1967

The effects of age and sex on performance, carcass characteristics and muscle tenderness of male cattle

Roger Eugene Hunsley

Iowa State University

Follow this and additional works at: https://lib.dr.iastate.edu/rtd

Part of the Agriculture Commons

Recommended Citation

https://lib.dr.iastate.edu/rtd/3396

This Dissertation is brought to you for free and open access by the Iowa State University Capstones, Theses and Dissertations at Iowa State University Digital Repository. It has been accepted for inclusion in Retrospective Theses and Dissertations by an authorized administrator of Iowa State University Digital Repository. For more information, please contact digirep@iastate.edu.
This dissertation has been
microfilmed exactly as received 68-2828

HUNSLEY, Roger Eugene, 1938-
THE EFFECTS OF AGE AND SEX ON PERFORMANCE,
CARCASS CHARACTERISTICS AND MUSCLE TENDER-
NESS OF MALE CATTLE.

Iowa State University, Ph.D., 1967
Agriculture, general

University Microfilms, Inc., Ann Arbor, Michigan
THE EFFECTS OF AGE AND SEX ON PERFORMANCE,
CARCASS CHARACTERISTICS AND MUSCLE TENDERNESS OF MALE CATTLE

by—

Roger Eugene Hunsley

A Dissertation Submitted to the
Graduate Faculty in Partial Fulfillment of
The Requirements for the Degree of

DOCTOR OF PHILOSOPHY

Major Subject: Animal Nutrition

Approved:

Signature was redacted for privacy.

In Charge of Major Work

Signature was redacted for privacy.

Head of Major Department

Signature was redacted for privacy.

Dean of Graduate College

Iowa State University
Of Science and Technology
Ames, Iowa

1967
## TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>LITERATURE REVIEW</td>
<td>3</td>
</tr>
<tr>
<td>Pre-weaning Performance</td>
<td>3</td>
</tr>
<tr>
<td>Effects of diethylstilbestrol implants</td>
<td>3</td>
</tr>
<tr>
<td>Effects of creep feeding</td>
<td>6</td>
</tr>
<tr>
<td>Post-weaning Performance and Carcass Characteristics</td>
<td>15</td>
</tr>
<tr>
<td>Effects of Age and Sex on Muscle Tenderness</td>
<td>38</td>
</tr>
<tr>
<td>EXPERIMENTAL PROCEDURE</td>
<td>44</td>
</tr>
<tr>
<td>Pre-weaning Phase</td>
<td>44</td>
</tr>
<tr>
<td>Post-weaning and Carcass Evaluation Phase</td>
<td>46</td>
</tr>
<tr>
<td>Experiment I</td>
<td>46</td>
</tr>
<tr>
<td>Experiments II and III</td>
<td>52</td>
</tr>
<tr>
<td>Experiment IV</td>
<td>54</td>
</tr>
<tr>
<td>Effects of Age and Sex on Muscle Tenderness</td>
<td>54</td>
</tr>
<tr>
<td>Experiment V</td>
<td>54</td>
</tr>
<tr>
<td>Statistical Analysis</td>
<td>58</td>
</tr>
<tr>
<td>EXPERIMENTAL RESULTS AND DISCUSSION</td>
<td>60</td>
</tr>
<tr>
<td>Pre-weaning Phase</td>
<td>60</td>
</tr>
<tr>
<td>Post-weaning Phase</td>
<td>70</td>
</tr>
<tr>
<td>Carcass Evaluation Phase</td>
<td>73</td>
</tr>
<tr>
<td>Evaluation of Factors Affecting Tenderness and Quality of Beef Muscle</td>
<td>81</td>
</tr>
<tr>
<td>GENERAL DISCUSSION</td>
<td>96</td>
</tr>
</tbody>
</table>
SUMMARY 109

BIBLIOGRAPHY 112

ACKNOWLEDGMENTS 123
INTRODUCTION

Among the major problems of beef producers for many years have been those of increasing growth rate and feed efficiency and improving carcass characteristics of beef animals. Competition from other classes of meat animals and from meat substitutes along with changing consumer demand has stimulated research directed towards the production of lean, tender beef with desirable eating qualities. Efforts are being made to produce more desirable carcasses through more efficient methods of breeding, feeding and management. The use of diethylstilbestrol (DES) has resulted in a considerable improvement in growth rate and feed efficiency. The fattening of bulls for the advantage of the naturally produced androgen (testosterone) is a practice of a similar nature. The main disadvantage to the marketing of bulls has been the lack of consumer and packer acceptance because of the assumption that bull meat is less desirable than steer or heifer beef. The maxim that bull beef is suitable only for canning or making bologna needs to be reconsidered. Not that beef from old bulls is suitable for anything more than that, but the quality of lean bull beef from short yearlings has been proven in a number of research studies and has consumer approval. When managed like steers, bulls have been outstanding in growth and economy of production. The reason most often given for finishing steers in preference to bulls is the superiority of the meat produced in castrated animals and thus its higher market value. The validity of the higher market value has found some support in research reports, but the degree or amount of superiority in beef quality is not well understood and deserves further study. In particular, it appears that
b Bulls finished at younger ages with improved feeding and management systems such as creep feeds and DES administration at early ages may produce top quality beef more efficiently than steers. Practically all bull beef, of any age, goes on the market today in processed meats. The market potential beyond this point is not fully known and must be evaluated on the basis of new information on bull feeding.

