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Influence of Proportions of Concentrates to Roughage with Various Feed Additives on the Feedlot Performance of Growing and Finishing Steers

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INFLUENCE OF PROPORTIONS OF CONCENTRATES TO ROUGHAGE WITH VARIOUS FEED ADDITIVES ON THE FEEDLOT PERFORMANCE OF GROWING AND FINISHING STEERS

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

In any feeding operation considerable attention should be given to the selection of a proper ration. A ration that will produce the most rapid gain will not necessarily produce the most economical gain. In addition to rate of gain, one must also consider cost of gain and degree of finish at different weights that can be obtained with various types of rations in order to select the most profitable feeding program.

Rate of gain and fattening depend on the intake of digestible energy in excess of maintenance when the ration contains adequate amounts of other essential nutrients. Energy consumption depends on the amounts and kinds of feeds consumed, or generally in the case of ruminants by the proportions of concentrates to roughages. The information needed in selecting the most economical feeding program for any specific conditions of feed supplies, feed prices and cattle prices is the rate of gain, feed requirement, length of feeding period and market weight necessary to reach the desired market grade with nutritionally adequate rations containing different amounts of energy.

Since many feed additives have become available in recent years, it is important to know their effects with various types of rations. Diethylstilbestrol has been reported to consistently improve gain and feed efficiency. Other feed additives have not been investigated as extensively as diethylstilbestrol, and only limited work has been reported concerning the value of various feed additives when fed with different types of rations.

The work reported in this thesis was undertaken to obtain more information on the effects of energy level in cattle fattening rations on rate of gain, feed consumption, feed efficiency and length of feeding period necessary to produce choice slaughter cattle. Diethylstilbestrol, diallyldiethylstilbestrol, tetra-alkylammonium stearate (dynafac) and an enzyme preparation (Agrozyme) were tested to determine the response to these compounds when feeding rations containing various levels of energy. Digestion trials were conducted in conjunction with the feeding trials to determine what effects the type of ration and the feed additives had on digestibility of the various nutrients.

REVIEW OF LITERATURE

Response of Fattening Cattle to Different Proportions of Concentrates to Roughages

A major problem in finishing cattle for market is selecting the proper energy level in rations which will result in the most economical gain and proper weight and finish at a desired time. The difference in price of roughages compared to concentrates which exists at times necessitates varying the amounts of these ration components in order to realize the most economical gain. The rate at which cattle gain and the time at which they are marketed will be largely influenced by the proportion of concentrates to roughages in the ration. A wise decision here may determine the difference between profit and loss in a feeding operation.

Several experiment stations have conducted studies to determine a satisfactory proportion, or ratio, of concentrates to roughage to feed fattening cattle at various ages. Some of the experiments reported in the literature pertain to proportions of concentrates to roughage and others to various levels of energy. Both types will be considered as studies on energy level of rations in this literature review.

Research on the use of roughage in rations for producing well-finished steers has been pursued quite extensively in the past decade. Dowe and Arthaud (1950a) used 5 lots of 10 yearling steers each to study the effect of various ratios of corn to alfalfa hay in fattening rations. Ratios of corn to alfalfa hay ranging from 1:1 to 5:1 were studied. The most rapid average daily gain (2.61 lb.) was made by the

steers receiving a 3:1 ratio of corn to alfalfa hay ration while the least gain (2.21 lb.) was made by steers on a 1:1 ratio of these feeds. The amount of feed required per 100 lb. of gain decreased somewhat with an increase in the proportion of corn in the ration. The corn to hay ratio of 5:1 resulted in the least feed requirement per 100 lb. of gain. No difference in dressing percent was noted between the various rations; however, the steers on the 3:1 ratio of corn to hay had slightly better carcass grades.

In two experiments at Colorado (Connell, 1951, 1953), 77 yearling steers were fed rations containing ratios of concentrates to roughage ranging from 3:1 to 1:2. Also investigated in one trial was a changing concentrates to roughage ratio which was fed at the rate of 1:2 the first 4 weeks of the experiment and then changed to 1:1, 2:1 and 3:1 ratios in succeeding 4-week periods. The concentrate mixture consisted of one-half rolled barley and one-half ground shelled corn. The roughage portion was ground alfalfa hay. In both trials more rapid average daily gains were made by steers receiving the 3:1 ratio of concentrates to roughage. Although these steers made the highest daily gains during the feeding period, it was made at either the highest or next to the highest cost. The cheapest gains were made by steers receiving the changing ratio. Feed efficiency improved as the level of concentrates was increased in the ration. The majority of the animals graded choice when marketed, but the high-concentrate rations produced the highest yielding carcasses. In another trial consisting of 2:1, 1:1 and a changing 1:2 to 3:1 ratios of concentrates to roughage, steers that received a 2:1 ratio produced the most rapid gain and required the

least feed per 100 lb. of gain (Connell, 1954).

In four feeding trials it was reported that steers fed a ration which consisted of 2 parts concentrates to 1 part roughage gained an average of 2.37 lb. daily as compared to 2.00 lb. for steers receiving a 1:1 ratio (Dowe et al., 1955a). Increasing the amount of roughage in the ration resulted in greater feed requirements. Steers fed a changing ratio which varied from 1:1 to 5:1 of concentrates to roughage had the highest average dressing percent while steers fed a 1:1 ratio had the lowest. Based on the results of this experiment, it was suggested by the authors that the minimum daily roughage allowance for fattening steers in drylot can be set at 0.60 lb. and the maximum at 0.95 lb. (air-dry basis) for each 100 lb. of live weight.

Test rations with concentrates to roughage ratios of 2:1, 1:1, 1:2 and 1:3 were studied by Pahnish et al. (1956). Daily gains decreased slightly as the proportion of roughage in the rations was increased. The trial consisted of 154 yearling steers fed rolled barley, Hegari grain, cottonseed meal and molasses as concentrates and alfalfa hay, cereal hay, cereal straw and cottonseed hulls as roughage. The rations contained approximately 10 percent protein which was maintained by varying the amount of cottonseed meal in each ration. Average daily gains of 2.71, 2.66, 2.52 and 2.46 lb. were made by steers receiving the concentrates to roughage ratios of 2:1, 1:1, 1:2 and 1:3, respectively. The feed required per 100 lb. of gain increased as the proportion of roughage was increased in the ration.

Since feed efficiency in the above experiment offered only a vague picture of ration utilization, digestion trials were conducted to determine the digestibility of the various rations used in the feeding trial. It was reported that each ration contained about 2 therms of gross energy per pound of feed, but digestibility of this energy decreased progressively from the 2:1 to the 1:3 ratios of concentrates to roughage.

In two other trials steers fed rations with various proportions of corn to alfalfa hay made more rapid gains when the ration contained 2 parts corn to 1 part alfalfa hay (Keith et al., 1952; Dowe et al., 1950b). Feed efficiency tended to improve as the amount of corn was increased in the ration.

Two trials using milo grain and alfalfa hay were conducted with steer calves to obtain further information on the optimum ratio of concentrates to roughage (Richardson et al., 1952). It was found that steer calves which received 3 lb. of milo grain to 1 lb. of chopped alfalfa hay made the largest average daily gain of 2.20 lb. daily. Two other groups, one fed a lower level (1:1 ratio) of concentrates and the other a higher level (5:1 ratio), gained 2.13 and 2.10 lb. daily respectively. Feed requirements were lowest for the steers receiving the 3:1 ratio of concentrates to roughage.

A summary of three tests, in which heifers were used, showed that the rate of gain increased as the concentrates were increased in the rations. However, the reverse was true in another test with steer calves (Richardson et al., 1956). Carcass grades were lower for the

animals on a 1:1 ratio of concentrates to roughage than with larger amounts of concentrates. Greatest digestibility of all nutrients was obtained with a 3:1 concentrates to roughage ratio. These authors reported that a ration consisting of 3 parts concentrates to 1 part roughage represents the optimum level of roughage that promotes greatest digestibility of the nutrients in a ration. When this level of roughage is greatly increased or decreased in cattle rations, the digestibility of nutrients will be decreased.

Studies have been conducted at various stations comparing the effects of pelleted versus meal or complete pelleted rations containing different proportions of concentrates to roughage when fed to cattle. McCroskey et al. (1959) conducted two trials involving 48 steer and heifer calves fed a ground milo-alfalfa hay ration. In the first trial a 4:1 ratio of concentrates to roughage was fed in chopped and in pellet forms. Pelleting the ration depressed gain, feed intake, carcass grade, dressing percent and net return per animal; however, feed efficiency was improved. Ratios of 1:4 and 4:1 of concentrates to roughage, in both meal and pellet form, were studied in the second trial. Calves fed a pelleted ration with a 1:4 ratio of concentrates to roughage made more rapid gains (2.33 lb.) than those fed the 4:1 ratio in either meal (2.26 lb.) or pelleted form (2.05 lb.). Pelleting the ration with the 4:1 ratio of concentrates to roughage decreased gain and feed intake with a slight improvement in feed efficiency.

Feed mixtures with ratios of concentrates to roughage of 70:30, 55:45 and 40:60 were fed either finely ground and pelleted or coarsely

ground and unpelleted to fattening steers for 141 days (Beardsley et al., 1958). The rations contained ground corn, cottonseed meal, molasses and Coastal Bermuda hay. A control lot was fed concentrates plus hay free access in a rack. An average daily gain of 2.97 lb. was made by the steers receiving the 70:30 unpelleted ration as compared to a gain of 2.68 lb. made by the steers on the control ration. In general, as the level of roughage was increased in the rations, steer gains were decreased on the non-pelleted and were increased on the pelleted rations. Only 850 lb. of feed were required to produce 100 lb. of gain for the steers fed the 70:30 pelleted ration as compared to 1040 lb. for the control group. No information was given in this study pertaining to carcass grade or yield.

Cmarik et al. (1957a) studied complete pelleted rations of varying ratios of concentrates to roughage. Sixty yearling steers were self-fed rations containing ground shelled corn, ground hay and soybean oil meal for a period of 153 days. Average daily gain and feed efficiency improved as the level of concentrates was increased in the ration. The most rapid average daily gain was made by the steers fed a ration with 75 percent concentrates. Dressing percent and carcass grade were similar for all groups.

Putnam and Davis (1963) presented results of 12 experiments in which pelleted rations were fed to cattle. Results showed equal or better steer gains made on about 10 percent less feed per lb. of gain when rations were pelleted. Feed intake decreased when high-concentrate rations were pelleted, but increased on high-roughage rations. In one

trial where digestion coefficients were determined, pelleting a high-roughage ration significantly lowered the digestibility of dry matter, crude protein, crude fiber and energy.

A series of experiments were conducted at Idaho to study the effect of level of protein intake on rate and economy of gains of steer calves fed various levels of concentrates to roughage (Keith et al., 1954, 1955, 1958). A total of 420 Hereford steers were fed rations containing concentrates to roughage ratios ranging from 1:3 to 4:1. In one trial steers fed a ration containing a concentrates to roughage ratio of 2:1 made an average of 15 to 23 percent higher gains and required 11 to 17 percent less feed than steers fed a ration containing a 1:2 ratio. In other trials no significant differences were noted in rate of gain between the different ratios; however, feed requirements tended to increase with an increase in the roughage level of the rations.

Workers at Nebraska (Matsushima et al., 1957) fed three levels of protein and energy to 9 lots of 5 steers each in a 3 x 3 factorial experiment. Medium levels of protein and energy were calculated to provide nutrients in amounts recommended by the National Research Council (N.R.C., 1959). High and low levels of protein and energy were approximately 18 and 10 percent, respectively, above and below the recommended levels. Urea and stabilized prime beef tallow were used to adjust the protein and energy levels in the rations. The largest average daily gain (2.06 lb.) was made by the group receiving the high-protein, medium-energy ration while lowest gain (1.63 lb.) was

made by steers fed the low-protein, high-energy ration. Efficiency of feed utilization increased as the level of energy and protein increased in the ration. Steers fed the medium-protein, medium-energy ration produced the highest carcass grades and dressing percentages. Digestion trials were conducted concurrently with the feeding trial in this study. It was found that as the energy in the ration increased, fiber digestibility decreased and ether extract digestibility increased.

Since digestibility appears to be influenced by certain energy levels, it is important to consider some of the work that has been done in this area. Mitchell and Hamilton (1932), using a Shorthorn steer in metabolism studies, investigated the effects of various levels of nutrition on utilization of energy in the ration. The steer was subjected to a full feed, four-fifths feed, three-fifths feed, two-fifths feed, one-fifth feed and fasting metabolism. The ration on the dry-matter basis contained 73.1 percent ground corn, 24.1 percent alfalfa hay, 2.0 percent linseed meal and 0.8 percent molasses. The lowest level of feeding (one-fifth feed) was associated with the most complete digestibility of all nutrients. There was a progressive decrease in digestibility in the case of nitrogen-free extract, ether extract and dry matter from the lowest to the highest ration. The results indicated that net energy values were related to the intake of dry matter and possibly the size of the animal.

