parallels average daily gain relationships among treatments.

Daily nutrient intake in this type of study has not been emphasized in the literature since it has been experimentally controlled in most cases. It has been discussed here in support of rate of gain differences, as well as to show variations from intended feeding levels. Prior investigations have emphasized feed efficiency, however. Feed efficiency values are presented in Table VIII, with a comparison of TDN and net energy as measures of efficiency of feed use. Corresponding individual trial values are shown in Appendix Table XXIII.

TABLE VIII. AVERAGE POUNDS OF FEED AND TDN AND THERMS OF NET ENERGY CONSUMED PER POUND OF GAIN BY STEERS ON DIFFERENT PLANES OF NUTRITION (TRIALS I, II AND III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Rolled milo | 6.6 | 5.5 | 5.4 | 4.4 |
| Cottonseed meal | 0.7 | 0.9 | 0.8 | 0.9 |
| Dehydrated alfalfa pellets | 0.5 | 0.6 | 0.5 | 0.6 |
| Cottonseed hulls | 2.3 | 4.0 | 3.2 | 4.9 |
| Total | 10.0[3] | 11.0 | 9.9[3] | 10.8 |
| TDN[2] | 7.0[4] | 7.1[4] | 6.5 | 6.6 |
| Net energy[2] | 6.5[4] | 6.4[4] | 5.9 | 5.7 |

[1]Corresponding values for individual trials are shown in Appendix Table XXIII.

[2]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

[3](HH + MH) significantly different from (HM + MM) at $P < .01$.

[4](HH + HM) significantly different from (MH + MM) at $P < .01$.

Using pounds of feed per pound of gain as the measure of efficiency, it is apparent from the 3-year average that the greatest efficiency was observed on the HH and MH regimes; the HM and MM groups consumed 0.8 to 1.1 pounds more feed per pound of gain ($P < .01$). In Trial I, no significant differences in total feed consumed per pound of gain were obtained. The trend, however, was similar to the overall average with the exception of the MM group, which proved to be remarkably efficient. The same trend observed in the 3-year average was noted in Trial II ($P < .005$) and Trial

III ($P < .05$). A slight interaction ($P < .10$) was also noted in the third year (HH and MM vs. MH and HM), due to the relatively poor gains of HH steers, despite maximum feed intake.

Use of total feed as a measure of efficiency can be misleading if the rations differ in kinds and amounts of feeds contained. From the average of 3 trials, TDN consumed per pound of gain was significantly lower for MH and MM groups than for HH and HM groups ($P < .01$). It may be recalled that HH and MH lots were most efficient in terms of total feed. While HH steers required less feed, the greatest proportion was rolled milo, and TDN content of the ration was 69.5 percent. In contrast, MM calves were fed a ration containing 61.2 percent TDN (Table III, Experimental). Thus, although 0.8 pound more feed was consumed, 0.4 pound less TDN was required per pound of gain by moderately-fed steers.

The same general trend applies when net energy is used, rather than TDN, as a measure of feed efficiency. However, values were lower and groups receiving a higher percentage of cottonseed hulls were slightly favored, since roughages are much lower in net energy than in TDN.

On an individual trial basis, the results are less easily interpreted. In Trial I, both TDN and net energy required per cwt. gain were significantly less ($P < .05$) on the HH and HM planes; the same was observed in Trial III for TDN ($P < .05$) and net energy ($P < .01$). These trends agree with the 3-year average. In the first trial, a slight interaction ($P < .10$) was noted, where HH and MM groups required less TDN per pound gained than the intermediate groups. However, when differences in fill were considered, this difference was no longer observed. Net energy required per pound of gain was less for HM and MM groups in Trial I ($P < .10$), which may be a reflection of higher roughage diets being favored when feed efficiency is expressed as net energy.

However, in Trial II the reverse situation occurred. Less net energy was needed by the HH and MH groups ($P < .10$). A more marked difference was noted for TDN, in which case HH and MH groups were again more efficient than steers on HM and MM treatments ($P < .01$). This is probably associated with maintenance requirements, since HH and MH groups reached final weight 68 days earlier than steers on the other treatments.

The effect of plane of nutrition on feed efficiency reported for Trials I, II and III is generally different from that found in the literature. McMeekan's swine studies (1940a, 1940b) have emphasized the greater efficiency of the HL group, followed in sequence by HH, LH and LL treatments, which is nearly the reverse of the array for TDN and net energy indicated in Table VIII.

One reason for this difference is that the impulse for the expensive fattening process is much stronger in swine than in cattle, particularly at the ages when these species are commonly being fed for slaughter. Most other reports with swine also cite advantages in feed effeciency by restricting energy content of the ration after 100 pounds live weight was attained (Shorrock, 1940; Lucas and Calder, 1956), although Merkel et al. (1958a) and Lucas et al. (1960) reported negligible differences in efficiency of feed conversion. Winters et al. (1949), with swine, observed the moderate group to be most efficient when maintenance requirements were considered.

With cattle, other workers have reported that HM regimes are more desirable than MH treatments because of the large amounts of expensive concentrates needed for the latter groups (Hammond, 1955; Brookes and Hodges, 1959; Guilbert et al., 1944). These studies were pursued, in part, on pasture or range and were of 1-3 year's duration. Winchester et al. (1957) found no difference in TDN required per cwt. gain when LH and HH calves (changed at 6 months of age) were fed to the same slaughter grade.

While no literature has been cited supporting the feed efficiency pattern obtained in the 3 trials reported herein, the conditions imposed and/or species used in previous studies make direct comparisons of little value. Most discrepancies can be explained on this basis.

## Effect of Plane of Nutrition on Carcass Merit

Carcass data for the first 3 trials are presented in Table IX, with the results of individual years shown in Appendix Table XXIV. Live slaughter grade scores, as determined independently by 3-5 members of the panel, favored the HH and MH groups full-fed in Phase II ($P < .01$). Grades were approximately "average-to-high good" for these groups and "average good" for the HM and MM treatments. Carcass grade scores, obtained in the same manner, showed an almost identical pattern ($P < .025$) but further revealed a significant difference ($P < .01$) between full-fed and moderately-fed calves in Phase I, which graded "high good" and "average good," respectively.

It is interesting to note that the differences, although statistically significant, were quite small. In Trials I and II, both live and carcass grades were significantly different ($P < .05$) when HH and MH treatments were compared to HM and MM groups. In Trial III, a different pattern appeared, where HH and HM groups graded higher than MH and MM groups ($P < .05$). This difference was also noted for carcass grades in Trial II.

TABLE IX. CARCASS DATA (TRIALS I, II AND III)[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Live slaughter grade[2] | 14.8[3] | 16.3 | 15.2[3] | 16.2 |
| Carcass grade[2] | 14.2[4,5] | 15.2[4] | 15.7[5] | 17.2 |
| Dressing percent[6] | 61.0 | 60.7 | 60.3 | 60.7 |
| Marbling score[7] | 16.7[8] | 17.0[8] | 20.2 | 20.8 |

[1]Carcass data for individual trials are shown in Appendix Table XXIV.