The objectives of the research reported herein were:

1. To determine the effects of DES implants and creep feeding on the pre-weaning performance of bull and steer calves.

2. To determine the effects of age and sex on growth rate, feed efficiency, carcass characteristics and meat quality of male cattle.

3. To measure the effects of age and sex on meat tenderness using the hydroxyproline analysis for connective tissue determinations.
LITERATURE REVIEW

Pre-weaning Performance

**Effects of diethylstilbestrol implants**

The response of calves to diethylstilbestrol (DES) during the suckling period has yielded variable results. Meiske et al. (1960) reported that steer calves implanted with 12 mg. DES at 50 to 75 days of age produced 8.8% greater gains and one-third higher grades at weaning with average daily feedlot gains of 1.76 and 1.92 lb. for the non-implanted and implanted groups, respectively. Both groups received a creep ration on a free-choice basis over the 126-day test period.

Nelson et al. (1960) reported that feeding 5 mg. DES per head daily increased the gains of creep-fed spring calves 26 lb. The response to feeding DES was nearly the same for heifers and steers, an increase of 27 and 24 lb. respectively. This is in contrast to the results of two previous tests in which feeding similar levels of DES had no effect on gains of creep-fed spring calves.

Ewing and Burroughs (1961) investigated DES implantation of nursing steer and heifer calves receiving a creep ration from approximately 3½ months of age to weaning. Six and 12 mg. DES implants increased pre-weaning weight gains by 11 and 14%, respectively. These workers found that post-weaning feedlot gain did not appear to be influenced by previous implantation.

Bradley et al. (1962) found that steer and heifer calves implanted with 12 mg. DES gained 20 to 30 lb. more than control calves. However, the
following year implanted steers gained 11 lb. less than non-implanted controls, while implanted heifers gained 24 lb. more than those which had not been implanted.

Implanting 3-month old suckling steer calves with 12 mg. DES increased weaning weight by 15 lb. in a 4-year study conducted by Melton and Riggs (1965). The weight advantage of the implanted calves ranged from 2 lb. less to 29 lb. more than the non-implanted calves over the 4 years. Implanting appeared to be most effective in increasing weight when range feed conditions were best. These workers concluded that some increase in weaning weight may be expected from implanted suckling calves, but this effect does not extend beyond weaning time at 7 to 8 months of age.

Nesler et al. (1966) conducted four trials involving 232 steer calves. Steers implanted with 12 mg. DES during the suckling period out gained non-implanted steers in every comparison.

Nelson and Kuhlman (1962) studied the effects of 6 and 12 mg. DES implants in 272 fall-born steer and heifer calves over a 4-year period. Weight gains were increased an average of 10 and 18 lb., respectively, by implanting with 6 and 12 mg. DES. There was only a small difference in gain response between steers and heifers. Implanting calves did not have any detrimental effect on subsequent feedlot gain. These same workers summarized 13 tests with spring calves implanted with 6 or 12 mg. DES implants and reported 22 and 36 lb. increases in gain for steers and heifers, respectively.

In a trial conducted by Ralston, Church and Kennick (1966), 48 bull
calves were randomly assigned to one of three treatments to study the effects of DES implants on weight gains from birth to weaning and the development of secondary sex characteristics of the intact male. The three treatment groups were no DES, a 12 mg, implant at birth or a 12 mg, implant at about 3 months of age. Calves implanted at birth made significantly (P < .05) greater gains up to 3 months of age. Gains from 3 months until weaning were almost identical for the three treatments, but the early implant group held a 0.11 lb. per day advantage from birth to weaning. The use of DES implants at any time reduced the size of the testicles and caused a delay in development of secondary sex characteristics, such as crest, curly hair about the head, and increased shoulder development. The improvement in live grade at weaning reflected the increase in fat deposition and additional bloom carried by the implanted calves.

Pilkington et al. (1959) investigated the effects of implanting and the carcass merit of bull calves slaughtered at 8 to 9 months of age. Thirty Hereford bull calves were used, of which 10 were castrated at 3 months of age, 10 remained as bulls without further treatment and 10 bulls received 12 and 24 mg, DES-implanted at 3½ and 6½ months of age, respectively. All calves were on dams and were creep-fed during the entire test. The DES-implanted bull calves made greater gains than implanted steer calves but somewhat less than non-implanted bull calves. The steers had more external finish, firmer, finer-textured muscle in the 1. dorsi muscle and graded one-third grade higher than bulls. Bulls had the largest 1. dorsi areas and a significantly higher percent moisture in
the 9-10-11 rib cut. Steers had a significantly higher percent ether extract of the same cut. Bulls had significantly more total muscle but there was little difference in percent bone and no significant difference in carcass conformation. No significant differences in tenderness were obtained when steaks from each carcass were evaluated by the Warner-Bratzler shear device, or taste panel scores. However, rib steaks from steer calves tended to be juicier than those from bulls as determined by taste panel tests. Although differences in shear values and taste panel scores were small, there was a consistent tendency for steers to be more desirable than bulls or implanted bulls.