Haynes et al. (1955) conducted digestibility studies with steers and cows fed rations consisting of 100, 75, 50 and 35 percent alfalfa hay. The grain portion of the ration consisted of ground corn and

distillers grains with solubles. There was a highly significant ($P<0.01$) difference in digestibility between cows and steers. The difference appeared to be due to lower digestibility of crude fiber and ether extract by the steers. Digestibility of all other constituents was similar for each group of animals. The percents TDN in the rations with the four levels of alfalfa hay, respectively, were 53.8, 62.0, 65.0 and 67.8 for cows; and 46.1, 52.8, 60.9 and 62.7 for steers. These results show an increase in percent TDN in the rations for both cows and steers as the amount of hay was decreased and concentrates were increased but with cows giving higher values in each instance.

Significant differences in digestibility were noted in trials with 54 Angus heifers fed various energy levels (Elam et al., 1958). Average digestibility of organic matter, nitrogen-free extract and energy was significantly greater ($P<0.01$) for heifers receiving a medium-energy ration than for either the high or low-energy rations. Digestibility of crude protein, ether extract and crude fiber was significantly lower ($P<0.01$) in the high-energy groups. The low-protein groups digested significantly less ($P<0.01$) organic matter, ether extract, crude fiber and energy than the medium or high-protein groups.

Dowe et al. (1955b) reported results taken from 28 digestion trials with cattle fed corn to alfalfa hay ratios ranging from 1:1 to 5:1. Dry matter, crude protein and nitrogen-free extract in the feces increased as the corn in the rations was increased. The apparent digestibility of dry matter and ether extract also increased as the

amount of corn was increased in the rations. When the coefficients of apparent digestibility for the nutrients studied were analyzed statistically, the differences in apparent digestibility of the nutrients between ratios were not significant. In a similar trial conducted with sheep, results indicated that as the corn in the ration was increased the apparent digestibility of the complete ration increased for all the nutrients except crude protein in one instance and crude fiber in another (Phillips et al., 1951).

A series of five trials was conducted to compare the performance of cattle fed high-concentrate rations and their effect on various levels of crude fiber (Davis et al., 1963). In general, cattle fed a ground shelled corn ration consumed significantly less feed than those fed a corn-and-cob ration. Daily gains, feed efficiency and carcass data were not different when analyzed statistically. A 2.6 percent versus 7.0 percent crude fiber rations were compared in one trial. The cattle consuming the 7.0 percent crude fiber ration ate 27 percent more feed than those fed the 2.6 percent ration ($P < 0.01$). No significant differences were noted in daily gains or feed efficiency.

In summary, it has generally been found that yearlings or 2-year-old cattle made the most rapid gain when fed rations consisting of either 2:1 or 3:1 ratio of concentrates to roughage. Higher levels of concentrates tended to depress gains and increase feed costs. On the other hand, lower levels of concentrates reduced gain and lessened the chances of reaching a good degree of finish. Morrison (1956) states that, "if it is desired to reduce the amount of grain fed, it

is best to feed but little grain during the first month of the fattening period, and then gradually increase it until the cattle get a liberal amount." It is quite evident that steers receiving a limited grain ration need a longer period in the feedlot to attain the weight and condition of steers on a more liberal grain ration. It is, in most cases, advisable to use a more concentrated ration to attain a slightly greater finish.

Feed efficiency has generally improved as the proportion of concentrates increased in the ration. Digestibility of the rations has tended to increase as the concentrates were increased.

The Value of Various Feed Additives With Rations Containing Different Proportions of Concentrates to Roughages

Diethylstilbestrol

A synthetic compound, diethylstilbestrol, having properties similar to the natural estrogens and commonly called "stilbestrol," has received considerable attention as a feed additive and as an implant. A vast amount of literature is available pertaining to the use of this growth stimulant with cattle and sheep. It is beyond the scope of this thesis to give detailed information on all studies concerning this feed additive. Summaries on the general effects of stilbestrol fed to beef cattle have been prepared by a few researchers. These will be discussed briefly with special attention being given to stilbestrol when used in conjunction with different proportions of concentrates to roughage or various energy levels in rations.

There is substantial evidence available which shows that stilbestrol will generally increase rate of gain and feed efficiency when used as a subcutaneous implant or fed in rations for fattening cattle (Burroughs et al., 1955; Morrison, 1956; Maynard and Loosli, 1962; Radabaugh, 1958 and Radabaugh and Embry, 1959). In the many trials summarized by these workers, stilbestrol increased gain on an average of from 12 to 16 percent over similar control animals. Although there was not conclusive information available, steers implanted with stilbestrol appeared to produce slightly more gain than did steers fed stilbestrol orally. In tests where feed efficiency was reported, feed required per 100 lb. of gain was from 10 to 12 percent less for the animals receiving stilbestrol.

In general stilbestrol treatments do not seem to significantly affect carcass grade. A level of 10 mg. of stilbestrol per animal daily is usually recommended when fed orally, while 24 and 36-mg. implants are most frequently used. Using implant levels higher than 36 mg. often results in undesirable side effects such as excessive mammary development, elevated tailhead, depressed loins, and sometimes in the case of heifers, prolapse of the vagina.

A summary of cattle feeding experiments with stilbestrol conducted at nine experiment stations was prepared by Burroughs et al. (1955). Cattle fed 10 mg. of stilbestrol or less per animal daily showed a 16 percent increase in daily gain and an average of 12 percent reduction in feed costs over the control groups. Little difference was noted in carcass value between the two groups. Although direct

comparisons of high-grain rations with high-roughage rations were not shown in this summary, greater gain stimulation occurred when stilbestrol was fed to cattle receiving high-grain rations. On the other hand, the percent response to stilbestrol for cattle on pasture or fed wintering rations has often been as much or more than the percent increase obtained on high-grain fattening rations (Radabaugh and Embry, 1959).

Stilbestrol gave the largest increase in daily gains on a high-concentrate ration (75 percent concentrate and 25 percent hay) in a trial conducted by Cmarik et al. (1957b). Steers implanted with 48 mg. of stilbestrol made an over-all average daily gain of 3.10 lb. as compared to 2.54 lb. for the control group. Carcass grade and yield were slightly favored by the control steers. In another report (Burroughs et al., 1958b) steers fed 10 mg. of stilbestrol were used to study the effect of rations differing in protein and energy contents. Steers receiving a high-energy-to-protein ration made the most rapid daily gain at a lower cost than those receiving a low-energy-to-protein ration.

Keith et al. (1960) conducted two trials to compare gains of 160 steer calves given four levels of stilbestrol with two ratios of concentrates to roughage. The rations consisted of ground barley, ground oats, dried molasses beet pulp, soybean oil meal and sodium chloride. The results of these tests are presented in tables 1 and 2.

In both experiments steers fed the higher concentrates to roughage ratio made more rapid gains and required less feed per 100 lb.

Table 1. Effects of Four Levels of Stilbestrol With Two Ratios of Concentrates to Roughage for Steer Calves (Keith et al., 1960)

Stilbestrol mg.	Ratio of concentrates to roughage	No. of steers	Average daily gain lb.	Average daily ration lb.	Feed per 100 lb. gain lb.
0	1:2	10	1.77	26.8	1515
12 implant	1:2	10	2.00	26.6	1426
36 implant	1:2	10	2.10	30.4	1445
10 oral daily	1:2	10	1.99	29.2	1469
0	2:1	10	1.89	22.8	1207
12 implant	2:1	10	2.17	23.2	1068
36 implant	2:1	10	2.16	22.6	1043
10 oral daily	2:1	10	2.12	24.0	1135

Table 2. Effects of Four Levels of Stilbestrol With Two Ratios of Concentrates to Roughage for Steer Calves (Keith et al., 1960)

Stilbestrol mg.	Ratio of concentrates to roughage	No. of steers	Average daily gain lb.	Average daily ration lb.	Feed per 100 lb. gain lb.
0	1:1	10	1.99	26.9	1359
12 implant	1:1	10	2.16	27.9	1335
36 implant	1:1	10	2.07	28.2	1365
10 oral daily	1:1	10	2.16	27.8	1295
0	3:1	10	2.07	22.1	1072
12 implant	3:1	10	2.17	21.2	1004
36 implant	3:1	10	2.24	22.0	934
10 oral daily	3:1	10	2.14	22.2	1042

gain. Steers receiving the high-concentrate rations with stilbestrol treatment had a lower carcass shrink and a larger rib-eye area than those without the stilbestrol treatment.

In a 109-day trial steers fed a high-concentrate ration with 10 mg. of stilbestrol per head daily gained 3.1 lb. per head daily as compared to 2.7 lb. for the control steers (Hentges et al., 1960). In a second trial steers fed a high-roughage ration and implanted with 24 mg. of stilbestrol gained faster than similar control steers. Less feed per 100 lb. gain was required by the stilbestrol-fed animals in both trials.

Several authors have tested stilbestrol in conjunction with various energy levels in fattening lamb rations. Hartman et al. (1958) used 698 Texas old-crop feeder lambs in rations self-fed in two forms (pellet and meal), with and without stilbestrol. The concentrates to roughage ratio for the two rations varied from 71 percent concentrates and 29 percent roughage to 41 percent concentrates and 59 percent roughage. Feeding 0.5 mg. of stilbestrol per pound of feed significantly ($P<0.05$) improved average daily gain and feed efficiency over the control lambs. This response was particularly interesting in that it was greater for the lambs fed the high-roughage ration rather than for those receiving the high-concentrate ration. A possible answer may be due to the fact that pelleting the high-roughage ration increased gain 15 percent while pelleting the high-concentrate ration depressed gains 14 percent. No difference was observed in carcass grade and quality between the control and stilbestrol-fed lambs.

Stilbestrol response in lamb fattening rations differing in protein and energy ratios has been studied by Preston and Burroughs (1957, 1958) and Jones et al. (1958). Stilbestrol significantly ($P < 0.01$) increased gain in all instances. It gave somewhat more stimulation on high-energy, high-protein rations than with low-energy, low-protein rations. Feed efficiency was improved with stilbestrol where high-energy rations were fed. Slight differences were noted in carcass grade and yield; however, in one trial dressing percent was substantially increased on a high-energy ration. Low-protein levels were adequate for low-energy rations but not for high-energy rations, which indicates that protein requirement is affected by the energy content of the ration.

From these trials it appears that stilbestrol gave the greatest response in rate of gain and feed efficiency when administered to cattle and sheep fed high-energy or high-concentrate rations. A possible exception to this may be in the case of lambs when high-roughage rations were pelleted. In most cases little difference was observed in carcass grade between stilbestrol-treated animals and untreated ones.

Diallyldiethylstilbestrol

Diallyldiethylstilbestrol (3,3'-diallyldiethylstilbestrol), commonly called diallylstilbestrol or abbreviated DAS, like diethylstilbestrol is a synthetic compound. Although it is similar in structure to diethylstilbestrol, studies indicate that it contains much less estrogenic activity. Only a limited amount of work

pertaining to this compound has been reported.

Thomas et al. (1959a) studied the effect of diallylstilbestrol in wintering rations, in supplements used for grazing steers and in feedlot rations for fattening heifers. In one trial 100 yearling Hereford steers were divided into two lots and grazed on winter pastures. Both lots of steers were fed 2 lb. per day of a 20 percent protein supplement with one lot receiving 8 mg. of diallylstilbestrol per pound of the supplement. Steers receiving diallylstilbestrol gained 19 lb. during the winter phase while the nontreated steers only maintained their initial weight. The steers were divided into four groups for a summer grazing trial. Steers fed 2 lb. per day of a 14 percent protein supplement gained 3.61 lb. daily while those fed the supplement plus 25 mg. of diallylstilbestrol per day gained at a lower rate of 3.43 pounds. Steers receiving similar treatment but fed 10 mg. of stilbestrol gained 3.71 pounds per day.

The fattening trial consisted of 50 heifers full-fed a basal ration composed of barley, beet pulp, wheat mixed feed, dehydrated alfalfa and grass hay. Levels of 15, 20 and 25 mg. of diallylstilbestrol were included in a 32 percent protein supplement and fed at the rate of 1 pound per head daily. Average daily gains increased as the level of diallylstilbestrol was increased in the ration. Daily gains were 2.19, 2.26 and 2.31 lb. for the steers receiving the 15, 20 and 25-mg. levels of diallylstilbestrol, respectively, while the control group gained 2.06 lb. per day. In another trial diallylstilbestrol fed at the rate of 16 mg. daily failed to increase gains in

steers fed a ration of chopped alfalfa hay, barley and a grain pellet (Thomas, 1959a).