[2]High good = 14, average good = 16 and low good = 18.

[3](HH + MH) significantly different from (HM + MM) at $P < .01$.

[4](HH + HM) significantly different from (MH + MM) at $P < .01$.

[5](HH + MH) significantly different from (HM + MM) at $P < .025$.

[6]Based on shrunk slaughter weight (16 hours) and chilled carcass weight (48 hours).

[7]Subjective score; lowest values indicate best marbling.

[8](HH + HM) significantly different from (MH + MM) at $P < .025$.

Thus, a variable effect of different planes of nutrition on live and carcass grades appears. With swine, decreased backfat thickness has been noted when lower nutritional planes have been imposed (Merkel et al., 1958b; Brugman, 1950; Shorrock, 1940; Winters et al., 1949;

Lucas and Calder, 1956; Lucas et al., 1960). However, Guilbert et al. (1944) and Winchester et al. (1957) did not detect grade differences when cattle were subjected to different feed levels and then fattened to approximately the same yield and weight. High-low treatment was found to decrease lamb carcass grades, when compared to the low-high treatment, by Weber et al. (1931) and Palsson and Verges (1952b).

Dressing percentages were generally less affected by changes in feeding plane. The 3-year average (Table IX) shows small, insignificant differences among treatments and no trend is apparent among the treatments imposed. Yield data for individual years was more variable, but, in general, no consistent trends were observed. This was expected since grade differences were not large. Merkel et al. (1958b) and Winters et al. (1949) obtained lower yields when swine were subjected to restricted rations, whereas other workers (Brugman, 1950; Shorrock, 1940; Lucas et al., 1960; Lucas and Calder, 1956) were unable to detect differences in yield with swine subjected to different nutritional levels. Similar results have been reported with cattle (Guilbert et al., 1944; Winchester et al., 1957). However, when sheep were used by several investigators, lower dressing percentages were obtained on restricted or low planes of nutrition (Weber et al., 1931; Palsson and Verges, 1952a, 1952b).

Marbling score data indicated more intramuscular fat for the HH and HM groups than in the case of MH and MM treatments ($P < .025$). This same general trend was observed in each of the three trials. Since marbling is an important consideration in carcass grading, it is not surprising that the two vary in the same direction. British workers, however, have observed that marbling in lambs is more dependent on age of the animal than on the plane of nutrition imposed (Palsson and Verges, 1952b). This may explain the difference in marbling score in favor of the HM group, compared to MH, despite the similarity in grade. High-moderate steers were slightly older at time of slaughter.

## Effect of Plane of Nutrition on Body and Carcass Measurements

Average live animal measurements for Trials I, II and III are presented in Table X. Appendix Tables XXV through XXX show corresponding values for individual trials, together with the reference points used in taking these measurements.

When the three trials were averaged, no significant differences were observed for height at withers or length of body, measurements which might be expected to reflect changes in skeletal development. In Trial I, Phase I, length of body increases were greater for HM and MM groups (3.4 inches vs. 2.0 inches), while height at withers increased 1.3 inches for MH and MM steers compared to -0.2 inches for the HH and HM steers ($P < .10$). This indicates a lack of precision in obtaining many of the live measurements, due to variations in stance of the animal and possible errors in use and position of the calipers.

Length and height measurements are less influenced by different nutritional levels than "thickness" dimensions. Waters (1908) observed an increase in height, even when steers were losing weight. At 200 pounds, swine on HL and LL treatments were longer in body and leg measurements than LH and HH groups, according to McMeekan (1940b).

TABLE X. AVERAGE LIVE ANIMAL MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIALS I, II AND III)[1,2]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Height at withers | | | | |
| Initial | 39.4 | 40.4 | 39.5 | 39.6 |
| Mid point | 41.4 | 41.3 | 41.3 | 41.2 |
| Final | 44.4 | 44.8 | 44.3 | 44.3 |
| Length of body | | | | |
| Initial | 47.4 | 47.2 | 47.6 | 47.7 |
| Mid point | 49.2 | 48.6 | 49.1 | 50.0 |
| Final | 51.4 | 51.6 | 51.9 | 52.2 |
| Heart Girth | | | | |
| Initial | 54.6 | 55.6 | 54.2 | 55.3 |
| Mid point | 63.1 | 62.6 | 62.0 | 62.6 |
| Final | 69.7[3] | 68.6 | 68.6[3] | 68.6 |
| Width of shoulder | | | | |
| Initial | 13.6 | 13.6 | 13.4 | 13.2 |
| Mid point | 16.6 | 16.6 | 16.0 | 16.0 |
| Final | 18.4 | 18.5 | 18.4 | 18.2 |
| Width of loin | | | | |
| Initial | 10.5 | 10.4 | 10.5 | 10.3 |
| Mid point | 11.6 | 11.7 | 11.4 | 11.5 |
| Final | 12.6 | 12.6 | 12.6 | 13.0 |
| Width of round | | | | |
| Initial | 12.9 | 13.0 | 12.8 | 12.3 |
| Mid point | 16.8 | 16.6 | 16.2 | 16.0 |
| Final | 18.2 | 18.0 | 18.2 | 17.9 |

[1]Live animal measurements for individual trials are shown in Appendix Tables XXV through XXX.

[2]All values are expressed in inches.

[3](HH + MH) significantly different from (HM + MM) at $P < .10$.

Wilson (1952)noted small but consistent differences in external measurements of poultry; larger values were found for the LL and HL groups, when compared at equal weights.

Heart girth measurements increased more, during Phase II, for the groups full-fed during that period ($P < .10$); the same trend was observed in each trial. This measurement was found by Kohli et al. (1951) to be more indicative of daily gains than height at withers, width of shoulders or length of body, and is generally considered as one of the more reliable live animal measurements.

Width measurements (shoulder, loin and round), which tend to reflect differences in fatness more than skeletal changes, and consequently may be more influenced by varied nutritional planes, did not reveal significant differences at any time during the three trials. As with height and length measurements, precision may have been quite low. These "thickness" measures have been shown by several workers to increase relatively more on higher planes of nutrition (Guilbert et al., 1944; McMeekan, 1940a; Brugman, 1950; Cook et al., 1951).

Carcass measurements are presented in Table XI. For individual trials, corresponding values may be found in Appendix Table XXXI. Reference points for the various measurements are given in Appendix Table XIX. Greater length of carcasses from the MH and MM groups was observed ($P < .10$) which agrees with the results obtained by McMeekan (1940a, 1940b) and Brugman (1950).