**Effects of creep feeding**

The early work of Black and Trowbridge (1930) showed that creep-fed high-grade Shorthorn calves outgained non-creep-fed calves by as much as 100 lb. during the suckling period. In addition, creep-fed calves maintained this advantage during an 84-day post-weaning feeding period. This advantage was lost in a post-weaning feeding period that lasted longer than 84 days. The dams of creep-fed calves outgained the dams of non-creep-fed calves during the nursing period. Bray (1934) reported a 50 lb. advantage in pre-weaning gain for creep-fed calves of predominately British breeding. A similar advantage in weight gain was reported by Duncan et al. (1949) over a 4-year period, but creep feeding was profitable only during one year in which rainfall was not adequate to maintain good pasture.

In a 4-year study by Johnson and Fenn (1943), creep-fed calves averaged 73 lb. greater gain during the suckling period and were more profitable when sold at weaning than non-creep-fed calves. However, the non-creep-
fed calves were more profitable in the feedlot when fed approximately 200
days following weaning. These workers found essentially no difference in
the weight change of cows due to creep feeding their calves. Foster et al.
(1946) found little advantage in weight gain and slaughter grade in creep
feeding grade Hereford calves on good native range. The results showed
practically no difference in weight change of cows due to creep feeding
their calves.

Taylor et al. (1938) reported that creep feeding of spring calves
produced heavier and fatter calves at weaning than similar calves not creep-
fed. However, creep-fed calves fed fattening rations in drylot for 5 or 6
months after weaning made slower and more expensive gains than calves which
had not been creep-fed. Later tests by Taylor et al. (1942) indicated that
creep feeding heifers, born in the spring from high-grade beef cows, re-
sulted in their being classed as slaughter calves at weaning each year.
The creep-fed heifers were 30 to 50 lb. heavier and returned $0.25 per
hundred weight more than their steer mates which received no supplemental
feed. With feed cost deducted, the heifers returned about $1.00 more per
head than the steers at weaning, when the heifers were sold for slaughter
and the steers as feeder calves.

Nelson et al. (1955) investigated the value of creep feeding spring
steer and heifer calves. A total of 197 calves were used in the study.
The calves were dropped in February and March by high-grade Hereford cows
grazing lush native grass pastures. The 3-year average feed consumption
and increase in gain resulting from creep feeding was 363 and 30 lb., re-
spectively. The value per calf minus summer feed cost was $1.80 in favor
of not creep feeding. The calves used in these tests were desirable feeder calves and the highest appraised value per 100 lb. at weaning was as feeders rather than for slaughter. Creep feeding would have increased profits if the calves had been sold for slaughter at weaning. When fattened to a grade of approximately U. S. Choice, steers which had not been creep-fed were more profitable to finish in drylot than steers which had been creep-fed. Heifers which had been creep-fed and those which had not received supplemental feed during the summer were of equal weight at the end of the wintering period in which they were fed prairie hay and cottonseed cake. The heifers which gained the most during the summer gained the least during the winter.

These workers also reported that creep feeding calves dropped by 2-year old heifers increased gains 108 lb. and the profit $5.33 per head during the summer season of 1954, a period of unusually low rainfall.

The cows nursing creep-fed calves gained 19 lb. more during the summer season than cows nursing non-creep-fed calves. However, in the 1954 study with 2-year old heifers in an unusually dry grazing season, the reverse was true. Although both groups lost weight during the summer, the dams of the creep-fed calves lost an average of 44 lb. per head and the dams of the non-creep-fed calves lost 25 lb. per head.

Cunningham et al. (1958) conducted five trials with two groups of 15 high-grade Hereford cows and their calves to determine the value of creep feeding in the production of feeder calves. The cows and calves grazed well-fertilized, bluegrass-white clover pastures which provided about 1.5 acres per cow. Each year calves from one group of cows had
access to a creep ration consisting of six parts coarsely ground yellow corn and one part soybean oil meal. Creep feeding improved the average feeder calf grade from good to choice and increased the average weaning weight of the steers by 83 lb. (0.6 lb. per day) and that of the heifers by 43 lb. (0.5 lb. per day). This improvement in grade and increase in weight resulted in an average increase in value of $38.19 per head for the steers and $19.15 for the heifers. Calves were creep-fed for an average of 131 days each year. During this period they consumed an average of 519.4 lb. of creep feed per head at a cost of $20.44. When the $20.44 feed cost was charged against each calf, creep feeding increased the average yearly net returns per steer by $17.74. However, in the case of the heifers there was a loss of $1.29 per head. Grazing conditions, as affected by the amount and distribution of rainfall, influenced the response of the calves to creep feeding and the amount of feed eaten. When moisture was insufficient, the calves ate more of the creep feed (815 lb.) than when there was sufficient rainfall (348 lb.) and grazing was good. The results obtained in these trials (assuming that the calf crop was equally divided between steers and heifers) show that creep feeding increased the yearly return per calf above feed costs by $8.23.