In another Montana experiment steers and heifers were fed diallylstilbestrol and stilbestrol in fattening rations (Thomas and Doty, 1959a). Ten-milligram levels of diethylstilbestrol and 15, 20 and 25-mg. levels of diallylstilbestrol were used. Heifers which received the 20-mg. level of diallylstilbestrol made the highest daily gain of 2.10 lb. compared to 1.99 lb. for the stilbestrol-fed heifers and 1.91 lb. for the controls. Lowest gains were made by heifers fed 15 mg. daily of diallylstilbestrol. The least feed per 100 lb. of gain was required by the heifers fed 20 mg. of diallylstilbestrol in their ration. Carcass grades and yields were not affected by any of the treatments applied. At the end of 161 days the steers fed the 25-mg. level of diallylstilbestrol had made the greatest gains.

Kercher (1960) fed 25 mg. of diallylstilbestrol per head daily to 16 yearling steers during a 154-day fattening trial. An equal number of steers fed a control ration gained 2.42 lb. per head daily while those receiving diallylstilbestrol gained 2.35 lb. per head daily. Differences in carcass grades, length of loin and length of body were not significant. Dressing percentage was significantly increased from 59.8 percent to 60.6 percent by feeding diallylstilbestrol.

Diallylhexestrol, another estrogen-like compound similar to diallylstilbestrol, has received some attention in improving the feedlot performance of cattle. Dyer and Ham (1958) fed 4 groups of

12 steers each a pelleted ration for 89 days. Steers treated with diallylhexestrol gained 3.22 lb. daily as compared to 3.08 lb. for the control steers. The treated steers required 544 lb. of feed to produce 100 lb. of gain while the control group required only 534 lb.

Three levels of diallylhexestrol were tested by Thomas and Doty (1959c). Ten heifers per lot were fed diallylhexestrol in one trial at the rate of 10, 15, 20 and 25 mg. per day for 135 days. Daily gains in pounds for the respective treatments were: control, 2.17; 10 mg. of stilbestrol, 2.10; 15 mg. of diallylhexestrol, 2.04; 20 mg. of diallylhexestrol, 2.40; and 25 mg. of diallylhexestrol, 2.19. Diallylhexestrol did not improve weight gains or feed efficiency of steers fed a fattening ration in another trial. Carcass grade and yield were not affected by any of the treatments.

In a 73-day trial Thomas and Doty (1960) implanted steer calves with various levels of diallylstilbestrol, diallylhexestrol or a combination of diallylstilbestrol and diallylhexestrol. The average daily ration was composed of 13 lb. of chopped alfalfa hay and 1 lb. of ground barley. Calves implanted with 12 mg. of diallylstilbestrol made the highest daily gain of 1.46 lb. per head. Steers implanted with 96 mg. of diallylstilbestrol or 12, 24 and 96 mg. of equal parts of diallylstilbestrol and diallylhexestrol gained less than the controls.

From the brief amount of literature available it is rather difficult to draw definite conclusions as to the effect of diallyl-stilbestrol when administered to fattening beef cattle. However, it

appears that diallylstilbestrol may improve gains slightly. Diallylhexestrol may also improve gains slightly over similar untreated cattle. The response of these compounds has been variable which suggests they are somewhat less effective than stilbestrol in improving gains and feed efficiency of cattle.

Dynafac (Trimethyl Alkylammonium Stearate)

Dynafac is a product which consists of 20 percent trimethyl alkylammonium stearate and 80 percent bonemeal or soybean oil meal as a carrier. It is sometimes referred to as a "chemobiotic growth promotant." Variable results have been reported concerning the value of dynafac in increasing gains when fed in rations to cattle and sheep. However, it is thought that dynafac may have some therapeutic action in reducing the severity of feedlot bloat, scours and other diseases of this nature.

Early work with dynafac in cattle fattening rations was done by Culbertson et al. (1957). Twenty-four yearling steers were fed a ration of ground corn, ground oats, soybean meal, molasses and minerals for a 119-day period. Two-gram levels of dynafac per animal daily in the rations failed to increase gains or reduce feed costs. One-half the steers receiving dynafac also received 10 mg. of stilbestrol per day. Dynafac gave no response when fed with or without stilbestrol. The average daily gain for the steers fed the control rations was 3.10 lb. while the dynafac groups averaged 2.96 lb. Feed required per 100 pounds of gain was also in favor of the control lots, 838 lb. as

compared to 872 lb. for dynafac-fed steers. No signs of shipping fever or other ailments were observed during the trial. A similar trial conducted by Burroughs et al. (1958a) did not show a response by cattle to dynafac as judged by rate of gain, feed efficiency, cost of gain and carcass characteristics.

Klosterman et al. (1957) fed dynafac at the rate of 1.5 gm. per head daily to a group of 7 steers. The steers fed dynafac gained at a slightly lower rate (2.05 lb. per day) than did the control steers (2.13 lb.). The dynafac-fed steers ate slightly more feed, but they graded and dressed higher when slaughtered. Because of the limited data available no definite conclusions were drawn from this trial.

Preliminary work with dynafac by Dyer and McGregor (1957) involved 120 yearling steers fed a basal ration of barley, alfalfa, cull peas, beet pulp, molasses and salt. Dynafac was fed at a level of 2 gm. per steer daily and 36-mg. implants of stilbestrol were used. Dynafac or stilbestrol administered singly increased daily gain 0.3 lb. per steer over the control group, while dynafac and diethylstilbestrol fed in combination produced 0.6 lb. faster gain. Steers fed a pelleted ration with dynafac gained 0.1 lb. more daily but they had a lower feed efficiency than the control group in another Washington experiment (Dyer and Ham, 1958).

Thomas (1957a) used 100 steers and 100 heifers which were hand-fed a ration of rolled barley, grass hay and dried molasses beet pulp. In addition, each animal was fed 1 pound per day of a pelleted 32 percent protein supplement with or without 1.5 gm. of dynafac or

10 mg. of stilbestrol added per pound of supplement. Diethylstilbestrol and a combination estrogen-progestrone (Synovex) implants were also tested. The greatest gains were made by steers receiving a combination of dynafac and 36-mg. implants of stilbestrol. These steers made an average daily gain of 2.85 lb. and gained 22 percent more than the controls and 10 percent more than those treated only with stilbestrol. Heifers gained somewhat slower than the steers, but the fastest gain (2.40 lb.) was made by those fed dynafac and implanted with 18 mg. of stilbestrol. Steers or heifers fed dynafac and implanted with stilbestrol produced more gain than those fed a combination of dynafac and stilbestrol. Steers and heifers fed dynafac alone gained 5 and 12 percent more, respectively, than the control groups. Feed efficiency data was not available for this trial.

In another experiment 40 yearling Hereford steers were tested to determine the value of stilbestrol and dynafac for steers self-fed grain on pasture (Thomas et al., 1957b). Barley, beet pulp and a 20 percent protein supplement were the ration constituents. Steers fed dynafac (2 gm. per lb. of feed) gained only about 2 percent more than the control steers. Implanted (36 mg.) or oral (10 mg.) stilbestrol increased gains approximately 5 percent over the control group.

Two trials were conducted with yearling beef steers to determine the value of dynafac and stilbestrol implants when used with pelleted rations (Thomas et al., 1958). In one trial 96 steers were fed a control ration of two-thirds barley and one-third beet pulp with grass hay being used as a roughage. The largest daily gains (2.85 lb.) were

made by the steers receiving 2 gm. of dynafac per animal daily plus a 36-mg. implant of stilbestrol. The control steers gained 2.33 lb. per day. Steers fed dynafac plus 10 mg. of stilbestrol orally gained 2.60 lb. daily while the steers fed dynafac alone gained 2.45 lb.

In a second trial 40 yearling steers were self-fed a ration in meal or pelleted form. Steers fed a pelleted ration with 200 gm. of dynafac per ton of feed and implanted with 36 mg. of stilbestrol produced the highest daily gain (3.41 lb.). Steers not implanted but fed dynafac in a pelleted ration gained 3.40 lb. daily, while those fed a similar ration without dynafac gained 2.89 lb. Feed requirements were the lowest for the pelleted ration with dynafac, 585 lb. per 100 lb. gain for the 84-day trial.

The effect of dynafac in wintering rations for heifers was also tested by Thomas (1959b). Four hundred and eighty weaned heifers were divided into six lots and group-fed a ration consisting of barley, chopped alfalfa hay and a grain pellet containing 2.5 percent fat. Two pounds of barley were also fed after 90 days on the trial. A tranquilizer and dynafac were added at the rate of 2.5 mg. and 0.5 gm., respectively, per heifer. Heifers receiving the rations with tranquilizer plus dynafac and tranquilizer plus dynafac with added phosphorus made daily gains of 1.17 and 0.97 lb. as compared to 1.21 lb. for the control group. When additional grain was included in the ration, the greatest increase in gain was made by the heifers receiving a combination of dynafac and tranquilizer plus added phosphorus. Rate of gain increased from 0.97 lb. per day to 1.71 lb. per day.

An experiment conducted by Zimmer and Embry (1958) involved 26 cattle fed a high-concentrate ration consisting of 67.5 percent rolled shelled corn, 20 percent ground alfalfa hay, 10 percent soybean meal and 2.5 percent mineral. One group of cattle received the basal ration supplemented with 200 gm. of dynafac per ton of feed. The cattle were hand-fed for 31 days and self-fed for the remainder of the 160-day trial. Considerably greater feed consumption was observed in the cattle receiving dynafac in their ration. However, no digestive disturbances were observed with these cattle, while several cases of scours and three cases of foundered animals were noted in the control lot. The dynafac-fed steers appeared to adjust to self-feeding somewhat more rapidly than the control steers.

Weight gains were highest for the dynafac-supplemented steers with 3.10 lb. per day compared to 2.79 lb. for the control group. The control animals ate less feed and required less feed to produce 100 lb. of gain. The dynafac-supplemented animals had higher carcass values than did the control group. Digestion studies with sheep indicated that dynafac did not affect the digestibility of any nutrients.

Wise et al. (1959) used 45 yearling steers and heifers to determine the influence of dynafac on weight gain and feed efficiency in drylot fattening and when wintered on hay with limited concentrate. The fattening ration consisted of ground shelled corn, a mixed grass hay and protein supplement. The wintering ration was composed of peanut hay fed ad libitum and a concentrate mixture consisting of 2

parts ground shelled corn and 1 part cottonseed meal fed at the rate of 3 lb. per head daily. The animals received 1.5 gm. of dynafac per head daily. Dynafac appeared to increase weight gains during the fattening period; whereas in the wintering phase, the control animals gained slightly more. Feed intake was lowered slightly in both trials when dynafac was added to the ration. The authors reported that there was an indication that dynafac increased feed efficiency but further work was needed to substantiate this.

Dynafac fed to steers in a ration of cracked shelled corn, soybean oil meal and mixed hay at the rate of 2 gm. per head daily failed to affect daily gains or feed efficiency (Neumann et al., 1958). Another trial conducted by England and Taylor (1959) indicated that dynafac fed at the rate of 1.5 gm. per head per day to steers did not improve average daily gain or feed efficiency.

Several experiments have been conducted to determine the value of dynafac when fed in lamb fattening rations. One of the early studies was made by Shinn et al. (1956). Three hundred and forty-five lambs were used to evaluate the effect of dynafac and chlortetracycline on growth. Ten milligrams of chlortetracycline and 50, 75 and 100-mg. levels of dynafac were fed per pound of feed. The lambs receiving the 50-mg. level of dynafac and those fed chlortetracycline made 17.5 and 15.8 percent faster daily gains and required 11.6 and 7.8 percent less feed, respectively, than the control group. Enterotoxemia was effectively controlled by both treatments. No differences were noted in carcass values between the various treatments.

Jordan (1958) conducted an experiment involving two trials with 185 lambs hand-fed a ration of shelled corn, brome hay and protein supplement. Trimethyl alkylammonium stearate was fed at the rate of 200 mg. per lamb daily (equivalent to 1 gm. of dynafac). In the first trial dynafac failed to have any effect on rate of gain, but a slight increase in gain was noted in the second trial. Little difference was observed in feed consumption in either trial. Several cases of bloat were noted in the dynafac-fed lambs in the first trial, but none in the second trial. The lambs in all lots developed scours during the early stages of the first trial.