None of the other carcass measurements taken were significantly different for the treatments studied. This suggests that dimensions of steers subjected to these treatments were not appreciably different

TABLE XI. AVERAGE CARCASS MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIALS I, II AND III)[1,2]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Carcass length | 45.1[3] | 44.9[3] | 45.3 | 45.7 |
| Length of leg | 29.0 | 29.3 | 29.2 | 29.6 |
| Circumference of round[4] | 33.0 | 32.8 | 32.5 | 33.5 |
| Length of loin | 23.7 | 23.9 | 23.9 | 24.3 |
| Depth of body | 15.0 | 15.0 | 15.2 | 15.2 |
| Width of shoulder | 8.2 | 7.9 | 8.0 | 8.0 |
| Width of round | 9.0 | 9.0 | 8.9 | 8.9 |

[1]Averages of right and left sides, in inches.

[2]Carcass measurements for individual trials are shown in Appendix Table XXXI.

[3](HH + HM) significantly different from (MH + MM) at $P < .10$.

[4]Trials I and II only.

since carcass measurements are easy to obtain with accuracy and to repeat with precision, in contrast to similar observations on the live animal. If any trends can be cited, they are the consistently higher values for measurements from the moderate group (MM). This would be expected, particularly with skeletal measurements, whenever differences in plane of nutrition were marked and animals were removed from experiment at constant weight or gain.

## Effect of Plane of Nutrition on Steers Fed for Equal Feedlot Gain or Equal Length of Time

As shown in Table XII, moderately-fed steers (Moderate II) required 65 days longer than full-fed steers to reach an estimated 350 pounds

TABLE XII. WEIGHT GAINS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIAL IV)

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Time on feed (days)[1] | 206[1] | 206[1] | 271 |
| Av. weights (lb)[2] | | | |
| Initial | 484 | 485 | 483 |
| Final | 838 | 755 | 831 |
| Av. daily gains (lb) | 1.72[3] | 1.31 | 1.29 |

[1](High + Moderate I) significantly different from 2 (Moderate II) at $P < .001$.

[2]Shrunk weights (16 hours off feed and water).

[3]2(High) significantly different from (Moderates I and II) at $P < .001$.

feedlot gain. The 2 moderate groups, I and II, gained at essentially the same rate, which was 0.41 and 0.43 pound less per day, respectively, than the high group. These results are nearly identical to the performance of the HH and MM groups in Trial III. It was anticipated that the Moderate I steers (removed with the highs) would gain more rapidly since, in Trial III, moderate groups gained approximately 1.6 pounds per day for the first 200 pounds gain. Total gain was only 270 pounds for the Moderate I group in Trial IV. The reason for the relatively low gain in this test is not apparent.

It can be seen from Tables III and V (Experimental) that actual percentages of TDN and net energy in the rations were 12.5 and 10.8 percent lower, respectively, for the high group and 15.7 and 12.3 percent less, respectively, for the low group, in Trial IV, as compared to the earlier trials. This was due primarily to the addition of silage in the fourth trial. However, increased consumption in Trial IV resulted in daily feed, TDN and net energy intakes slightly above those in previous years (Table XIII). The moderate groups consumed about 3.0

TABLE XIII. FEED, TDN AND NET ENERGY CONSUMED PER DAY AND PER POUND OF GAIN BY STEERS ON DIFFERENT PLANES OF NUTRITION (TRIAL IV)

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Average daily feed (lb) | | | |
| Rolled milo | 12.4 | 6.5 | 6.9 |
| Cottonseed meal | 1.5 | 1.5 | 1.5 |
| Dehydrated alfalfa pellets | 1.0 | 1.0 | 1.1 |
| Cottonseed hulls | 2.0 | 3.9 | 4.2 |
| Sorghum silage | 6.8 | 11.5 | 9.7 |
| Total | 23.6 | 24.4 | 23.4 |
| Average daily TDN (lb)[1] | 13.5 | 10.4 | 10.6 |
| Average daily net energy (therms)[1] | 12.7 | 9.5 | 9.6 |
| Feed per lb. gain (lb) | | | |
| Rolled milo | 7.2 | 5.0 | 5.3 |
| Cottonseed meal | 0.8 | 1.1 | 1.1 |
| Dehydrated alfalfa pellets | 0.6 | 0.8 | 0.9 |
| Cottonseed hulls | 1.2 | 3.0 | 3.3 |
| Sorghum silage | 4.0 | 8.8 | 7.5 |
| Total | 13.7[2] | 18.6 | 18.2 |
| TDN per lb. gain (lb)[1] | 7.8 | 8.0 | 8.3 |
| Net energy per lb. gain (therms)[1] | 7.3 | 7.2 | 7.5 |

[1]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

[2]2(High) significantly different from (Moderates I and II) at $P < .025$.

pounds less TDN and 3.2 pounds less net energy per day than the High group, although daily feed intakes were quite similar.

Full-fed steers were more efficient in terms of total feed consumed per pound of gain ($P < .025$), requiring 4.7 pounds less than the moderately-fed groups. This agrees with the earlier trials. However, no significant differences among treatments were observed when efficiency of feed conversion was expressed on the basis of TDN or net energy. Highs required 0.2 pound less TDN than Moderates slaughtered at the same time, but consumed 0.1 therm more net energy. The Moderate I group needed 0.3 pound less TDN or therm net energy than calves fed moderately for 350 pounds gain. As mentioned in discussing earlier trials, other investigators have observed variable effects of different nutritional planes on efficiency of feed conversion. In some instances, little effect was noted; in others, restricted or lower feeding levels improved feed efficiency. Both situations have been observed in the 4 trials reported herein.

Carcass data are presented in Table XIV. Live slaughter grade and carcass grade gave identical trends. The High group graded "average good," which was significantly higher ($P < .05$) than the average grade of the moderate groups. Grades for Moderates I and II were "average to high standard" and "low good," respectively, which were also significantly different ($P < .05$).

Dressing percentages were lowest for Moderate I steers ($P < .05$), while yields were essentially equal for the High and Moderate II groups. The Moderate I group also showed the least desirable marbling, with little difference between the other treatments. However, due to wide variation in the marbling scores, no statistical significance was obtained.

TABLE XIV. CARCASS DATA (TRIAL IV)

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Live slaughter grade[1] | 16.2[2] | 20.8[3] | 17.8 |
| Carcass grade[1] | 16.8[2] | 21.0[3] | 18.2 |
| Dressing percent[4] | 58.8 | 56.6[3] | 59.0 |
| Marbling score[5] | 19.0 | 22.4 | 19.4 |

[1]Average good = 16, low good = 18, high standard = 20 and average standard = 22.

[2]2(High) significantly different from (Moderates I and II) at $P < .05$.

[3](Moderate I) significantly different from (Moderate II) at $P < .05$.

[4]Based on shrunk slaughter weight (16 hours) and chilled carcass weight (48 hours).

[5]Subjective score; lowest values indicate best marbling.

It appears that feeding steers on a moderate plane of nutrition for no longer than full-fed steers produces a relatively undesirable carcass.