Woods et al. (1958) investigated methods of intensive feeder calf production on Iowa corn land by creep feeding calves that were nursing cows fed grass-legume soilage in drylot. Creep feeding calves in drylot increased the gain by 63 and 98 lb. over the non-creep-fed drylot and pasture calves, respectively. The drylot creep-fed calves consumed 795 lb. of creep per head at a cost of $18.63. The estimated value of the calves
that were creep-fed was $2.00 per 100 lb. higher than the value of the non-creep calves. Drylot creep-fed calves returned $5.92 more per head than the non-creep-fed drylot calves. However, pasture non-creep-fed calves returned $3.42 more per head than drylot creep-fed calves.

Ewing et al. (1959) studied the effects of creep feeding beef calves in drylot and on improved grass-legume pasture. The drylot creep-fed calves gained 184 lb. during the 112-day test period compared to 216 lb. for the creep-fed calves on the improved pasture. The drylot creep-fed calves consumed 7.94 lb. of creep daily and the improved pasture creep-fed calves ate 4.30 lb. of creep per day at costs of 15.3 and 8.3 cents, respectively. The practice of creep feeding calves in drylot resulted in the smallest margin among the treatments. Creep feeding provided an additional 47 lb. of gain on calves produced on improved pasture. Because of favorable feeder cattle prices, this resulted in a net advantage of $10.70 over similar non-creep-fed calves. The cows nursing the creep-fed calves on improved pasture gained 24 lb. more during the test period than cows nursing non-creep-fed calves on similar pasture. Creep-fed calves and non-creep-fed calves produced on improved grass-legume pasture netted $24.89 and $14.19 more per head, respectively, than calves produced on native bluegrass pasture.

Furr et al. (1959) investigated the effects of creep feeding fall calves. An average of 84% of the 70 lb. increase in weaning weight was present at the end of the winter feeding period (mid-April). Approximately one-third (330 lb.) of the total consumption (992 lb.) of creep feed had occurred by the end of the 3½ month winter creep feeding period. Over-all
creep feeding costs until weaning were $25.60 per calf compared to $8.75 to creep the calves until spring. Creep feeding until weaning was not profitable when costs during the time of the tests were considered.

Nelson et al. (1963) conducted a 4-year study to determine if creep feeding fall calves was profitable and, if so, what method of creep feeding was most desirable. Creep feeding increased gains of fall calves from 50 to 100 lb. depending on the level of winter feeding, milk production and age of cow. Calves ate an average of 875 lb. of creep feed. In most years, both creep-fed and non-creep-fed calves sold at the same price per 100 lb., although the creep-fed calves were fleshier. Creep feeding a concentrate mixture only until green grass was available in the spring (late April or May) increased gains an average of 48 lb. However, non-creep-fed calves tended to recover by gaining more until weaning. Creep feed consumption to spring was 256 lb. per calf and the increased value of the calf was greater than the cost of the small amount of creep feed. Creep feeding fall dropped calves until spring with either average quality alfalfa hay fed long or in pellets proved to be more profitable than the various concentrate creep feeds that were studied. Calves consumed more pounds of the alfalfa pellets but feed costs were higher due to the extra feed processing involved. Creep feeding profitably increased the weaning weights of calves from first-calf heifers in a fall-calving system. These workers found essentially no difference in weight change of cows due to creep feeding their calves.

In a 4-year study that involved 661 calves from five breed groups, Burns et al. (1966) showed that creep feeding for approximately 60 days
before weaning increased the weaning weights of calves 30 lb. and raised the market grade at weaning one-third of a grade. The creep-fed calves ate an average of 583 lb. of creep for each 100 lb. they gained over the weight of non-creep-fed calves. Creep feeding had no significant effect on the weight change of dams during the nursing period. Post-weaning gain of 251 replacement heifer calves was 18 lb. in favor of the calves that were not creep-fed before weaning. This compensatory gain was not sufficient to completely offset the pre-weaning advantage for the creep-fed calves which maintained a 10 lb. advantage in weight at 19 months of age.

Christian et al. (1965) studied the effects of creep feeding on weaning weight of beef calves. The calves were creep-fed from 60 to 240 days of age during which time the average creep consumed per calf was 782 lb. These workers found that the amount of creep feed consumed significantly (r = 0.64) affected the weaning weight of the calf.

Wilson et al. (1966) compared early weaning (90 days of age), creep feeding and non-creep feeding for fall beef calves. The trial started when the calves averaged 90 days of age and lasted 114 days. At the start of the trial one-third of the calves were weaned and the cows were fed a maintenance ration for the remainder of the test period. One-third of the calves were creep-fed and one-third were assigned to a non-creep treatment. The cows nursing the calves on the creep and non-creep treatments were furnished approximately 76% of the energy requirements for a lactating beef cow so as to simulate a scarce forage supply. The weight losses were significantly (P < .01) greater for the cows that were fed the maintenance ration after the calves were weaned at 90 days of age. The cows nursing
the creep-fed calves lost 23 lb. compared to 25 lb. for the cows nursing
the non-creep-fed calves. Weight gains were significantly lower ($P < .01$)
for the non-creep-fed calves. Cow and calf feed costs per pound of calf
gain were lowest for the creep-fed group and highest for the non-creep-fed
group.

Jones and Jones (1932) reported that dams of creep-fed calves gained
80 lb. per head during a 160-day suckling period compared to 28 lb. for
cows nursing the non-creep-fed calves.