In a 65-day trial 80 white-faced lambs were fed a high-roughage pellet ration with dynafac added at the rate of 50 mg. per lb. of ration (Church and Fox, 1958). The control lambs made an average daily gain of 0.474 lb. while the dynafac-fed group gained 0.418 lb. The lambs receiving dynafac in their ration were only 87.3 percent as efficient as the control lambs in feed conversion. Dynafac gave no benefit to other criteria studied in this experiment.

Blakeslee et al. (1959) reported on a trial involving lambs fed dynafac in either pelleted or meal rations consisting of 55 percent ground yellow corn and 45 percent alfalfa hay. Dynafac added at the rate of 0.3 gm. per pound of total ration did not cause any significant improvement in gain, feed efficiency, dressing percent or carcass grade. Pelleting the rations increased daily gains 23 percent and feed efficiency 23 percent over the non-pelleted rations.

There has been considerable variation in the results reported concerning the value of dynafac in improving daily gain, feed efficiency and carcass values in fattening lambs and cattle. Type of ration fed may have some influence on the response of dynafac. Greater benefit from dynafac has been reported where high-concentrate rations were fed and the least benefit when included in wintering rations.

Feeding rations high in concentrates to cattle and sheep will sometimes result in nutritional upsets which may prove fatal if not corrected. There is some indication that dynafac may alleviate the severity of a few of these disturbances such as bloat and scours in cattle and enterotoxemia in sheep. Further studies need to be made concerning this aspect of dynafac.

Enzyme Preparation (Agrozyme)

Efforts to improve the feedlot performance of fattening cattle has led to the development of several enzyme preparations. Agrozyme, a dried enzyme mixture of bacterial origin, has been investigated recently. It is a crude fermentation product containing both protein and starch digesting enzymes. The possibility that Agrozyme may show response in improving daily gain and feed efficiency has prompted researchers to test this substance more thoroughly.

Thomas and Doty (1959b) tested the value of Agrozyme in cattle fattening rations consisting primarily of barley. At the end of 162 days steers receiving .00375 lb. per day of Agrozyme had made an

average daily gain of 2.74 lb., over 5 percent more than the controls. Steers fed other levels of this enzyme premix made similar or less gains than the control steers. Carcass and feed efficiency data were not available at the time this report was prepared.

The value of adding an enzyme (Agrozyme) mixture to beef cattle rations was investigated in 10 feeding experiments by Burroughs et al. (1960). The enzyme mixture, incorporated in a protein supplement, was fed at the rate of either 0.0075 or 0.0150 lb. per animal daily. Steers and heifers fed both fattening and growing rations were fed for periods ranging from 84 to 240 days in various experiments. The enzyme mixture increased live weight gains over the control lots on an average of 7 percent or from 1.86 to 1.98 lb. per animal daily. Six percent less feed per 100 lb. of gain was required by the enzyme-supplemented lots. Little or no influence was noted in feed consumption or carcass values between the two groups. Digestibility studies revealed no differences in total digestibility between the enzyme-supplemented and control rations.

In six of the above experiments the animals received a ration of ground ear corn, alfalfa hay and protein supplement. The cattle used in the remaining four trials were fed rations consisting of silage, alfalfa-brome hay, ground ear corn and protein supplement. The general response of the enzyme addition on daily gains was as great where the silage rations were fed as where the high corn rations were fed. This is not in agreement with earlier work by Burroughs et al. (1959) where it was reported that Agrozyme increased gains and improved

feed efficiency on steers receiving a dry-corn ration, but not those receiving a high-moisture corn ration.

Mitchell et al. (1959) used 4 lots of 10 steers each to study the effect of Agrozyme and tapazole when added to fattening steer rations. A ration consisting of alfalfa-corn silage, soybean oil meal and hay was fed to steers for 97 days. Tapazole and Agrozyme were added to the rations so the steers would receive 500 mg. and 0.0075 lb. respectively, per head daily. Steers fed Agrozyme singly and in combination with tapazole gained 2.18 lb. and 1.72 lb. per day, respectively, compared with 2.13 lb. for the control steers. Agrozyme had no effect on feed conversion in this experiment.

Pope et al. (1960) observed no beneficial results in rate of gain, feed intake or feed efficiency when Agrozyme was added to different preparations of milo fed to steers.

Theurer et al. (1958) used Agrozyme in a series of digestion trials to determine its effect upon the digestibility of certain rations fed to steers and lambs. The addition of 7 gm. per head daily of the enzyme mixture decreased protein digestibility in a 9 percent but not in a 12 percent protein ration. Dry matter, organic matter and cellulose digestion were not affected by the addition of Agrozyme to the ration. Similar results were obtained with 1 and 2 gm. levels of enzyme mixture added to lamb rations.

A feeding trial conducted by Rea and Ross (1960) was designed to study the response of stilbestrol implanted lambs to enzymes fed in rations varying in protein and energy. Under the conditions of this

experiment, there were no measurable effects due to the addition of enzymes. The specific enzyme used in this experiment was not given in this progress report.

The brief amount of work that has been conducted with Agrozyme has left many questions unanswered as to its possible value in livestock rations. Its effect on only a few types of rations has been tested. The experiments that have been reported with steers fed Agrozyme indicate that this enzyme may be beneficial when added to both dry-corn and silage rations. However, because of the limited number of experiments conducted and the variable results obtained, conclusions pertaining to the value of Agrozyme in cattle feeding rations would only be speculative at the present.

METHODS OF PROCEDURE

Feeding Trial

The main objective of this experiment was to study the effects of different proportions of concentrates to roughage containing various feed additives in fattening rations for steers. Two hundred and fifty-two steers averaging 605 lb. were used in the experiment. They were stratified on the basis of weight and randomly allotted into 28 lots on July 9, 1959. These steers were purchased about one month previously and were used in a study on the value of a tranquilizer in a feedlot adaptation study. During this study they had gained approximately 150 lb. per head including recovery of shrink resulting from shipping.

The initial filled weights of the steers were taken on the afternoon of July 8, 1959, and shrunk weights were taken the following afternoon. They were fed in 28 lots which were 24' x 56' with fence-line feed bunks. The lots were without shelter and pavement except for an 8-foot concrete strip located adjacent to the feed bunk. Each lot was equipped with a stock watering tank and two-compartment salt and mineral box. Electric heaters were used during cold weather to prevent the water from freezing.

A balanced factorial design with three factors was used in the feeding trial. There were seven lots of steers fed each level of roughage. There were four different levels of roughage fed as a grain-hay mixture and supplement; a 50, 35 and 20 percent level and a fourth which contained a variable level of 50-35-20 percent roughage. The

steers receiving the variable level of roughage were fed the 50 percent roughage ration the first 9 weeks of the trial, 35 percent the second 9 weeks and 20 percent until they reached a final weight of about 1100 lb.

Within the 4 groups of 7 lots there was a control, diethylstilbestrol, diallylstilbestrol, dynafac, enzyme preparation (Agrozyme), diethylstilbestrol and dynafac and diallylstilbestrol and dynafac treatment. Each group of seven lots fed on the different levels of concentrates to roughage were randomly assigned adjacent pens. This was done for convenience in feeding the grain-hay mixture. The feed additive treatments were then randomly allotted within each level of concentrates to roughage.

The grain-hay mixture consisted of rolled shelled corn and coarsely ground alfalfa hay. It was prepared as needed by the college feed unit and stored in four separate feed bins located in the feedlot area. The hay was ground with a hammer mill using an 1 inch screen.

The ration ingredients of the grain-hay mixtures are shown in table 3, and the rates at which the additives were added to the supplements are shown in the footnotes of this table. Since the grain-hay mixtures and the control, dynafac and Agrozyme supplements used during the feeding trial were the same as for the digestion trial, chemical composition for these feeds were determined during the digestion trial and shown in table 5. The other supplements used during this feeding trial for each level of roughage were mixed to be the same as those used in the digestion trial.

Table 3. Rations for Feeding Trials

Roughage level	50%	35%	20%
Grain-hay mixture:			
Coarsely ground alfalfa hay, %	55.0	38.0	22.0
Rolled shelled corn, %	45.0	62.0	78.0
Pelleted supplement:[a]			
Ground shelled corn, %	100.0	68.6	34.3
Soybean oil meal, %	---	31.4	65.7

[a] Composition of the control supplement. The following additives were used to form the other supplements. In each case they replaced an equal weight of ground shelled corn.

Dynafac (trimethyl alkylammonium stearate) premix: 1 gm. per lb. of supplement. Supplied by Armour and Company, Chicago, Illinois.

Agrozyme premix: 1.70 gm. per lb. of supplement. An enzyme mixture of bacterial origin containing both amylolytic and proteolytic enzymes. Supplied by Merck, Sharp and Dohme Research Laboratories, Rahway, New Jersey.

Diethylstilbestrol premix: 0.005 percent to furnish 5 mg. of diethylstilbestrol per lb. of supplement. Supplied by Eli Lilly Company, Indianapolis, Indiana.

Diallylstilbestrol premix: 2.88 gm. per lb. of supplement to furnish 12.5 mg. of diallylstilbestrol. Supplied by Armour and Company, Chicago, Illinois.

Diethylstilbestrol-dynafac and diallylstilbestrol-dynafac supplements furnished the additives at the same levels as when fed alone.

The total protein content of the rations was maintained at approximately 12 percent by varying the amount of soybean oil meal to corn in the supplements. The protein content of the supplement was about 9 percent (corn only) when fed with the 50 percent roughage ration, 20 percent with the 35 percent roughage ration and 30 percent with the 20 percent roughage ration.

The feed additives were mixed with the protein supplements which were pelleted. The additives were added at a rate to supply 10 mg. diethylstilbestrol, 25 mg. diallylstilbestrol, 2 gm. dynafac and 3.4 gm. of the enzyme preparation. Premixes composed of approximately 400 lbs. were mixed in a 500-lb. tank-type premixer. The mixes were sacked and trucked to DeSmet, South Dakota where they were pelleted. The pelleted supplements were stored in steel granaries located near the college feed unit until needed.

One and one-half ton batches of each protein supplement were pelleted at one time. This quantity of supplement lasted for about 100 days; therefore, pelleting was done at two separate times, once at the beginning of the trial and again when the trial was about one-half completed.

The cattle were started on the grain-hay mixture at a rate of 10 lb. per steer daily and increased 1 lb. daily until they were on full feed. Thereafter, they were fed once daily in amounts so feed would be available at all times. The pelleted protein supplement was fed on top of the grain-hay mixture at the rate of 1 lb. of supplement to every 10 lb. of the grain-hay mixture. This procedure

was used to maintain constant proportions of concentrates to roughage and protein levels in the rations. A mineral supplement composed of 1 part ground limestone, 1 part trace mineral salt and 3 parts dicalcium phosphate in addition to trace mineral salt was offered free-choice.

During the trial, a number of cases of pinkeye, footrot and bloat were observed. Pinkeye cases were treated with an antibiotic powder. The powder was administered directly to the infected eye of the animal. Animals having footrot were given 1 ounce of sulfamethiozine by capsule and injected intramuscularly with 5 cc. of penicillin. Bloated animals were closely observed and the degree of severity recorded.

The cattle were weighed at 4 or 5-week intervals. In the case of the 50-35-20 percent roughage group, the rations were changed after each 9-week period. At this time, weighbacks were made on the feed remaining in the mangers and weights recorded.

The steers were sold in four separate groups. The group of seven lots on each level of concentrates to roughage was sold when the average weight for all lots in the group was about 1100 lb. The first group to be sold was the 20 percent roughage steers on January 19, 1960, after a 194-day feeding period. The steers receiving the 50-35-20 percent roughage rations were sold next, followed in order by the 35 percent and 50 percent roughage groups. Feeding periods of 201, 215 and 222 days, respectively, were required by these groups of steers. All groups had been removed from trial by February 17, 1960.

Final filled weights were taken on the afternoon prior to marketing and the steers were ear tagged for identification at slaughter. The cattle were kept in their respective lots overnight without feed and water until about 5:00 a.m. the next morning. The cattle were weighed prior to loading and trucked 75 miles to Huron, South Dakota where they were sold to the Armour and Company packing plant. Individual market weights and live weight grades were recorded before slaughter. During slaughter the carcasses were tagged with the same number that was on the ear tag so carcass information could be obtained for each steer.

The carcasses were chilled for 48 hours. Cold carcass weights, rib-eye tracings and federal carcass grades were obtained for each carcass. Cold carcass weights were obtained by taking a 2.5 percent shrink from the hot carcass weights.