Live animal measurements are presented in Table XV. In general, increases in the various dimensions were less for the Moderate I group, which was expected, since these steers weighed approximately 80 pounds less than the other steers at time of slaughter. The differences were significantly greater ($P < .05$) for the Moderate II group, when compared to Moderate I, in height at withers (6.3 vs. 3.7 inches) and heart girth (13.4 vs. 10.0 inches). Increases in heart girth also favored the High group ($P < .10$) when compared to the average of the moderate groups (14.5 vs. 11.7 inches). As in earlier trials, heart girth appeared to be a more reliable indicator of differences in nutritional plane than the other measurements. Large errors in measuring technique may have influenced results obtained.

TABLE XV. LIVE ANIMAL MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIAL IV)[1]

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Height at withers | | | |
| Initial | 39.6 | 39.1 | 39.3 |
| Final | 44.7 | 42.8[2] | 45.6 |
| Length of body | | | |
| Initial | 47.2 | 47.4 | 47.8 |
| Final | 51.8 | 51.2 | 51.4 |
| Heart girth | | | |
| Initial | 55.4 | 54.6 | 54.9 |
| Final | 69.9[3] | 64.6[2] | 68.3 |
| Width of shoulder | | | |
| Initial | 13.1 | 12.9 | 13.4 |
| Final | 18.0 | 17.3 | 18.0 |
| Width of loin | | | |
| Initial | 10.4 | 10.4 | 10.3 |
| Final | 12.7 | 12.1 | 12.8 |
| Width of round | | | |
| Initial | 12.8 | 13.0 | 12.5 |
| Final | 18.1 | 17.8 | 17.4 |

[1]All values are expressed in inches.

[2](Moderate I) significantly different from (Moderate II) at $P < .05$.

[3]2(High) significantly different from (Moderates I and II) at $P < .10$.

Carcass measurements, as shown in Table XVI, were remarkably similar among the 3 groups; particularly carcass length, length of leg, length of loin and depth of body, all of which reflect skeletal growth.

TABLE XVI. CARCASS MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION (TRIAL IV)[1]

| Plane of Nutrition | High | Moderate I | Moderate II |
|---|---|---|---|
| Carcass length | 45.4 | 45.2 | 45.8 |
| Length of leg | 29.3 | 29.0 | 29.5 |
| Length of loin | 24.0 | 24.0 | 24.2 |
| Depth of body | 15.0 | 14.9 | 15.1 |
| Width of shoulder | 7.9 | 7.5[2] | 7.9 |
| Width of round | 9.0 | 8.6[2] | 9.0 |

[1]Averages of right and left sides, in inches.

[2](Moderate I) significantly different from (Moderate II) at $P < .10$.

Values for the Moderate I group were slightly less, and for the Moderate II group slightly greater, than for the High group. Width of round and width of shoulder, however, were considerably less ($P < .10$) for the Moderate I group. It appears that when full-fed and moderately-fed steers are removed from treatment after the same period of time, the lower plane of nutrition does not appreciably affect skeletal growth but causes primarily a retardation in "thickness" or fleshing dimensions. This trend is in agreement with the theory of differential rates of development of body parts suggested by McMeekan (1940a).

In Trial IV, removal of moderately-fed steers with the High group instead of feeding them to an equal amount of gain had little effect on rate of gain and slightly improved feed efficiency, but resulted in narrower carcasses which were inferior in grade and yield.

## SUMMARY

Three trials, involving 64 weanling steer calves, were conducted to study the effects of different planes of nutrition on feedlot performance, carcass merit and growth and development of body parts. The planes of nutrition imposed were: Full-feeding until the steers had attained 360 to 400 pounds feedlot gain (HH); full-feeding for approximately half of the total gain, followed by a moderate level of feeding (HM); moderate feeding, followed by full-feeding (MH); and a moderate level of feeding throughout (MM). The different nutritional planes were achieved by varying the amount of rolled milo and cottonseed hulls in the ration, with cottonseed meal and dehydrated alfalfa pellets as the other ingredients. The cattle were individually-fed and were removed from experiment when each had gained 360 to 400 pounds total feedlot gain.

Rates of gain varied with the nutritional planes imposed. HH and MH groups gained 0.29 pound more per day, consumed 1.4 pounds more daily feed, but required 1.0 pound less feed per pound of gain than HM and MM groups. However, the MH and MM groups were more efficient on either a TDN or net energy basis. Slaughter and carcass grades were similar, but favored the HH group, the MM group grading lowest. Differences in dressing percentage, live animal measurements and carcass measurements were generally negligible and non-significant, except for heart girth, which increased more for the HH and HM treatments.

In an additional trial, 24 steer calves were used to compare the effects of removing moderately-fed steers after having been on feed an equal length of time as full-fed steers (Moderate I), with removal after equal feedlot gain of 350 pounds (Moderate II). Full-feeding resulted in 0.42 pound more gain per day on 4.7 pounds less feed per pound of gain, when compared to the moderate groups. However, feed efficiency differences were negligible when expressed as TDN or net energy. Live and carcass grades were improved by full-feeding, but yield, marbling score and body and carcass measurements of the High group were similar to those for the Moderate II group.

Removal of moderately-fed steers at the same time as the High group (Moderate I) rather than feeding for the same total gain (Moderate II) had essentially no effect on rate of gain, but improved feed efficiency slightly, and lowered live and carcass grades, yield and marbling score. Live animal and carcass measurements were not appreciably affected except for a decrease in heart girth, and in width of shoulder and round in the carcasses of the Moderate I group.

## LITERATURE CITED

Brookes, A. J. and John Hodges. 1959. Studies in beef production. I. The effects of level of feeding and of breed on the growth and fattening of spring born cattle. J. Agr. Sci. 53:78.

Brugman, H. H. 1950. The effect of the plane of nutrition on the carcass quality of a line of swine based on a Chester White and Danish Landrace cross. J. Animal Sci. 9:602.

Cook, A. C., M. L. Kohli and W. M. Dawson. 1951. Relationships of five body measurements to slaughter grade, carcass grade, and dressing percentage in Milking Shorthorn steers. J. Animal Sci. 10:386.

Eckles, C. H. and W. W. Swett. 1918. Some factors influencing the rate of growth and the size of dairy heifers at maturity. Mo. Agr. Exp. Sta. Res. Bul. 31.

Edinger, A. T. 1925. The physical composition of a lean, a half fat, and a fat beef carcass and the relative cost of the nutrients contained in each. Mo. Agr. Exp. Sta. Res. Bul. 83.

Guilbert, H. R., G. H. Hart, K. A. Wagnon and H. Goss. 1944. The importance of continuous growth in beef cattle. Calif. Agr. Exp. Sta. Bul. 688.

Haecker, T. L. 1916. Investigation in animal nutrition. Beef-production. Minn. Agr. Exp. Sta. Bul. 155.