Marlowe and Gaines (1958) found that sex of the calf significantly
influenced growth rate but had little effect on type score. Bull calves
grew approximately 5% faster than steer calves and steer calves grew about
8% faster than heifer calves. The differences were slightly larger in the
creep-fed groups. Creep feeding of calves appeared to increase their
growth rate approximately 0.11 lb. per day and their type score approxi­
mately one-seventh of a grade. The most striking influence that creep
feeding exerted on the effects studied was to decrease the influence of
season of birth.

Cundiff (1966) observed an important interaction between sex and type
of management. Differences in weaning weight among sexes were larger in
calves that were creep-fed than in those that were not indicating that
bulls benefit more from creep feeding than steers or heifers.

Multiplicative corrections were found to be more appropriate in ad­
justing for the effect of sex. In addition to more nearly equalizing
variances within sexes, multiplicative corrections completely accounted
for the interaction observed between sex and type of management.
Under the conditions involved in this study, an additive correction of 28 lb. was used to adjust for type of management (creep vs. no creep).

The response of beef calves to DES during the suckling period has been less thoroughly studied than the response received when DES is administered to more mature animals. The various research reports show that administration of DES to young calves results in a reasonably consistent weight gain response. Six or 12 mg. DES implants administered to suckling calves resulted in 11 lb. less gain to 36 lb. more gain than non-implanted calves. The response to DES implants was usually greatest when the suckling calf had enough energy available to bring about the increased gain potential. For this reason the combination of various creep feeds and DES implant levels are very important tools for increasing the weaning weights of male beef calves.

Creep feeding beef calves has long been a very controversial issue. Although economy of creep feeding is often challenged, it is frequently recommended when conditions are unfavorable for the growth of the calves. The majority of the reports in the literature indicate that creep feeding increased the weaning weights of calves but in many cases the creep-fed animals made slower less efficient gains in the feedlot. Management as well as many other environmental factors that are associated with the surroundings of the creep-fed animals are, no doubt, responsible for the occasional negative economic returns from creep feeding. The numerous reports showed that creep feeding resulted in little to no advantage to 100 lb. more gain at weaning than non-creep-fed calves. Creep feeding costs ranged from very minimal costs up to values as high as $35.00 per calf.
Experiments conducted at Arizona (1946-47) showed that fattening bulls made more rapid and economical gains than steers. A greater net profit was received from the bulls in the first experiment but in the second experiment bulls showed a slightly smaller profit than the steers. The bull carcasses graded very satisfactory.

Extensive investigations with bulls and steers were reported by Klosterman et al. (1954, 1955, 1958). In 1950-51, on a 252-day feed test, steers gained 2.00 lb. per head daily while bulls gained 2.23 lb. per head. In 1951-52, steers were fed longer to reach the same final weight as bulls (848 lb.) and averaged 0.48 lb. less per head daily than the daily gain for bulls. In both experiments the bulls gained at a significantly faster rate than either early or late castrated steers. The appraised selling price per 100 lb. was about $4.00 more for steers than for bulls. Initial weight of animals in these experiments was about 375 lb. The feed cost per cwt. gain was $1.25 less for the bulls than the average for the steers in the first experiment and $3.78 less in the second experiment. The differences in dressing percentage were significant (P < .05) with bulls having the lower dressing percentage. The following differences were significant (P < .01): the bulls had heavier hides, lower carcass grade, heavier forequarters and lighter rearquarters and lighter weight flanks and kidney knobs. The bull carcasses also had significantly (P < .01) less fat trim and a greater percentage of edible portion. There were no significant differences in tenderness ratings between the bull and steer carcasses in the 1950-51 experiment, but there were highly significant differences in
the 1951-52 experiment.

The results indicate that there is very little difference between steers and fat, young bulls in the proportion of valuable, edible meat in the rear quarter. There was also a highly significant correlation between carcass grade and tenderness score by the Warner-Bratzler shear test. There were no significant differences in any of the slaughter or carcass determinations between steers castrated shortly after birth or those castrated at weaning age. When the cost of the edible portion was based on the appraised selling price, the bull carcasses supplied a pound of edible meat for 10 to 12 cents less than the steer carcasses. This difference was somewhat less, 5 to 7 cents, when the cost of edible portion was based on the wholesale value of the carcass obtained.

In three experiments from 1952-55, Klosterman investigated the effects of implanting bulls and steers with DES. In the 1952-53 experiment one group of bulls was implanted subcutaneously in the neck region with 84 mg. DES at the start of a 182-day feeding test and after 98 days the bulls were implanted with an additional 132 mg. DES. In the 1953-54 experiment one lot of bulls and one lot of steers were implanted in the mid-portion of the ear with 84 mg. DES at the start of the test and an additional 84 mg. midway through the feeding period. In the 1954-55 experiment one lot of steers was implanted with 60 mg. and one lot of bulls with 84 mg. DES at the start of the feeding period and after 80 days on test the bulls were given an additional 120 mg. implant.