The data were analyzed statistically using a factorial analysis of variance with equal subclass numbers. The significance of differences between means were determined by use of Duncan's Multiple Range Test (1955).

Digestion Trial

The primary objective of the digestion trial was to determine the effects of the different proportions of concentrates to roughages on digestibility of the rations.

Nine Hereford steers having an average initial weight of 748 lb. were used as the experimental animals and were fed in individual stanchions at the college nutrition laboratory. The experiment was

divided into four consecutive periods each consisting of a 15-day preliminary period and a 5-day collection period. Fecal collections were made by means of a canvas bag and harness fitted to the animals. They were fastened in stanchions for 3 hours for feeding twice daily. At other times they were allowed to run as a group in an exercise lot where they had free access to water and the mineral supplement that was offered in the feeding trial.

The steers were divided into 3 groups of 3 each and fed rations composed of 50, 35 and 20 percent roughage. Within the 3 roughage groups, 1 steer was fed the control supplement and 1 each was fed supplements with the enzyme preparation (Agrozyme) and dynafac. These additives were selected since it was thought that they might affect digestibility of the rations. The design of the digestion trial is shown in table 4.

The grain-hay mixtures and protein supplements were the same as fed in the feeding trial. They were also fed in the same ratio as in the feeding trial. Chemical composition of the feeds is shown in table 5.

The steers were individually fed twice daily on the basis of body weight. They were started at the rate of 2800 grams of grain-hay mixture daily and raised 200 grams each day until at approximately a full feed for most of the steers. After Period II had terminated, some of the steers were not consuming all of the ration they were offered. In succeeding periods, the feed was adjusted during the preliminary period according to what each steer would consume. During

Table 4. Design of Digestion Trial

Roughage levels	Control	Agrozyme	Dynafac
		Steer Numbers	
		Period I	
50%	3	14	13
35%	15	7	12
20%	6	8	5
		Period II	
50%	7	4	15
35%	10	6	13
20%	9	12	14
		Period III	
50%	12	10	5
35%	14	8	3
20%	15	7	13
		Period IV	
50%	5	10	8
35%	3	6	14
20%	12	7	15

Table 5. Chemical Composition of Feeds Used in Digestion Trials[1]

	Dry matter as fed	Crude protein	Crude fiber	Ether extract	Ash	Nitrogen-free extract	Gross energy
	%	%	%	%	%	%	kcal./gm.
			50% Roughage Ration				
Grain-hay mix	85.00	12.89	15.68	3.48	6.04	47.91	4.36
Dynafac supplement	90.70	9.78	2.07	4.78	1.90	72.17	4.46
Agrozyme supplement	90.71	9.90	2.07	4.41	1.58	72.75	4.46
Control supplement	90.26	9.60	3.01	4.42	1.43	71.80	4.47
			35% Roughage Ration				
Grain-hay mix	85.49	12.74	14.15	3.48	4.84	50.28	4.44
Dynafac supplement	89.74	21.34	3.31	3.52	3.58	57.99	4.52
Agrozyme supplement	91.23	21.31	3.43	4.15	3.68	58.66	4.52
Control supplement	92.33	22.09	3.33	3.81	3.35	59.75	4.43
			20% Roughage Ration				
Grain-hay mix	85.89	11.75	9.53	4.26	3.75	56.60	4.51
Dynafac supplement	91.02	31.73	4.81	2.94	4.49	47.05	4.54
Agrozyme supplement	90.64	31.47	4.68	3.01	4.65	46.83	4.59
Control supplement	90.86	33.19	4.28	2.92	4.67	45.80	4.54

[1] Chemical composition on basis of dry matter as fed.

each collection period a constant daily feed was offered for each animal. Feed consumption and weight records were kept for each animal.

Feed refused (orts) during the collection periods was left to accumulate until the period had ended. Where orts had accumulated, they were weighed, sampled and dried at 100° C. in a forced-draft oven for dry matter determinations. A representative portion was ground through a one-millimeter mesh screen in a standard-type Wiley mill to furnish two samples. One sample was sent to the Experiment Station Biochemistry Department for complete proximate chemical analysis, and the other saved for later energy determinations. Samples of the grain-hay mixture and protein supplements were taken during the collection period and treated in a similar manner as the orts for dry matter determinations, chemical analyses and energy determinations.

The fecal bags were emptied twice daily as near 9:00 a.m. and 4:00 p.m. as possible and total weight of the feces recorded. A 3 percent sample of feces was taken from each steer at each weighing and frozen in 1-gallon glass jars. At the end of each period the samples were removed, thawed and ground in an ordinary meat grinder and two representative samples were analyzed as for the feed and ort samples. After the completion of analyses on feces, feed and orts, coefficients of apparent digestibility were calculated for dry matter, crude protein, ether extract, crude fiber and nitrogen-free extract.

Gross energy was determined on the duplicate samples of feces, feed and orts. A representative portion of each sample was placed in

a small aluminum-foil dish and subsequently dried in a convection drying oven. The feces were dried at a temperature of 80° C. for 72 hours and the feed and orts dried at 100° C. for 48 hours. Energy determinations were made on samples of not more than 1.5 grams in a Parr adiabatic oxygen bomb calorimeter. Prior to bombing, the feces were ground through a 40 mesh screen in an intermediate-type Wiley mill. All weight determinations were made on a Mettler gramatic balance scale. Energy digestion coefficients were calculated for the various rations used in the trial.

The data were analyzed statistically using the same procedures as for the feeding trial.

RESULTS AND DISCUSSION

Feeding Trial

The steers which received the variable ratio of concentrates to roughage were fed rations with 50 percent roughage during the first 9 weeks of the trial, 35 percent the second 9 weeks and 20 percent until the experiment was terminated. Weight gain data on basis of filled weights and feed consumption data were obtained during these three periods for all lots of cattle. Since performance at various stages of finishing was of interest in this experiment, comparisons between the various levels of roughage (alfalfa hay) were made during each of the three periods as well as for the complete trial.

Weight Gains of Steers Fed Different Levels of Concentrates to Roughage

Average daily gains obtained with rations containing various levels of alfalfa hay and corn grain are presented in table 6. Results of the statistical analysis are presented in tables 7 and 8. Average daily gains for the different levels of alfalfa hay include the average with all the feed additives.

The cattle were marketed when the average feedlot weight for the group on each roughage level reached approximately 1100 lb. Increasing the level of alfalfa hay in the rations resulted in lower gains and required a longer feeding period to reach this market weight. However, there were only small differences in daily gain between the cattle fed the rations with 50 and 35 percent alfalfa hay or those fed the 20 percent and variable level of hay. Changing the level of alfalfa hay

Table 6. Weight Gains of Steers Fed Different Levels of Concentrates to Roughage

Period	Days fed	Av. init. wt.[1]	Av. final wt.[1]	Av. daily gain[1]
		lb.	lb.	lb.
		50% Roughage Rations		
1	63	606.1	770.8	2.61[a]
2	63	770.8	933.0	2.58[c]
3	96	933.0	1111.5	1.86[a]
Total	222	534.6	1084.2	2.48[a]
		35% Roughage Rations		
1	63	605.6	772.4	2.65[a]
2	63	772.4	941.2	2.68[b,c]
3	89	941.2	1075.0	1.50[b]
Total	215	533.6	1059.1	2.43[a]
		20% Roughage Rations		
1	63	597.5	767.1	2.69[a]
2	63	767.1	947.8	2.87[a]
3	68	947.8	1092.8	2.13[c]
Total	194	529.8	1068.2	2.77[b]
		50-35-20% Roughage Rations		
1	63	603.1	762.4	2.53[a]
2	63	762.4	938.6	2.78[a,b]
3	75	938.6	1093.7	2.21[c]
Total	201	530.8	1072.2	2.70[b]

[1] Weight gains for periods 1, 2 and 3 are based on initial and final filled weight. Total weight gains are based on initial and final shrunk weights.

[a,b,c] Means within the same period having different superscript letters differ significantly ($P<0.01$).

| Means within a roughage level not covered by the same line differ significantly ($P<0.05$).

Table 7. Analysis of Variance for Average Daily Gain (Total Trial)

Source	d.f.	S.S.	M.S.	F value
Total	251	32.1693		
Roughage levels	3	4.9201	1.6400	16.942**
Additives	6	3.4219	.5703	5.891**
Roughage x additives	18	2.1488	.1194	1.233
Residual	224	21.6785	.0968	

** Significant at the 1% level of probability.

periodically improved rate of gain over feeding a constant level of 50 percent or 35 percent throughout the feeding period. The differences in gain between the cattle fed the rations with 20 or 50-35-20 percent alfalfa hay and those fed the rations with 35 or 50 percent alfalfa hay were statistically significant ($P < 0.01$).

During the first 9 weeks of the experiment only small differences were noted in the rate of gain between the various treatments indicating that level of roughage within the ranges used had only a small effect on rate of gain during the early stages of fattening. The rate of gain increased as the level of concentrates was increased and hay decreased during the second 9 weeks of the trial. There was an improvement in rate of gain over the first period when feeding the 20 percent hay rations and when the hay was reduced from 50 to 35 percent of the ration. Differences in gains between periods 1 and 2 were significant ($P < 0.05$) only in these two instances. These results would indicate an advantage for a high-energy ration in later stages of finishing and of concentrating the energy content of the rations as the cattle

Table 8. Analysis of Variance for Average Daily Gain (Periods 1, 2 and 3)

Source	d.f.	S.S.	M.S.	F value
Total	755	284.9568		
Periods	2	104.7338	52.3669	268.824**
Roughage levels	3	9.0339	3.0113	15.458**
Additives	6	10.5110	1.7518	8.993**
Periods x roughages	6	10.3274	1.7212	8.836**
Periods x additives	12	2.3564	.1964	1.008
Roughage x additives	18	6.5336	.3630	1.863*
Periods x roughage x additives	36	10.5732	.2937	1.507*
Residual	672	130.8875	.1948	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

become fatter.

Average daily gains for the steers during period 3 were 1.86, 1.50, 2.13 and 2.21 lb. per head daily for the 50, 35, 20 and 50-35-20 percent alfalfa hay rations, respectively. All steers showed a significantly ($P<0.05$) lower rate of gain during this period with the heavier and more highly finished cattle. The colder weather conditions which existed during this time also probably influenced the performance. The two groups of cattle fed the rations with 20 percent alfalfa hay made significantly ($P<0.01$) faster gains than those fed rations with either 35 percent or 50 percent hay. There was a slightly larger gain for the

steers which had received the ration with 35 percent hay during period 2 and the one with 20 percent hay in period 3 in comparison to the cattle fed rations with 20 percent hay during all periods, but the difference was not statistically significant.

The poorer performance made by the cattle fed the ration containing 35 percent hay is somewhat surprising. Bloat was more of a problem with this group than for those fed either the higher or lower level of hay. The possibility of feeding a high level of roughage during the early stages of feeding and changing directly to a high-concentrate ration during the later stages may be indicated by the performance made by these cattle. However, more studies need to be made in this area of feeding to substantiate this possibility.

Results of period 2 where gains improved as the level of concentrates was increased in the ration are in agreement with Richardson et al. (1956) and Beardsley et al. (1958). However, comparisons made at the termination of the trial where slower gains were noted on steers receiving the 35 percent roughage ration are not in agreement with Connell (1954) and Keith et al. (1954, 1955, 1958) who reported steers fed a 2:1 ratio of concentrates to roughage made the most rapid gains. Dowe and Arthaud (1950a) found that a 1:1 ratio of corn to alfalfa hay resulted in the lowest gains by steers.

Results of this experiment would indicate a need for high-concentrate rations where a desired market weight and finish is to be reached in the shortest length of time. On the other hand, if the availability of roughages exceeds that of concentrates and length of

feeding period is not an important factor, satisfactory gains and market weights may be reached economically on high-roughage rations. The performance during the first 9 weeks of the trial and that of the steers fed the 50-35-20 percent alfalfa hay rations would indicate that high-roughage rations may be used during the early stages of finishing and still obtain satisfactory gains and market weights without much increase in the time required. This is in agreement with comments made by Morrison (1956).

Weight Gains of Steers Fed Various Feed Additives

Daily gains for steers fed various feed additives based on initial and final shrunk weights are presented in table 9. Results of the statistical analysis are shown in table 7.

Average rates of gain at all roughage levels were increased by 7.4 and 6.6 percent over the controls ($P < 0.05$) by diethylstilbestrol and diethylstilbestrol plus dynafac, respectively. These steers also gained significantly ($P < 0.05$) faster than steers which received any of the other treatments, but there were no significant differences between the other treatments.