Haecker, T. L. 1920. Investigations in beef production. Minn. Agr. Exp. Sta. Bul. 193.

Hammond, John. 1955. Progress in the physiology of farm animals. volume 2. Butterworths Scientific Publications, London.

Hogan, A. G. 1929. Retarded growth and mature size of beef steers. Mo. Agr. Exp. Sta. Res. Bul. 123.

Jordan, Whitman H. 1895. The relation of food to the growth and composition of the bodies of steers. Me. State Col. Agr. Exp. Sta. Rpt. p. 36.

Kohli, M. L., A. C. Cook and W. M. Dawson. 1951. Relations between some body measurements and certain performance characters in Milking Shorthorn steers. J. Animal Sci. 10:352.

Lucas, I. A. M. and A. F. C. Calder. 1956. The response of different types of pigs to varying levels of feeding from weaning to bacon weight, with particular reference to carcass quality. J. Agr. Sci. 47:287.

Lucas, I. A. M., I. McDonald and A. F. C. Calder. 1960. Some further observations upon the effects of varying the plane of feeding for pigs between weaning and bacon weight. J. Agr. Sci. 54:81.

McMeekan, C. P. 1940a. Growth and development in the pig, with special reference to carcass quality characters. I. J. Agr. Sci. 30:276.

McMeekan, C. P. 1940b. Growth and development in the pig, with special reference to carcass quality characters. Part II. The influence of the plane of nutrition on growth and development. J. Agr. Sci. 30:387.

McMeekan, C. P. 1940c. Growth and development in the pig, with special reference to carcass quality characters. Part III. Effect of the plane of nutrition on the form and composition of the bacon pig. J. Agr. Sci. 30:511.

Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt. 1958a. The influence of limited feeding, using high-fiber rations, upon growth and carcass characteristics of swine. I. Effects upon feed-lot performance. J. Animal Sci. 17:3.

Merkel, R. A., R. W. Bray, R. H. Grummer, P. H. Phillips and G. Bohstedt. 1958b. The influence of limited feeding, using high-fiber rations, upon growth and carcass characteristics of swine. II. Effects upon carcass characteristics. J. Animal Sci. 17:13.

Morrison, F. B. 1956. Feeds and Feeding. 22nd Ed. Morrison Publishing Company, Ithaca, New York.

Moulton, C. Robert, P. F. Trowbridge and L. D. Haigh. 1921. Studies in animal nutrition. I. Changes in form and weight on different planes of nutrition. Mo. Agr. Exp. Sta. Res. Bul. 43.

Moulton, C. Robert, P. F. Trowbridge and L. D. Haigh. 1922a. Studies in animal nutrition. II. Changes of proportions of carcass and offal on different planes of nutrition. Mo. Agr. Exp. Sta. Res. Bul. 54.

Moulton, C. Robert, P. F. Trowbridge and L. D. Haigh. 1922b. Studies in animal nutrition. III. Changes in chemical composition on different planes of nutrition. Mo. Agr. Exp. Sta. Res. Bul. 55.

Nelson, Aaron G. 1945. Relation of feed consumed to food products produced by fattening cattle. U S D A Tech. Bul. 900.

Osbourn, D. F. and P. N. Wilson. 1960. Effects of different patterns of allocation of a restricted quantity of food upon the growth and development of cockerels. J. Agr. Sci. 54:278.

Palsson, H. and Juan B. Verges. 1952a. Effects of the plane of nutrition on growth and development of carcass quality in lambs. Part I. The effects of high and low planes of nutrition at different ages. J. Agr. Sci. 42:1.

Palsson, H. and Juan B. Verges. 1952b. Effects of the plane of nutrition on growth and the development of carcass quality in lambs. Part II. Effects on lambs of 30 lb. carcass weight. J. Agr. Sci. 42:93.

Shorrock, R. W. 1940. The "restricted" feeding of bacon pigs. J. Agr. Sci. 30:598.

Snedecor, G. W. 1956. Statistical methods. 5th Ed. The Iowa State College Press, Ames, Iowa.

Trowbridge, P. F., C. R. Moulton and L. D. Haigh. 1918. Effect of limited foods on growth of beef animals. Mo. Agr. Exp. Sta. Res. Bul. 28.

Trowbridge, P. F., C. R. Moulton and L. D. Haigh. 1919. Composition of the beef animal and energy cost of fattening. Mo. Agr. Exp. Sta. Res. Bul. 30.

Waters, H. J. 1908. The capacity of animals to grow under adverse conditions. Soc. Prom. Agr. Sci. Proc. 29th Assoc. Meeting. p.71.

Weber, A. D., Wm. J. Loeffel and Matilda Peters. 1931. Length of feeding period and plane of nutrition as factors in lamb feeding. Neb. Agr. Exp. Sta. Bul. 262.

Wilson, P. N. 1952. Growth analysis of the domestic fowl. I. Effect of plane of nutrition and sex on live-weights and external measurements. J. Agr. Sci. 42:369.

Wilson, P. N. 1958. The effect of plane of nutrition on the growth and development of the East African dwarf goat. I. Effect of plane of nutrition on the live-weight gains and the external measurement of kids. J. Agr. Sci. 50:198.

Wilson, P. N. 1960. The effect of plane of nutrition on the growth and development of the East African dwarf goat. III. The effect of plane of nutrition and sex on the carcass composition of the kid at two stages of growth, 16 lb. weight and 30 lb. weight. J. Agr. Sci. 60:105.

Winchester, C. F., R. L. Hiner and V. C. Scarborough. 1957. Some effects on beef cattle of protein and energy restriction. J. Animal Sci. 16:426.

Winters, L. M., C. F. Sierk and J. N. Cummings. 1949. The effect of plane of nutrition on the economy of production and carcass quality of swine. J. Animal Sci. 8:132.

# A P P E N D I X

TABLE XVII. ANALYSIS OF VARIANCE TABLES USED FOR ALL DATA EXCLUDING LIVE ANIMAL MEASUREMENTS

| Trial Number | Source of Variation | Degrees of Freedom |
|---|---|---|
| I | Total | 15 |
| | Treatment | 3 |
| | Steers within treatment | 12 |
| II | Total | 19 |
| | Treatment | 3 |
| | Steers within treatment | 16 |
| III | Total | 21 |
| | Treatment | 3 |
| | Steers within treatment | 18 |
| I, II, III | Total | 57 |
| | Treatment | 3 |
| | Year | 2 |
| | Treatment x year | 6 |
| | Steers within treatment within year | 46 |
| IV | Total | 23 |
| | Treatment | 2 |
| | Steers within treatment | 21 |