In 1952-53 the differences in average daily gains between bulls and steers and between DES treated and untreated bulls or steers were signifi-
cant (P < .01). The implantation of DES in the 1953-54 study increased daily rate of gain more in steers (0.48 lb.) than in bulls (0.20 lb.). In the 1954-55 experiment, DES implantation increased the average daily gains of steers by 0.52 lb. and bulls by 0.11 lb. The total pounds of feed required to produce 100 lb. of gain in these three experiments were as follows for bulls and steers, respectively (including concentrates, hay and hay equivalent): 1952-53, first period, 595, 707, second period, 705, 769; 1953-54, 644, 788 and 1954-55, 736, 774. The 1952-53 and 1953-54 values were for animals not treated with DES. When animals were treated with DES, the amount of feed required for 100 lb. of gain was usually less than for those not treated. Implanted bulls required 534 and 652 lb. of feed per 100 lb. of gain in the first and second periods, respectively, of the 1952-53 experiment. Implanted bulls and steers, respectively, required 657 and 667 lb. of feed per 100 lb. of gain in the 1953-54 experiment.

The authors reported a highly significant (P < .01) difference between the carcass grade for steers (choice average) and bulls (choice minus). There was also a significant (P < .05) interaction between castration and DES treatment. The implantation of DES significantly (P < .05) increased the carcass grade of the bulls (a full one-third grade), but lowered the grade of the steer carcasses by one-fourth of a grade. The bull carcasses in these experiments produced a significantly (P < .01) higher percentage of edible portion. In the second experiment, there was a significant (P < .05) interaction between castration and DES treatment. The implantation of DES increased the amount of edible meat in the steer carcasses but reduced it in the bull carcasses. This relationship is the
direct opposite of what was found in carcass grade, and shows the in-
fluence of degree of finish of a carcass upon its yield of edible portion.
The implantation of DES in weanling bull calves caused some retardation in
sexual development. Although there was individual variation in response,
the treated bulls generally did not develop as heavy a crest or as mas-
culine a head as the untreated bulls. There was some depression of testes
growth and development in the treated bulls. The implantation of DES in
fattening bull calves gave results similar to those reported from the treat-
ment of steers and heifers, except for the effect on carcass grade.

In a review of DES work, Sykes et al. (1953) concluded that lower
grades of DES-implanted steer and heifer carcasses resulted from reduced
amounts of subcutaneous fat. Conversely, it is the increased subcutaneous
fat on implanted bull carcasses along with the excellent muscular develop-
ment that qualifies them for a higher grade.

Higda and Močalovskii (1959) found that bulls sterilized by punc-
turing the epididymis gained 0.11 lb. per day faster than steers on a 150-
day feeding test. Meat from the sterilized bulls had a better flavor than
that of the castrates.

Amschler and Meinx (1950) reported that bulls gained 0.79 lb. per
day faster than steers during fattening periods ranging from 119 to 147
days. The bulls were superior to the steers in efficiency of feed con-
version. In recent trials in Russia using Black Pied-Gorbatov cattle,
Rostovcev (1961) found that bulls had 15% faster average daily gain than
steers and the beef quality in 18 month old bulls was better than that of
steers the same age. Homb (1961), working with 4 pairs of twins in Norway,
reported live weight gains of steers to be 70 to 75% of that of bulls with animals older than 1 year on indoor feeding. Significantly higher taste panel scores were reported for steer beef, but bull carcasses sold as well on the Norwegian market. The author concluded that, on intensive rearing, bulls were more efficient whereas steers were superior on pasture. Watson (1956) cited figures for average daily gains of bulls and steers on a performance testing program for beef sires in Ontario. Over a period of 196 days, bulls had average daily gains of 2.33 lb. compared to 1.88 lb. for steers.

Tyleček (1957) compared gains in bulls with those of steers in which castration took place either at 36 days old or 110 days prior to the end of the fattening period. Average daily gains were 2.51 lb. for the bulls and 1.94 and 2.09 lb. for the castrated groups, respectively. The beef from steers was judged more desirable than that obtained from the bulls.

Brännäng (1960), working with 12 pairs of monozygotic twins of the Swedish Red-and-White breed, found that castration at 1, 6 or 12 months did not significantly affect finishing weights at 25 months of age but the average live weight of the bulls was 70 lb. greater than that of the steers. Bulls were superior to steers in feed required per unit of gain. These studies suggest that, within limits, the effect of time of castration is small. Kirillov and Gorbačev (1958) reported gains of 229 lb. for steers and 267 lb. for bulls of an East Friesian herd over a 270-day period.

There is experimental evidence of early castrates having a higher finishing weight or greater average daily gains than late castrates. With
late castration the early augmentation of average daily gains by the presence of male hormones may be nullified by the setback to growth caused by the castration operation. For example, steers castrated at 880 and 1100 lb. weighed, respectively, 8.0 and 7.2% less than bulls at slaughter according to Pícha and Župka (1960). These workers found that steer beef was more acceptable than beef from bulls.

Bocsor et al. (1955) reported that bulls gained 0.55 lb. more per day than steers and required 20% less feed per unit of gain. There was no appreciable difference in quality between carcasses of bulls and steers slaughtered at 21 months, but the taste of the bull beef was preferred.

Andreas (1959), working with four pairs of identical twins, found bulls to have a greater conversion efficiency than steers, the difference increasing with age. This author stated that those studies on rate and efficiency of gain have extended over a number of breeds; there is no real evidence either way that breed influences the effect of castration on these production characteristics.