Roughage level did not appear to have any appreciable effect on the response made by the additives tested in this experiment and the roughage x additive interaction was nonsignificant for the entire trial. However, there were greater rates of gain for all the additives except Agrozyme over the control group when included in the rations with 20 percent hay.

Table 9. Weight Gains of Steers Fed Various Feed Additives

Feed additive	50% roughage rations	35% roughage rations	20% roughage rations	50-35-20% roughage rations	Average
	lb.	lb.	lb.	lb.	lb.
Control	2.42	2.45	2.61	2.84	2.58[a]
Diethylstilbestrol	2.59	2.69	2.82	2.98	2.77[b]
Diallylstilbestrol	2.39	2.28	2.79	2.44	2.52[a]
Dynafac	2.49	2.36	2.80	2.64	2.57[a]
Agrozyme	2.49	2.27	2.57	2.51	2.46[a]
Diethylstilbestrol + dynafac	2.66	2.65	3.05	2.65	2.75[b]
Diallylstilbestrol + dynafac	2.35	2.32	2.78	2.81	2.56[a]
Average	2.48	2.43	2.77	2.70	

[a,b] Average mean values having different superscript letters differ significantly ($P < 0.05$).

The improvement in rate of gain made by steers fed rations containing diethylstilbestrol was fairly constant at all roughage levels, but was lower than the improvement resulting from this additive in data summarized by Burroughs et al. (1955) and Radabaugh and Embry (1959). These workers reported an increase of 12 and 16 percent in daily gains for cattle fed diethylstilbestrol. Although diethylstilbestrol plus dynafac resulted in gains approximately the same as for diethylstilbestrol alone, it would appear that this effect was due primarily to diethylstilbestrol since dynafac alone gave little or no improvement in rate of gain except when fed with the 20 percent hay rations. Zimmer

and Embry (1958) and Thomas (1957a) found dynafac fed to steers receiving high-concentrate rations improved rate of gain which would agree with the results of this experiment.

The results obtained by other workers with diallylstilbestrol, dynafac and enzyme products, including Agrozyme, have been quite variable. The work reported by other workers and the results of this experiment indicate a questionable value for these products in rations for cattle.

Feed Consumption

Average feed consumption for the different roughage levels and various feed additives is shown in tables 10 and 13, respectively. Results of the statistical analysis are presented in tables 11 and 12.

There was an increase in feed consumption with increasing amounts of hay in the ration during all periods ($P<0.05$) with the one exception with 35 percent hay in period 3. This was the period in which the cattle fed the rations with 35 percent hay made poor gains. Cattle fed a 50 percent hay ration in period 1 and 35 percent in period 2 consumed ($P<0.05$) more feed than those fed the 35 percent during both periods 1 and 2. Also, when fed the 20 percent hay ration in period 3, they consumed ($P<0.05$) more than those fed the 20 percent level of hay during all periods.

The higher feed consumption with larger amounts of hay illustrates that animals tend to consume feed on basis of energy requirements and will thus consume more of a lower energy ration. However, the higher feed consumption with increasing amounts of hay was not enough to

Table 10. Daily Feed Consumption of Steers Fed Different Levels of Concentrates to Roughage

Period	Grain-hay mix: Chopped alfalfa hay	Grain-hay mix: Rolled shelled corn	Pelleted suppl.	Total feed
	lb.	lb.	lb.	lb.
		50% Roughage Rations		
1	11.1	9.0	2.2	22.2[a]
2	12.8	10.5	2.6	26.0[a]
3	11.5	9.4	2.3	23.2[a]
Total	11.8	9.6	2.4	23.8[a]
		35% Roughage Rations		
1	7.4	12.1	2.2	21.6[b]
2	8.4	13.4	2.4	24.0[b]
3	7.0	11.4	2.0	20.6[b]
Total	7.5	12.2	2.2	21.9[b]
		20% Roughage Rations		
1	4.0	14.3	2.0	20.4[c]
2	4.4	15.6	2.2	22.2[c]
3	4.0	14.4	2.0	20.4[b]
Total	4.1	14.8	2.1	21.0[c]
		50-35-20% Roughage Rations		
1	11.1	9.0	2.2	22.4[a]
2	8.6	13.9	2.5	24.9[d]
3	4.2	14.9	2.1	21.2[c]
Total	7.7	12.8	2.2	22.8[a]

[a,b,c,d] Means within the same period having different superscript letters differ significantly ($P < 0.05$).

Table 11. Analysis of Variance for Daily Feed Consumption (Total Trial)

Source	d.f.	S.S.	M.S.	F value
Total	27	42.11		
Roughage levels	3	28.40	9.47	28.697**
Additives	6	7.86	1.31	3.970*
Residual	18	5.85	.33	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

overcome the reduction in energy content of the rations and gains were lower. The performance in rate of gain would indicate that the inability of cattle to consume adequate amounts of energy on high-roughage rations for maximum gains becomes more pronounced as they gain in weight and condition.

Steers fed diethylstilbestrol or diethylstilbestrol plus dynafac in their rations consumed significantly ($P < 0.05$) more feed than those fed the other additives when averaged at all roughage levels. Most of the research conducted with diethylstilbestrol has shown an increase in feed consumption as well as rate of gain.

Table 12. Analysis of Variance for Daily Feed Consumption (Periods 1, 2 and 3)

Source	d.f.	S.S.	M.S.	F value
Total	83	330.81		
Periods	2	142.31	71.16	116.656**
Roughage levels	3	89.19	29.73	48.737**
Additives	6	28.14	4.69	.769
Periods x roughages	6	20.74	3.46	.567
Periods x additives	12	6.86	.57	.093
Roughage x additives	18	21.48	1.19	.195
Residual	36	22.09	.61	

** Significant at the 1% level of probability.

Table 13. Average Daily Feed Consumption of Steers Fed Various Feed Additives

Feed additive	50% roughage rations	35% roughage rations	20% roughage rations	50-35-20% roughage rations	Average
	lb.	lb.	lb.	lb.	lb.
Control	22.9	22.0	20.3	23.3	22.1[a]
Diethylstilbestrol	24.1	23.3	21.3	24.2	23.2[b]
Diallylstilbestrol	23.3	21.4	20.8	22.1	21.9[a]
Dynafac	23.8	21.0	20.9	22.3	22.0[a]
Agrozyme	24.3	21.3	20.9	22.3	22.2[a]
Diethylstilbestrol + dynafac	25.4	22.7	22.1	22.6	23.2[b]
Diallylstilbestrol + dynafac	22.6	21.8	20.9	22.8	22.0[a]
Average	23.8	21.9	21.0	22.8	

[a,b] Average mean values having different superscript letters differ significantly ($P < 0.05$).

Feed Efficiency

Feed efficiency data and the analysis are shown in tables 14, 15, 16 and 17.

Feed efficiency improved as the level of concentrates were increased in the rations. Steers fed the 50-35-20 percent alfalfa hay rations were not as efficient in feed conversion as those fed the 20 percent hay rations, but they required less feed per 100 lb. gain than those fed the 35 or 50 percent hay rations. These differences were significant ($P<0.05$) and showed that steers fed a high-grain ration gain faster, consume less feed per 100 lb. of gain and require less time in the feedlot to reach a desirable market weight and finish. This is in agreement with research reported by other workers.

All the steers made good gains during period 1 and required less feed per 100 lb. of gain than during the other periods of the experiment. The cattle made larger gains during period 2, but feed requirements were increased over period 1. This increase in feed requirements with increases in weight and condition has been shown by several workers. The higher feed requirements during period 2 over period 1 was most pronounced when feeding rations with 50 percent hay and was only slightly higher when feeding the rations with 20 percent hay or when changed from 50 to 35 percent hay for the second period of the experiment. This increase in feed requirements continued during period 3 with a somewhat greater increase, especially when feeding rations with 20 percent hay and when reducing the amount of hay from 35 to 20 percent. Feed efficiency as well as rate of gain was poor for the

Table 14. Feed Efficiency of Steers Fed Different Levels of Concentrates to Roughage

Period	Feed/100 lb. gain, lb. Chopped alfalfa hay	Rolled shelled corn	Pelleted suppl.	Total feed
	lb.	lb.	lb.	lb.
		50% Roughage Rations		
1	421	344	85	852[a]
2	500	409	101	1012[a]
3	618	506	124	1250[a]
Total	516	422	104	1042[a]
		35% Roughage Rations		
1	278	453	81	812[b]
2	308	503	90	901[b]
3	478	779	140	1397[b]
Total	344	560	100	1004[a]
		20% Roughage Rations		
1	150	534	76	761[b] |
2	153	544	78	775[c]
3	190	672	96	958[c]
Total	162	576	82	821[b]
		50-35-20% Roughage Rations		
1	440	374	89	890[a] |
2	308	504	90	902[b]
3	204	724	103	1032[d]
Total	318	525	94	936[c]

[a,b,c,d] Means within the same period having different superscript letters differ significantly ($P<0.05$).

\| Means within a roughage level not covered by the same line differ significantly ($P<0.05$).

Table 15. Analysis of Variance for Feed Efficiency (Total Trial)

Source	d.f.	S.S.	M.S.	F value
Total	27	2366.029		
Roughage levels	3	1952.358	650.786	59.454**
Additives	6	216.644	36.107	3.297*
Residual	18	197.027	10.946	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

cattle fed the rations with 35 percent hay during period 3 of the experiment.

Results of this experiment on basis of feed efficiency, as well as rate of gain, show an advantage for the high-concentrate rations and of increasing the energy content of rations during late stages of finishing.

Even though gains were lower and feed requirements higher with the higher roughage rations, the relative economy of the rations would depend on the feed replacement values and the prices of the feeds. Feed replacement values calculated for the complete trial showed that each additional 100 lb. of hay consumed by the cattle fed the rations with 50 percent hay saved 38.4 lb. of concentrates (corn and supplement). The saving during period 1 only was considerably higher than for periods 2 and 3, being 66.8 lb. of total concentrates for period 1 and 32.3 for both periods 2 and 3. These results show that at usual prices of hay and corn the 50 percent hay ration would generally be

Table 16. Analysis of Variance for Feed Efficiency (Periods 1, 2 and 3)

Source	d.f.	S.S.	M.S.	F value
Total	83	48536.142		
Periods	2	20485.914	10242.957	46.336**
Roughage levels	3	4457.353	1485.784	6.721**
Additives	6	1895.095	315.849	1.429
Periods x roughages	6	6394.301	1065.717	4.821**
Periods x additives	12	2597.893	216.491	.979
Roughages x additives	18	4747.441	263.747	1.19
Residual	36	7958.145	221.060	

** Significant at the 1% level of probability.

economical during the early stages of finishing cattle. The hay should cost only about one-third as much per ton as corn grain for the 50 percent hay ration to be more economical on basis of feed costs than the one with 20 percent hay during late stages of finishing. Less protein supplement would be required with the larger amount of hay which would offer a slight additional advantage.

Feeding the ration with 35 percent hay did not show an advantage in saving of concentrates over feeding the one with 20 percent hay over the complete trial. The results were more favorable for the rations with 35 percent hay during period 1 than during periods 2 and 3, but less than for the rations with 50 percent hay. There appeared to be no particular advantage of feeding rations with 35 percent hay in this

Table 17. Feed Efficiency of Steers Fed Various Feed Additives

Feed additive	50% roughage rations	35% roughage rations	20% roughage rations	50-35-20% roughage rations	Average
	lb.	lb.	lb.	lb.	lb.
Control	1025	988	855	904	943[a]
Diethylstilbestrol	1004	954	805	871	908[b]
Diallylstilbestrol	1033	1038	822	1005	974[c]
Dynafac	1054	995	808	929	946[a]
Agrozyme	1034	1072	875	992	993[d]
Diethylstilbestrol + dynafac	1044	936	768	934	920[b]
Diallylstilbestrol + dynafac	1097	1049	815	920	970[c]
Average	1042	1004	821	936	

[a,b,c,d] Average mean values having different superscript letters differ significantly ($P < 0.05$).

experiment over those with 50 or 20 percent hay.

Steers fed diethylstilbestrol alone or in combination with dynafac consumed more feed and made faster gains than all other steers and they had the most favorable feed efficiency ($P < 0.05$). Similar results with diethylstilbestrol have been reported by Burroughs et al. (1955), Radabaugh and Embry (1959), Keith et al. (1960) and Hentges et al. (1960). Diallylstilbestrol or diallylstilbestrol plus dynafac gave no improvement in feed efficiency over similar control rations in this experiment. This is not in agreement with work conducted by

Thomas and Doty (1959c).