TABLE XVIII. ANALYSIS OF COVARIANCE TABLES USED FOR LIVE ANIMAL MEASUREMENTS

| Trial Number | Source of Variation | Degrees of Freedom | Deviations from Regression Degrees of Freedom |
|---|---|---|---|
| I | Total | 15 | 14 |
| | Treatment | 3 | |
| | Steers within treatment | 12 | 11 |
| | Adjusted means | | 3 |
| II | Total | 19 | 18 |
| | Treatment | 3 | |
| | Steers within treatment | 16 | 15 |
| | Adjusted means | | 3 |
| III | Total | 21 | 20 |
| | Treatment | 3 | |
| | Steers within treatment | 18 | 17 |
| | Adjusted means | | 3 |
| I, II, III | Total | 57 | |
| | Treatment | 3 | |
| | Year | 2 | |
| | Treatment x year | 6 | 5 |
| | Steers within treatment within year | 46 | |
| | Treatment + (treatment x year) | 9 | 8 |
| | Adjusted means | | 3 |
| IV | Total | 23 | 22 |
| | Treatment | 2 | |
| | Steers within treatment | 21 | 20 |
| | Adjusted means | | 2 |

TABLE XIX. REFERENCE POINTS FOR CARCASS MEASUREMENTS

| Measurement | Reference Points |
|---|---|
| Carcass length | Distance from anterior edge of the first rib, adjacent to the vertebrae, to the anterior edge of the aitch-bone. |
| Length of leg | Distance from anterior edge of the aitch-bone to the furthest extremity of the round. |
| Circumference of round | Circumference at a point 40 percent of the distance obtained for length of leg from the anterior edge of the aitch-bone, and parallel to the floor. |
| Length of loin | Distance from anterior edge of the aitch-bone to the center of the eighth vertebra, counting anteriorly from the last lumbar vertebra. |
| Depth of body | Distance from the dorsal edge of the spinal canal at the fifth thoracic vertebra to the ventral edge of the sternum, on a line parallel to the floor. |
| Width of shoulder | Horizontal distance from center of first thoracic vertebra to the exterior surface, perpendicular to dorsal-ventral midline of carcass. |
| Width of round | Horizontal distance from center of aitch-bone to the exterior surface, perpendicular to dorsal-ventral midline of carcass. |

TABLE XX. AVERAGE COMPOSITION OF RATIONS (Percent)

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Trial I | | | | |
| Rolled milo | 67.3 | 47.9 | 55.6 | 36.4 |
| Cottonseed meal | 5.1 | 6.6 | 6.3 | 7.7 |
| Dehydrated alfalfa pellets | 4.8 | 4.8 | 5.2 | 5.2 |
| Cottonseed hulls | 22.8 | 40.6 | 32.9 | 50.7 |
| Trial II | | | | |
| Rolled milo | 67.3 | 48.7 | 55.7 | 40.3 |
| Cottonseed meal | 7.0 | 7.7 | 7.9 | 8.3 |
| Dehydrated alfalfa pellets | 5.1 | 5.6 | 5.3 | 5.6 |
| Cottonseed hulls | 20.6 | 38.0 | 31.0 | 45.8 |
| Trial III | | | | |
| Rolled milo | 63.0 | 52.1 | 53.9 | 43.7 |
| Cottonseed meal | 7.6 | 9.2 | 8.6 | 9.9 |
| Dehydrated alfalfa pellets | 5.2 | 6.1 | 5.6 | 6.6 |
| Cottonseed hulls | 24.1 | 32.7 | 31.8 | 39.8 |

TABLE XXI. WEIGHT GAINS OF STEERS ON DIFFERENT PLANES OF NUTRITION

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Trial I | | | | |
| Time on feed (days) | 178[1] | 198 | 190[1] | 188 |
| Av. weights (lb)[2] | | | | |
| Initial 12-26-56 | 520 | 520 | 508 | 525 |
| Final | 885 | 882 | 872 | 894 |
| Av. daily gains (lb) | | | | |
| Phase I | 2.60[3] | 2.48[3] | 2.13[4] | 2.22 |
| Phase II | 1.67[4,5] | 1.39[5] | 1.74[4] | 1.70 |
| Total period | 2.07[1] | 1.84 | 1.94[1] | 1.96 |
| Total period minus fill[6] | 1.68[7] | 1.39 | 1.53[7] | 1.40 |
| Trial II | | | | |
| Time on feed (days) | 205[8] | 261 | 222[8] | 281 |
| Av. weights (lb)[2] | | | | |
| Initial 11-12-57 | 504 | 477 | 475 | 515 |
| Final | 899 | 860 | 875 | 915 |
| Av. daily gains (lb) | | | | |
| Phase I | 1.99[3] | 1.96[3] | 1.66 | 1.60 |
| Phase II | 1.88[8,3] | 1.16[3] | 2.01[8] | 1.30 |
| Total period | 1.94[8] | 1.47 | 1.81[8] | 1.43 |
| Total period minus fill[6] | 1.65[8] | 1.24 | 1.52[8] | 1.19 |
| Trial III | | | | |
| Time on feed (days) | 239[8] | 279 | 241[8] | 310 |
| Av. weights (lb)[2] | | | | |
| Initial 11-18-58 | 445 | 447 | 448 | 431 |
| Final | 847 | 835 | 847 | 828 |
| Av. daily gains (lb) | | | | |
| Phase I | 2.24[9,4] | 2.09[9] | 1.94[4] | 1.62 |
| Phase II | 1.38[8] | 1.04 | 1.53[8] | 1.09 |
| Total period | 1.70[7] | 1.40 | 1.68[7] | 1.28 |
| Total period minus fill[6] | 1.47[4] | 1.25 | 1.44[4] | 1.13 |

[1](HH + MH) significantly different from (HM + MM) at $P < .10$.

[2]Shrunk weights (16 hours off feed and water).

[3](HH + HM) significantly different from (MH + MM) at $P < .01$.

[4](HH + MH) significantly different from (HM + MM) at $P < .05$.

[5](HH + HM) significantly different from (MH + MM) at $P < .05$.

[6]Contents of rumen, reticulum, omasum and abomasum were determined at time of slaughter and deducted from live animal weight.

[7](HH + MH) significantly different from (HM + MM) at $P < .025$.

[8](HH + MH) significantly different from (HM + MM) at $P < .001$.

[9](HH + HM) significantly different from (MH + MM) at $P < .025$.