The carcass quality of steers is widely reported as being better than that of bulls. Market demand sets the standards for quality and varies somewhat from country to country. Wierbicki et al. (1955) reported on carcass quality and composition of Hereford bulls and steers slaughtered at 13 and 15 months of age. Bulls had lower carcass grades and slightly lower dressing percentages but the authors concluded that the better consumer quality and tenderness of beef from steers was perhaps not worth the increased cost of production. The edible portion of the bull carcass was significantly (P<.05) higher by 3 to 4% than that of steer carcasses.
Koger et al. (1960) fed 16 bulls and 16 steers a 60% concentrate, all pelleted ration from weaning to 1000 lb. At weaning half of the bulls and half of the steers were implanted with 84 and 36 mg. DES, respectively. Implanting weanling bull calves had no appreciable effect on gain, efficiency or carcass traits, but implanting steer calves induced marked differences in performance. The two groups of bulls and the group of implanted steers made faster gains, were more efficient and produced a higher percentage of retail trimmed cuts of chilled carcass than did the non-implanted steers. No significant differences were observed between the bull groups or between the bull groups and the implanted steers. Observed differences favored the implanted steers for performance and the bulls for carcass traits. A taste panel reported no unfavorable response to any of the meat as to the tenderness, flavor, juiciness or general desirability.

Comparisons of performance, carcass cut-out data and eating quality of bulls and steers were made by Brown, Bartee and Lewis in 1962. Eleven bulls and 11 steers representing five sires were group fed 56 days and individually fed 112 days a ration consisting of 2 parts grain and 1 part hay. All animals were slaughtered at an average age of 13 months. There were no significant differences between the means of performance traits of bulls and steers although differences favored bulls. Comparisons of cut-out data indicate a highly significant ($P < .01$) difference in loin eye area in favor of the bulls. Steers had significantly ($P < .05$) more percent trimmed loin and percent waste. Weight of percent chuck of bulls was significantly ($P < .05$) higher. There was no difference between the taste panel scores of steaks from bulls and steers. No differences were noted
between bulls and steers in dressing percent, chemical analysis (fat, moisture and protein) of 9-10-11 rib cuts or in weight of wholesale cuts. Steers slightly exceeded bulls in carcass grade, but the differences were not significant. The correlation between tenderness score and cooked shear value was negative, and in the case of the bulls significantly \((P < .05)\) so. This would indicate that with these 22 animals, the shear value was not consistent with tenderness scores by the taste panel.

Adams and Arthaud (1963) obtained Warner-Bratzler shear values on cooked samples of l. dorsi muscle at the 10-11th rib of Angus bulls, steers and heifers fed alike. Carcasses graded from low good to average choice and were from animals averaging 439 and 479 days of age from group I and group II, respectively. Samples from group I were significantly \((P < .05)\) more tender than from group II. Steers were significantly \((P < .01)\) more tender than bulls. However, no significant difference was found in tenderness between bulls and heifers or between heifers and steers.

Thirty-eight Angus male calves, one-half of which were castrated shortly after birth, were used in a study by Field et al. (1964) to compare performance, carcass yield and consumer acceptance of retail cuts from steers and bulls. Initial weights of steers were 391 lb. while bulls weighed 422 lb. Nine bulls and 9 steers were fed 232 days while the remainder were fed 260 days. The cattle were slaughtered at an average age of 16 months. Bulls gained 0.24 lb. per day more than steers \((P < .05)\), but accurate consumption information was not available. Very little difference was noted in the amount of restlessness between bulls and steers in the feedlot or in handling the animals during feeding and weighing.
Bulls and steers, respectively, had: 13.38 and 10.54 sq. in. of rib eye area; 2.32 and 2.07 sq. in. of rib eye area per 100 lb. cold carcass weight; 0.34 and 0.67 in. of fat cover over the 12th rib; 2.74 and 3.53% estimated kidney fat; 53.56 and 51.95% forequarter and 47.0 and 42.74% bone-in retail cuts from the chuck, rib, loin and round. Differences between the means were all significant (P < .01). The Denver area supervisor of the U.S.D.A. meat grading branch found marbling scores, texture of marbling, color of lean, texture of lean and firmness of lean to be significantly more desirable (P < .01) for the steers when compared to the bulls. Mean grades for the bulls and steers were average good and average choice, respectively. Only one bull carcass which was not recognized as such by the grader was graded choice.

Consumers selected bull chuck roasts by a ratio of approximately 3:2 over steer chuck roasts when unidentified cuts were placed side by side in a self service counter. Differences in selection of other retail cuts studied were not as great. Consumers gave bull steaks significantly lower taste and tenderness ratings but thought that chuck roasts from bulls were more desirable because of less intermuscular fat. Over 85% of the consumers scored taste of bull meat as good or very good while less than 3% of the consumers rated bull meat as having a poor taste. Six and 3% of the consumers thought that bull steaks and roasts, respectively, were tough as compared with 1% for steer steaks and roasts. Ninety and 91% of the consumers who bought steaks and 88 and 92% of the consumers who bought roasts from bulls and steers, respectively, said they would buy them again. Higher palatability ratings for steer meat indicate that under the con-
ditions of this experiment, consumers could tell a difference in quality of bull meat and steer meat; however, these results cannot be interpreted to mean that bull meat is not acceptable. This difference is of a slightly greater magnitude than the difference reported between good and choice grade steer beef. Nevertheless, it is possible that bull and steer beef of the good grade may be equally acceptable to the consumer.