Steers fed rations containing dynafac required less feed than those fed diallylstilbestrol or the combination of dynafac and diallylstilbestrol but showed no improvement over similar control steers. Steers fed Agrozyme required the most feed per 100 lb. of gain in this experiment.

Carcass Characteristics

Data on carcass grade, conformation score, marbling score, area of lean of rib-eye, and depth of fat over the rib-eye muscle are shown in table 18. Tests of significance for these carcass characteristics are presented in tables 19 through 23.

Carcass characteristics showed only small and nonsignificant differences between carcass grade, conformation score, marbling score, and depth of fat over the rib-eye muscle when compared for either roughage levels or additives. However, they were slightly favored by the steers fed the 20 percent alfalfa hay rations and would tend to agree with studies made by Dowe and Arthaud (1950a). Cattle fed diethylstilbestrol or diethylstilbestrol plus dynafac tended to have a greater amount of fat covering over the rib-eye muscle in all comparisons. The faster rates of gain and greater live weights of these cattle probably would explain these results.

The steers fed the 35 percent alfalfa hay rations had significantly ($P<0.05$) smaller rib-eye area than those fed rations with other levels of hay. The lighter market weights of these cattle may have had an influence on the size of the rib-eye. These cattle dressed

Table 18. Carcass Characteristics for the Steers Fed Different Levels of Concentrates to Roughage and Various Feed Additives

Treatment	Carcass grade[1]	Conformation score[1]	Marbling score[2]	Area of lean	Depth of fat	Dressing percent	Av. mkt. wt.
				sq. in.	cm.	%	lb.
Roughage Levels (All Additives)							
50% roughage rations	19.1	19.5	6.1	10.75[a]	2.28	59.9	1075.5
35% roughage rations	19.1	19.6	5.8	9.99[b]	2.36	60.1	1047.7
20% roughage rations	19.3	19.9	6.3	10.74[a]	2.23	59.5	1072.7
50-35-20% roughage rations	19.2	19.9	6.1	10.66[a]	2.13	59.7	1073.6
Feed Additives (All Roughage Levels)							
Control	19.1	19.7	6.0	10.36[a]	2.32	59.6	1072.0
Diethylstilbestrol	19.1	19.8	6.0	10.71[a,b]	2.30	60.6	1097.9
Diallylstilbestrol	19.1	19.8	6.0	10.42[a,b]	2.11	59.8	1038.9
Dynafac	19.1	19.7	6.0	10.44[a,b]	2.25	59.8	1048.8
Agrozyme	19.2	19.7	6.0	10.30[a]	2.24	59.2	1039.9
Diethylstilbestrol-dynafac	19.3	19.8	6.0	10.88[b]	2.32	60.2	1091.1
Diallylstilbestrol-dynafac	19.4	19.6	6.3	10.64[a,b]	2.23	59.5	1083.0

[a,b] Means within each column having different superscript letters differ significantly ($P < 0.05$).

[1] Prime, 22; choice, 20; good, 17; standard, 14. Graded within a third of a grade.

[2] Extremely abundant, 12; very abundant, 11; abundant, 10; moderately abundant, 9; slightly abundant, 8; moderate, 7; modest, 6; small, 5; slight, 4; traces, 3; etc.

Table 19. Analysis of Variance for Carcass Grade

Source	d.f.	S.S.	M.S.	F value
Total	251	281.270		
Roughage levels	3	2.635	.878	.077
Additives	6	3.659	.610	.053
Roughage x additives	18	19.198	1.067	.934
Residual	224	255.778	1.142	

significantly ($P<0.05$) higher than those fed the other levels of hay which may have been due to a higher transit shrink for this group of cattle. The cattle fed each level of roughage were marketed on separate days. Consequently, uniform conditions could not be maintained even though each group was handled in a similar manner.

In the comparisons of the feed additives, the cattle fed diethylstilbestrol, with and without dynafac, had the largest rib-eye area. However, the only significant differences were between diethylstilbestrol plus dynafac and the control and Agrozyme ($P<0.05$).

The statistical analysis showed a significant effect of feed additives on dressing percent. The highest dressing percent was obtained when feeding diethylstilbestrol, with and without dynafac. In view of the marketing procedure used, comparison between treatments on dressing percent would be of questionable value.

Table 20. Analysis of Variance for Marbling Score

Source	d.f.	S.S.	M.S.	F value
Total	251	339.57		
Roughage levels	3	4.78	1.59	1.144
Additives	6	5.54	.92	.662
Roughage x additives	18	17.47	.97	.698
Residual	224	311.78	1.39	

Table 21. Analysis of Variance for Rib-eye Area

Source	d.f.	S.S.	M.S.	F value
Total	251	240.840		
Roughage levels	3	22.898	7.633	9.331**
Additives	6	11.244	1.874	2.291*
Roughage x additives	18	23.571	1.310	1.601
Residual	224	183.127	.818	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Table 22. Analysis of Variance for Fat Depth

Source	d.f.	S.S.	M.S.	F value
Total	251	67.357		
Roughage levels	3	1.431	.477	1.722
Additives	6	.851	.142	.051
Roughage x additives	18	2.955	.164	.059
Residual	224	62.120	.277	

Table 23. Analysis of Variance for Dressing Percent

Source	d.f.	S.S.	M.S.	F value
Total	251	489.287		
Roughage levels	3	15.978	5.326	2.965*
Additives	6	44.463	7.411	4.126**
Roughage x additives	18	26.642	1.480	.824
Residual	224	402.204	1.796	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Costs and Returns

The costs and returns for the steers fed rations with the various proportions of alfalfa hay and corn grain and the feed additives are presented in table 24.

When the cattle fed rations with the various levels of hay were marketed at approximately the same weights, there were only small differences in carcass grade and dressing percent. Therefore, differences in selling price would result primarily from changes in the market price within the period of time required to reach the same final weight with the various rations. Selling prices presented in table 24 were calculated using the same carcass prices for all groups of cattle even though they were sold at different times. On this basis, the selling price per 100 lb. of live weight was about the same for the cattle fed rations with the various levels of hay and grain. Therefore, differences in the return above feed cost would be primarily a reflection of the amount of hay, corn and supplement required by the cattle on the various treatments and the market prices of these feeds.

The cattle fed rations with 20 percent alfalfa hay had the lowest feed cost in this experiment. Those fed the rations in which the amount of hay was reduced during the experiment had the next lowest feed cost. The highest feed cost resulted when feeding the rations with 50 or 35 percent hay with only a small difference between cost of these two rations.

In order for the higher roughage rations to be economical, the price of alfalfa hay would have to be less in relation to corn grain

Table 24. Costs and Returns of Steers Fed Different Levels of Concentrates to Roughage and Various Feed Additives

Treatment	Feed cost per head[1]	Av. selling price per cwt.[2]	Av. selling price per head	Return over feed cost
	$	$	$	$
	Roughage Levels (All Additives)			
50% roughage rations	95.05	25.35	272.64	177.59
35% roughage rations	95.63	25.50	268.43	172.80
20% roughage rations	88.04	25.42	272.35	184.31
50-35-20% roughage rations	92.33	25.41	269.48	177.15
	Feed Additives (All Roughage Levels)			
Control	91.89	25.32	268.68	176.79
Diethylstilbestrol	95.36	25.54	282.84	187.48
Diallylstilbestrol	90.80	25.34	263.89	173.09
Dynafac	91.32	25.52	268.90	177.58
Agrozyme	92.08	25.44	264.84	172.76
Diethylstilbestrol-dynafac	95.38	25.42	279.06	183.68
Diallylstilbestrol-dynafac	92.04	25.34	266.80	174.76

[1] Based on the following prices per ton: Alfalfa hay, $25.00; corn, $40.00; protein supplement, $70.00.

[2] Calculated on the basis of average carcass weights and selling prices.

than used in this experiment. As previously discussed, the rations with 50 percent hay were economical during the early part of the experiment. Also, reducing the amount of hay during the experiment improved gains and feed efficiency and reduced feed cost in comparison to feeding rations with a constant level of 35 percent hay even though the average proportion of hay to grain in these two rations was similar.

Among the feed additives, only diethylstilbestrol and diethylstilbestrol with dynafac resulted in an over-all improvement in feed efficiency and lower feed cost in comparison to the control group of cattle. It appears from the results of this experiment that diethylstilbestrol was the only feed additive of any important value in lowering feed cost and improving the return on the cattle.

Digestion Trial

The coefficients of apparent digestibility of dry matter, crude protein, ether extract, crude fiber, nitrogen-free extract, digestible energy and the statistical analysis of the digestion data are reported in tables 25 to 31. The TDN contents of the rations and the caloric values for TDN are presented in table 32.

Digestibility of Dry Matter

The average coefficients of apparent digestibility of dry matter are shown in table 25 with the statistical analysis shown in table 26. Average digestion coefficients of 64.43, 65.74 and 73.60 were obtained with all rations that contained 50, 35 and 20 percent roughage,

Table 25. Coefficients of Apparent Digestibility for the Steers Fed Different Roughage Levels and Various Feed Additives

Roughage level	Control	Dynafac	Agrozyme	Average
	%	%	%	%
		Dry Matter		
50%	66.24	68.88	58.18	64.43
35%	62.25	66.20	68.78	65.74
20%	72.24	74.85	73.72	73.60
Average	66.91	69.98	66.89	
		Crude Protein		
50%	59.72	60.93	52.62	57.76
35%	56.67	60.87	59.06	58.87
20%	61.72	67.90	63.77	64.46
Average	59.37	63.23	58.48	
		Ether Extract		
50%	63.09	61.28	53.90	59.42
35%	57.54	64.83	70.19	64.19
20%	70.84	74.36	74.99	73.40
Average	63.82	66.82	66.36	
		Crude Fiber		
50%	52.24	49.28	40.68	47.40
35%	49.60	50.20	54.44	51.41
20%	47.97	49.81	51.35	49.71
Average	49.94	49.76	48.82	
		Nitrogen-free Extract		
50%	74.54	79.83	67.83	74.07
35%	70.37	73.17	76.90	73.48
20%	80.04	82.32	81.46	81.27
Average	74.98	78.44	75.40	
		Digestible Energy		
50%	65.16	67.74	56.67	63.19
35%	62.19	64.64	68.05	64.96
20%	70.24	74.64	72.62	72.50
Average	65.86	69.01	65.78	

Table 26. Analysis of Variance for Dry Matter

Source	d.f.	S.S.	M.S.	F value
Total	35	1515.790		
Periods	3	87.803	29.268	1.729
Roughage levels	2	579.611	289.806	9.681*
Additives	2	70.271	35.136	1.55
Periods x roughages	6	179.616	29.936	1.768
Periods x additives	6	135.689	22.615	1.34
Roughages x additives	4	259.641	64.910	3.83*
Residual	12	203.159	16.930	

* Significant at the 5% level of probability.

respectively. The differences between the rations with 20 percent hay and those with either 50 or 35 percent hay were statistically significant ($P < 0.05$).

Dowe et al. (1955b) reported that the apparent digestibility of dry matter was increased as the amount of corn was increased in the ration. This is in agreement with the results of this trial. The results of the trial also appear to be in agreement with work conducted by Richardson et al. (1956) who reported that the greatest digestibility of nutrients was obtained with a 3:1 ratio of concentrates to roughage.

The coefficients of digestibility between the various additives used were not significant. However, there was a significant ($P < 0.05$) roughages x additives interaction. Digestibility of dry matter was somewhat lower for the control group with the 35 percent hay rations

than with 50 percent hay and lower than with dynafac and Agrozyme. Digestibility of dry matter appeared to be reduced by Agrozyme in rations with 50 percent hay. These apparent effects might be questioned in view of the lack of an effect obtained with dynafac by Zimmer and Embry (1958) and with Agrozyme by Burroughs et al. (1960) and Theurer et al. (1958). The number of animals involved probably were not great enough to accurately measure the interaction of treatments in these digestion trials.

Digestibility of Crude Protein

Average apparent digestion coefficients of 57.76, 58.87 and 64.19 percent were obtained by all rations that contained 50, 35 and 20 percent roughage, respectively (table 25). Although the differences in digestibility between the roughage levels were not significant (table 27), digestibility of crude protein increased slightly as the concentrates were increased in the rations. This effect of concentrates and roughage on digestibility of protein has been observed by several other workers. It indicates a need for considering type of ration in determining the amount of total protein needed.

The effects of dynafac and Agrozyme on protein digestibility were also nonsignificant.