TABLE XXII. AVERAGE POUNDS OF FEED AND TDN AND THERMS OF NET ENERGY CONSUMED PER DAY BY STEERS ON DIFFERENT PLANES OF NUTRITION

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Trial I | | | | |
| Rolled milo | 13.6 | 9.4 | 10.4 | 6.8 |
| Cottonseed meal | 1.0 | 1.3 | 1.2 | 1.4 |
| Dehydrated alfalfa pellets | 1.0 | 0.9 | 1.0 | 1.0 |
| Cottonseed hulls | 4.6 | 7.9 | 6.2 | 9.4 |
| Total | 20.2 | 19.5 | 18.8 | 18.6 |
| TDN[1] | 14.1 | 12.3 | 12.4 | 11.1 |
| Net energy[1] | 13.1 | 11.0 | 11.2 | 9.5 |
| Trial II | | | | |
| Rolled milo | 12.6 | 8.4 | 10.2 | 7.0 |
| Cottonseed meal | 1.3 | 1.3 | 1.4 | 1.5 |
| Dehydrated alfalfa pellets | 1.0 | 1.0 | 1.0 | 1.0 |
| Cottonseed hulls | 3.9 | 6.6 | 5.7 | 8.0 |
| Total | 18.8 | 17.3 | 18.3 | 17.5 |
| TDN[1] | 13.2 | 11.0 | 12.1 | 10.7 |
| Net energy[1] | 12.3 | 9.9 | 11.1 | 9.3 |
| Trial III | | | | |
| Rolled milo | 11.6 | 8.2 | 9.1 | 6.4 |
| Cottonseed meal | 1.4 | 1.4 | 1.4 | 1.5 |
| Dehydrated alfalfa pellets | 0.9 | 1.0 | 1.0 | 1.0 |
| Cottonseed hulls | 4.4 | 5.1 | 5.4 | 5.8 |
| Total | 18.4 | 15.7 | 17.0 | 14.7 |
| TDN[1] | 12.7 | 10.3 | 11.2 | 9.2 |
| Net energy[1] | 11.8 | 9.3 | 10.2 | 8.2 |

[1]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

TABLE XXIII. POUNDS OF FEED AND TDN AND THERMS OF NET ENERGY CONSUMED PER POUND OF GAIN BY STEERS ON DIFFERENT PLANES OF NUTRITION

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Trial I | | | | |
| Rolled milo | 6.6 | 5.2 | 5.4 | 3.5 |
| Cottonseed meal | 0.5 | 0.7 | 0.6 | 0.7 |
| Dehydrated alfalfa pellets | 0.5 | 0.5 | 0.5 | 0.5 |
| Cottonseed hulls | 2.2 | 4.3 | 3.2 | 4.8 |
| Total | 9.8 | 10.7 | 9.7 | 9.5 |
| TDN[1] | 6.6[2,3] | 6.8[2] | 6.4 | 5.7[3] |
| Net energy[1] | 6.4[2,4] | 6.0[2] | 5.8[4] | 4.9 |
| Trial II | | | | |
| Rolled milo | 6.6 | 5.8 | 5.6 | 5.0 |
| Cottonseed meal | 0.7 | 0.9 | 0.8 | 1.0 |
| Dehydrated alfalfa pellets | 0.5 | 0.6 | 0.6 | 0.7 |
| Cottonseed hulls | 2.0 | 4.5 | 3.1 | 5.6 |
| Total | 9.8[5] | 11.8 | 10.1[5] | 12.3 |
| TDN[1] | 6.8[6] | 7.5 | 6.7[6] | 7.5 |
| Net energy[1] | 6.4[4] | 6.7 | 6.1[4] | 6.6 |
| Trial III | | | | |
| Rolled milo | 6.9 | 5.9 | 5.5 | 5.0 |
| Cottonseed meal | 0.8 | 1.0 | 0.9 | 1.1 |
| Dehydrated alfalfa pellets | 0.6 | 0.7 | 0.6 | 0.8 |
| Cottonseed hulls | 2.6 | 3.7 | 3.2 | 4.5 |
| Total | 11.1[2,3] | 11.3 | 10.3[2] | 11.4[3] |
| TDN[1] | 7.5[2] | 7.4[2] | 6.7 | 7.2 |
| Net energy[1] | 7.1[7] | 6.7[7] | 6.2 | 6.3 |

[1]TDN and net energy were calculated using TDN and net energy values of Morrison (1956).

[2](HH + HM) significantly different from (MH + MM) at $P < .05$.

[3](HH + MM) significantly different from (MH + HM) at $P < .10$.

[4](HH + MH) significantly different from (HM + MM) at $P < .10$.

[5](HH + MH) significantly different from (HM + MM) at $P < .005$.

[6](HH + MH) significantly different from (HM + MM) at $P < .01$.

[7](HH + HM) significantly different from (MH + MM) at $P < .01$.

TABLE XXIV. CARCASS DATA

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Live slaughter grade[1] | | | | |
| Trial I | 12.6[2] | 15.7 | 12.6[2] | 14.6 |
| Trial II | 14.8[3] | 17.1 | 15.4[3] | 15.6 |
| Trial III | 16.3[4] | 16.0[4] | 16.9 | 18.7 |
| Carcass grade[1] | | | | |
| Trial I | 11.5[3] | 14.0 | 13.0[3] | 15.2 |
| Trial II | 14.5[3,4] | 15.6[4] | 15.5[3] | 16.7 |
| Trial III | 15.8[5] | 15.6[5] | 17.6 | 19.8 |
| Dressing percent[6] | | | | |
| Trial I | 63.6 | 61.3 | 62.4 | 61.2 |
| Trial II | 60.9 | 60.3 | 60.7 | 60.8 |
| Trial III | 59.3 | 60.5 | 58.5 | 60.0 |
| Marbling score[7] | | | | |
| Trial I | 15.3[8] | 16.2[8] | 18.3 | 19.5 |
| Trial II | 16.9[8] | 16.5[8] | 20.0 | 19.4 |
| Trial III | 17.4[4] | 17.9[4] | 21.6 | 23.7 |

[1]Low choice = 12, high good = 14, average good = 16, low good = 18 and high standard = 20.

[2](HH + MH) significantly different from (HM + MM) at $P < .025$.

[3](HH + MH) significantly different from (HM + MM) at $P < .05$.

[4](HH + HM) significantly different from (MH + MM) at $P < .05$.

[5](HH + HM) significantly different from (MH + MM) at $P < .01$.

[6]Based on shrunk slaughter weight (16 hours) and chilled carcass weight (48 hours).

[7]Subjective score; lowest values indicate best marbling.

[8](HH + HM) significantly different from (MH + MM) at $P < .10$.

TABLE XXV. HEIGHT AT WITHERS MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 40.2 | 42.5 | 39.4 | 39.2 |
| Trial II | 38.8 | 39.5 | 39.3 | 39.8 |
| Trial III | 39.4 | 39.8 | 39.8 | 39.7 |
| Mid point | | | | |
| Trial I | 41.0[2] | 41.2[2] | 40.6 | 40.6 |
| Trial II | 42.1 | 42.2 | 41.7 | 42.0 |
| Trial III | 41.0 | 40.7 | 41.4 | 40.8 |
| Final | | | | |
| Trial I | 44.5 | 44.3 | 43.5 | 43.4 |
| Trial II | 44.8 | 45.9 | 45.1 | 45.4 |
| Trial III | 44.0 | 44.3 | 44.1 | 43.8 |

[1]Shortest vertical distance from top of withers to floor with steer in normal standing position. All values are expressed in inches.