Table 27. Analysis of Variance for Crude Protein

Source	d.f.	S.S.	M.S.	F value
Total	35	1806.667		
Periods	3	312.211	104.070	5.649*
Roughage levels	2	308.721	154.361	3.424
Additives	2	154.326	77.163	1.114
Periods x roughages	6	270.515	45.086	2.447
Periods x additives	6	415.710	69.285	3.761*
Roughages x additives	4	124.108	31.027	1.684
Residual	12	221.076	18.423	

* Significant at the 5% level of probability.

Digestibility of Ether Extract

The coefficients of apparent digestibility of ether extract and the statistical analysis are presented in tables 25 and 28. Average digestion coefficients for the 50, 35 and 20 percent roughage rations, respectively, were 59.42, 64.19 and 73.40 percent. There was a significant ($P < 0.01$) difference in ether extract digestibility between roughage levels with the highest value being obtained with steers which received the 20 percent roughage rations. This is in agreement with research by Pahnish et al. (1956) and Matsushima et al. (1957). However, Elam et al. (1958) found digestibility of ether extract to be lower when heifers were fed high-energy rations.

Table 28. Analysis of Variance for Ether Extract

Source	d.f.	S.S.	M.S.	F value
Total	35	6554.232		
Periods	3	2727.565	909.188	9.383**
Roughage levels	2	1210.309	605.155	5.358*
Additives	2	62.269	31.135	.831
Periods x roughages	6	677.665	112.944	1.166
Periods x additives	6	224.758	37.460	.386
Roughages x additives	4	488.904	122.226	1.261
Residual	12	1162.762	96.897	

* Significant at the 5% level of probability.
** Significant at the 1% level of probability.

Agrozyme or dynafac did not significantly affect digestibility of ether extract over similar control rations.

Digestibility of Crude Fiber

Coefficients of apparent digestibility for crude fiber by the steers fed different roughage levels and various feed additives are shown in table 25. Statistical analysis of the data is presented in table 29.

Differences in crude fiber digestibility between the different roughage levels were quite variable and nonsignificant. The average coefficients for all rations that contained 50, 35 and 20 percent roughage were 47.40, 51.41 and 49.71 percent, respectively. Digestibility of this nutrient appeared to be slightly lowered by feeding the

Table 29. Analysis of Variance for Crude Fiber

Source	d.f.	S.S.	M.S.	F value
Total	35	3833.796		
Periods	3	399.167	133.056	2.177
Roughage levels	2	97.101	48.551	.184
Additives	2	8.658	4.329	.040
Periods x roughages	6	1580.381	263.397	4.310*
Periods x additives	6	655.318	109.220	1.787
Roughages x additives	4	359.787	89.947	1.471
Residual	12	733.384	61.115	

* Significant at the 5% level of probability.

50 percent roughage ration. These results agree with Richardson et al. (1956). Dowe et al. (1955b), however, found no significant difference in apparent digestibility of this nutrient between different ratios of concentrates to roughage ranging from 1:1 to 5:1.

No differences were noted in crude fiber digestibility when dynafac or Agrozyme was added to the rations tested.

Digestibility of Nitrogen-free Extract

Coefficients of digestibility of nitrogen-free extract are shown in table 25. Statistical analysis are presented in table 30.

Steers fed the rations with 20 percent roughage had significantly ($P < 0.05$) larger digestion coefficients for nitrogen-free extract than those fed rations with 50 or 35 percent hay. Dynafac and Agrozyme had

Table 30. Analysis of Variance for Nitrogen-free Extract

Source	d.f.	S.S.	M.S.	F value
Total	35	1576.080		
Periods	3	232.580	77.527	3.093
Roughage levels	2	449.047	224.524	13.108**
Additives	2	84.935	42.468	2.460
Periods x roughages	6	102.773	17.129	.683
Periods x additives	6	103.565	17.261	.689
Roughages x additives	4	302.363	75.591	3.015
Residual	12	300.817	25.068	

** Significant at the 1% level of probability.

no significant effect in digestibility of nitrogen-free extract.

Elam et al. (1958) found digestibility of nitrogen-free extract to be significantly ($P<0.01$) greater for heifers receiving a medium-energy ration than for either a high or low-energy ration. This does not agree with the results of this experiment. Since the nitrogen-free extract content would be highest in the rations with only 20 percent hay, the highest digestibility for nitrogen-free extract should be expected with these rations as was obtained in this experiment.

Digestibility of Energy

Average digestion coefficients for energy of 63.19, 64.96 and 72.50 percent were obtained with rations containing 50, 35 and 20 percent roughage, respectively (table 25). The results are quite

similar to those obtained from digestibility of dry matter. The differences between the 20 percent roughage ration and the ones with 35 or 50 percent roughage (table 31) were statistically significant ($P < 0.05$).

Pahnish et al. (1956) reported that energy digestibility decreased progressively from a 2:1 to a 1:3 ratio of concentrates to roughage, indicating that a high roughage ration would not suffice for maximum energy digestibility. The results of this trial also agree with studies made by Richardson et al. (1956) and Phillips et al. (1951).

Table 31. Analysis of Variance for Digestible Energy

Source	d.f.	S.S.	M.S.	F value
Total	35	1643.710		
Periods	3	148.281	49.427	3.587*
Roughage levels	2	585.065	292.533	7.607*
Additives	2	81.980	40.990	1.785
Periods x roughages	6	230.737	38.456	2.791
Periods x additives	6	137.796	22.966	1.667
Roughages x additives	4	294.520	73.630	5.344*
Residual	12	165.331	13.778	

* Significant at the 5% level of probability.

Total Digestible Nutrients (TDN) and Caloric Value for TDN

The TDN values calculated from the digestion trials for the various roughage rations are shown in table 32. The TDN values were calculated on the basis of roughage level only since feed additives gave small and nonsignificant effects on digestibility of individual nutrients.

The TDN contents of the 20, 35 and 50 percent roughage rations on a dry basis were 75.8, 66.5 and 64.9, respectively. These values follow the same trend as digestibility of dry matter and digestibility of energy as would be expected. Dowe et al. (1955) reported some TDN values resulting from a total of 28 digestion trials using different ratios of concentrates to roughage. These values were similar to those obtained in this trial.

The similarity in TDN values of the rations with 35 and 50 percent hay and the somewhat greater value for the rations with 20 percent hay would appear to explain the performance of the cattle in the feeding trials. The cattle fed the rations with 35 percent hay gained about the same as those fed the rations with 50 percent hay. Feed consumption was slightly higher in the feeding trial when feeding the ration with 50 percent hay but this ration had a slightly lower TDN value in the digestion trial. Rate of gain was considerably better when feeding the rations with 20 percent hay. Feed consumption was lower than with higher levels of hay in the feeding trial, but the ration with 20 percent hay had a considerably higher TDN value in the digestion trial.

Table 32. Energy Contents and Energy Values of Rations Fed During the Digestion Trial[1]

	50% roughage rations	35% roughage rations	20% roughage rations
Composition of dry matter			
Gross energy, kcal./lb.	1982	2018	2046
TDN, %	64.9	66.5	75.8
Digestible energy, %	63.2	65.0	72.5
Average daily consumption			
Dry matter, lb.	12.1	12.6	13.8
TDN, lb.	7.8	8.4	10.5
Digestible energy, mcal.	151.2	165.1	204.2
Digestible energy			
Per lb. of TDN, kcal.	1938	1965	1945

[1] All values shown are on an air dry basis.

The failure to obtain an increase in the energy value of the rations when reducing the hay from 50 to 35 percent may indicate that the ratio of concentrates to roughage has an important effect on the digestibility of the ration. Results of this experiment would indicate that high-roughage rations or low-roughage rations may offer definite advantages over rations with intermediate levels of roughage.

The digestible energy values expressed in kilocalories per pound of TDN were 1938, 1965 and 1945 for the 50, 35 and 20 percent roughage levels, respectively. Crampton (1956) stated that the calorie value of TDN of individual feeds will differ according to their proximate composition, but that an average for all feeds appears to be about 1990 kilocalories per pound of TDN. The National Research Council

Committee on Animal Nutrition (N.R.C., 1959) recommends a value of 2000 kilocalories per pound of TDN be used to calculate the digestible energy requirements of beef cattle from TDN requirements. The values obtained in this experiment are only slightly less than the average caloric value per pound of TDN quoted by Crampton and were rather constant for rations with 20, 35 and 50 percent alfalfa hay. The results would also indicate that the value of 2000 could be used for rations with a considerable variation in amount of energy without serious error.

SUMMARY

Two hundred and fifty-two yearling Hereford steers averaging about 605 lb. were stratified on the basis of weight and randomly allotted into 28 lots and used in a balanced factorial design feeding trial conducted between July and February of 1959-60. Seven lots of steers each were fed rations containing alfalfa hay at levels of 50, 35, 20 percent and a variable level at 50 percent hay the first 9 weeks (period 1) of the trial, 35 percent the second 9 weeks (period 2) and 20 percent until the trial was terminated (period 3). Within each group of seven lots there was a control, diethylstilbestrol, diallylstilbestrol, dynafac, enzyme preparation (Agrozyme), diethylstilbestrol and dynafac and diallylstilbestrol and dynafac treatment. A grain-hay mixture and a protein supplement were full-fed at the rate of 1 lb. of supplement to each 10 lb. of grain-hay mixture. Mineral and salt were offered free-choice. Digestibility of the various nutrients in the rations were determined in a conventional digestion trial consisting of 4 periods with 9 steers each. Total and digestible energy were also determined by use of an adiabatic bomb calorimeter.

During the feeding trial, rations containing alfalfa hay at levels of 20 and 50-35-20 percent improved rate of gain over rations with 50 and 35 percent alfalfa ($P < 0.01$). Changing the level of hay periodically improved rate of gain over feeding a constant level of 50 percent or 35 percent throughout the feeding period. Level of roughage within the ranges used had only a small effect on rate of gain during the first 9 weeks of the experiment. A higher rate of gain

($P<0.05$) was noted at all roughage levels during the second 9 weeks of the trial and improved as the level of concentrates were increased in the rations. All steers showed significantly ($P<0.05$) lower gains during the last period of the experiment; however, the two groups of cattle fed the rations with 20 percent alfalfa hay made significantly ($P<0.05$) faster gains than those fed with either 35 or 50 percent hay during this time.

Diethylstilbestrol and diethylstilbestrol plus dynafac increased rate of gain at all roughage levels by 7.4 and 6.6 percent, respectively, over the controls ($P<0.05$) and made faster gains than any of the other feed additive treatments ($P<0.05$). There were no significant differences between the other feed additives.

There was an increase in feed consumption as the amount of alfalfa hay was increased in the ration during all periods ($P<0.05$) except with the 35 percent hay during period 3. Diethylstilbestrol and diethylstilbestrol plus dynafac resulted in significant ($P<0.05$) increases in feed consumption at all levels of roughage.

Feed efficiency for the experiment improved as the level of concentrates were increased in the rations ($P<0.01$). There was a significant ($P<0.05$) increase in feed requirements with increases in weights and finish of the cattle. Feed replacement values calculated for the complete trial and periods 1, 2 and 3, respectively, showed that each additional 100 lb. of hay consumed by the cattle fed the rations with 50 percent hay saved 38.4, 66.8, 32.3 and 32.3 lb. of corn and supplement when compared to those fed the 20 percent hay rations. There

appeared to be no particular advantage of the rations with 35 percent hay over those with 50 or 20 percent hay. Diethylstilbestrol and diethylstilbestrol plus dynafac resulted in significant ($P<0.05$) improvements in feed efficiency over control lots.

Carcass grade, conformation score, marbling score and fat depth were not affected by the roughage levels or feed additives used in this experiment when the cattle were marketed at approximately the same final weights. Cattle fed diethylstilbestrol and diethylstilbestrol plus dynafac had the largest ($P<0.05$) rib-eye areas and had a higher dressing percentage than those fed the other additives.

In the digestion trial, digestibility of dry matter, nitrogen-free extract and energy was significantly ($P<0.05$) higher for the steers fed rations with 20 percent alfalfa hay than those fed with either 35 or 50 percent hay. Level of roughage did not appear to affect digestibility of crude protein or crude fiber in this experiment. Only small and nonsignificant differences were noted in digestibility of crude protein, crude fiber, nitrogen-free extract, ether extract and digestible energy when the rations with the various levels of hay were fed with dynafac or Agrozyme.

The TDN contents were 75.8, 66.5 and 64.9 percent for the rations containing 20, 35 and 50 percent alfalfa hay. These values appear to be in agreement with the literature. The caloric values for TDN that were obtained were 1938, 1965 and 1945 kilocalories per lb. of TDN for the 50, 35 and 20 percent levels of alfalfa hay, respectively, and are only slightly less than the average caloric value per lb. of TDN quoted in

the literature. They were rather constant for the rations with the various levels of hay.

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