[2](HH + HM) significantly different from (MH + MM) at $P < .10$.

TABLE XXVI. LENGTH OF BODY MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 50.1 | 49.9 | 49.4 | 48.4 |
| Trial II | 46.9 | 47.1 | 48.1 | 48.6 |
| Trial III | 46.1 | 45.4 | 46.2 | 45.8 |
| Mid point | | | | |
| Trial I | 51.8[2] | 52.5 | 51.8[2] | 52.5 |
| Trial II | 49.1 | 48.0 | 49.2 | 49.8 |
| Trial III | 47.5 | 46.7 | 47.2 | 46.8 |
| Final | | | | |
| Trial I | 54.5 | 55.2 | 54.4 | 55.3 |
| Trial II | 50.5 | 50.9 | 51.5 | 52.2 |
| Trial III | 50.1 | 49.7 | 50.6 | 49.1 |

[1]Shortest distance from point of shoulder to pins, parallel to midline, with steer in normal standing position. All values are expressed in inches.

[2](HH + MH) significantly different from (HM + MM) at $P < .10$.

TABLE XXVII. HEART GIRTH MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 53.8 | 55.9 | 54.4 | 54.8 |
| Trial II | 55.7 | 55.2 | 54.5 | 56.2 |
| Trial III | 54.2 | 55.8 | 53.9 | 54.8 |
| Mid-point | | | | |
| Trial I | 62.5 | 62.5 | 61.6 | 61.5 |
| Trial II | 65.5 | 63.4 | 63.6 | 65.4 |
| Trial III | 61.6 | 62.1 | 60.8 | 60.2 |
| Final | | | | |
| Trial I | 68.8 | 68.2 | 68.2 | 67.5 |
| Trial II | 71.2 | 69.3 | 70.5 | 70.9 |
| Trial III | 69.1 | 68.3 | 67.3 | 66.8 |

[1]Circumference of body immediately behind elbow with steer in normal standing position. All values are expressed in inches.

TABLE XXVIII. WIDTH OF SHOULDER MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 12.6 | 12.6 | 12.2 | 12.1 |
| Trial II | 13.5 | 12.8 | 12.8 | 13.3 |
| Trial III | 14.3 | 14.8 | 14.8 | 14.2 |
| Mid-point | | | | |
| Trial I | 15.2 | 15.6 | 14.7 | 14.8 |
| Trial II | 17.6 | 16.7 | 16.2 | 16.8 |
| Trial III | 16.8 | 17.2 | 16.8 | 16.3 |
| Final | | | | |
| Trial I | 16.2 | 17.0 | 16.2 | 16.3 |
| Trial II | 19.5 | 18.5 | 19.0 | 19.1 |
| Trial III | 19.1 | 19.4 | 19.3 | 18.9 |

[1]Widest points, perpendicular to midline, with steer in normal standing position. All values are expressed in inches.

TABLE XXIX. WIDTH OF LOIN MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 10.0 | 9.8 | 10.1 | 10.0 |
| Trial II | 11.1 | 10.3 | 10.1 | 10.7 |
| Trial III | 10.3 | 10.9 | 10.9 | 10.0 |
| Mid-point | | | | |
| Trial I | 11.4 | 11.2 | 10.5 | 11.0 |
| Trial II | 11.7 | 11.7 | 11.7 | 12.0 |
| Trial III | 11.7 | 11.8 | 11.6 | 11.4 |
| Final | | | | |
| Trial I | 12.6 | 12.8 | 12.6 | 13.5 |
| Trial II | 12.6 | 12.4 | 12.4 | 12.9 |
| Trial III | 12.6 | 12.8 | 12.7 | 12.5 |

[1]Width of loin measured at half the distance from hooks to last rib, perpendicular to midline, with steer in normal standing position. All values are expressed in inches.

TABLE XXX. WIDTH OF ROUND MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Initial | | | | |
| Trial I | 10.7 | 11.1 | 10.6 | 10.5 |
| Trial II | 13.5 | 12.8 | 12.7 | 12.2 |
| Trial III | 14.0 | 14.5 | 14.4 | 14.0 |
| Mid-point | | | | |
| Trial I | 13.8 | 13.9 | 12.8 | 13.3 |
| Trial II | 18.5 | 17.0 | 16.6 | 16.8 |
| Trial III | 17.5 | 18.0 | 18.1 | 17.7 |
| Final | | | | |
| Trial I | 15.7 | 14.9 | 15.4 | 15.6 |
| Trial II | 19.2 | 18.7 | 18.7 | 18.7 |
| Trial III | 19.0 | 19.4 | 19.7 | 19.2 |

[1]Widest points, perpendicular to midline, with steer in normal standing position. All values are expressed in inches.

TABLE XXXI. CARCASS MEASUREMENTS OF STEERS ON DIFFERENT PLANES OF NUTRITION[1]

| Plane of Nutrition | HH | HM | MH | MM |
|---|---|---|---|---|
| Carcass length | | | | |
| Trial I | 44.4 | 44.4 | 44.2 | 44.2 |
| Trial II | 45.4 | 45.8 | 45.7 | 46.9 |
| Trial III | 45.3 | 44.5 | 45.6 | 45.6 |
| Length of leg | | | | |
| Trial I | 28.6 | 28.8 | 28.2 | 28.6 |
| Trial II | 28.9 | 29.7 | 29.4 | 30.3 |
| Trial III | 29.3 | 29.3 | 29.6 | 29.8 |
| Circumference of round | | | | |
| Trial I | 34.2 | 33.9 | 33.1 | 34.0 |
| Trial II | 32.0 | 31.9 | 32.1 | 33.1 |
| Trial III | ---- | ---- | ---- | ---- |
| Length of loin | | | | |
| Trial I | 23.7 | 23.9 | 23.6 | 24.0 |
| Trial II | 23.7 | 24.3 | 24.2 | 24.8 |
| Trial III | 23.8 | 23.5 | 23.8 | 24.1 |
| Depth of body | | | | |
| Trial I | 14.8 | 14.4 | 14.8 | 14.6 |
| Trial II | 15.0 | 15.2 | 15.2 | 15.7 |
| Trial III | 15.1 | 15.3 | 15.4 | 15.2 |
| Width of shoulder | | | | |
| Trial I | 8.3 | 7.9 | 7.8 | 7.7 |
| Trial II | 8.5 | 8.0 | 8.3 | 8.3 |
| Trial III | 7.8 | 7.9 | 8.0 | 8.0 |
| Width of round | | | | |
| Trial I | 8.4 | 8.8 | 8.2 | 8.3 |
| Trial II | 9.4 | 9.1 | 9.2 | 9.3 |
| Trial III | 9.0 | 9.0 | 9.1 | 9.1 |

[1]Averages of right and left sides, in inches.

# VITA

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