Matsushima et al. (1963, 1964, 1965) studied the effects of DES (fed orally and implanted) on the performance and carcass characteristics of bulls, steers and stags (castrated when put in the feedlot). In the 1963 test, bulls consistently gained more rapidly and more efficiently than steers. Bulls implanted with 45 mg. DES gained 3.5 and 6% greater than non-implanted bulls and stags, respectively. The most significant finding from this experiment was the effect of the DES implant in minimizing some of the bullish characteristics of the animal on hoof and also in the carcass. The most recognizable characteristic was the reduction of the heavy crest usually evident in older bulls. All of the animals involved in this study were fed in one lot and the authors concluded that steers and bulls could be fed together in the same pen provided they are put in the feedlot at the same time. A certain amount of riding took place during the first few days but it gradually subsided and was no problem.

Bulls reached the terminal weight of 950 lb. 10 to 20 days sooner than stags or steers in the 1964 experiment. Feed efficiency was in favor of the bulls (14%). Although bulls made faster and more efficient gains than steers or stags, the carcasses lacked marbling and desirable color. None of the 20 bull carcasses made the choice grade. Failure to make the
grade was not due to extreme stagginess or masculine characteristics. Bull carcasses had the largest rib eye area and the least fat cover. Oral feeding of DES (10 mg. daily) had the least effect on bulls and the greatest effect on steers. This effect was shown in both the full-fed and delayed-fed groups. Steers fed 10 mg. DES gained as much as bulls without DES. In the early part of the test, bulls which received the DES showed a depression in gains. However, this was overcome after a 60 to 180-day feeding period.

In the 1965 study, bulls gained 4.1 and 8.0% faster than steers and stags, respectively. DES was included in the daily ration at the rate of 10 mg. per head after the 84th day of the test. Steers outperformed stags in nearly every comparison as late castration appeared to depress performance of the animal in the feedlot.

Champagne et al. (1964) studied the effects of age at castration on feedlot performance and carcass characteristics of bulls and steers. Bulls gained 0.5 and 0.6 lb. per day faster than early and late castrates, respectively. Bulls required 105 and 140 lb. less feed per 100 lb. of gain and produced 5.1 and 4.4% greater edible portions of carcass than early and late castrates, respectively. Consumer studies indicated no differences in tenderness among the three treatments.

Väpf et al. (1964) investigated the effects of slaughter age and DES implants on feedlot performance and carcass characteristics of bulls and steers. Eighty-four Brahma-Hereford calves were used in the experiment, half of which were castrated at birth. Half the bulls and half the steers were implanted with 24 mg. DES at weaning. Seven animals from each treatment group were slaughtered at 9 (weaning), 12 and 15 months of age. Im-
planted steers gained 0.22 and 0.31 lb. per day faster than control steers at 12 and 15 months, respectively. DES implants failed to improve the daily gain of bulls; however, bulls gained 0.5 lb. per day faster than steers. Differences in degree of marbling due to DES implant and sex condition were not apparent among animals slaughtered either at 9 or 12 months of age. However, the steers at 15 months showed more marbling than bulls. U.S.D.A. grades showed no difference between DES bulls and steers at 9 and 12 months. However, at 15 months the DES bulls graded slightly higher than the control bulls, and the DES steers graded slightly lower than the control steers. All bulls had a higher estimated percent cutability than steers. Taste panel scores and Warner-Bratzler shear values for short loin steaks showed no differences among treatments (sex) for the 9 and 12 months age level groups.

Casas and Raun (1964) observed no growth response when 2-year old bulls were implanted with 12, 24, or 48 mg. DES. Two trials were designed to further study the effects of 72 and 96 mg. DES implants on the growth rate of 2-year old bulls. The bulls implanted with 72 mg. DES gained 14.4% faster (P < .05) than control animals and the bulls implanted with 96 mg. DES gained 10.6% faster than controls. In both trials DES implantation was without effect on weight gain during the first 56 days following implantation. However, in the subsequent 56 days, DES implanted bulls gained 19 to 41% faster than controls.

King et al. (1965) investigated the cutability of bull, steer and heifer carcasses. Twenty bulls, 19 steers and 20 heifers were fed for 150 days. Bull carcasses had significantly larger l. dorsi areas, less fat
over the l. dorsi, less marbling, less total fat trim, a higher percentage of retail boneless "cushion" round, chuck and total yield of retail boneless, closely trimmed cuts than did either steer or heifer carcasses. Steer carcasses were significantly different from heifer carcasses in fat thickness over the l. dorsi, marbling in the l. dorsi, graded lower, had a higher percentage of retail boneless rib, chuck and total yield of retail boneless, closely trimmed cuts. Heifer carcasses were significantly superior to steer and bull carcasses in the degree of marbling in the l. dorsi, carcass grade, yield of retail boneless, closely trimmed loin and less total percent bone.

A comparison of the growth rate and carcass traits of bulls, DES-treated bulls and steers of the Holstein-Friesian breed was conducted by Martin et al. (1965). In the study, 36 male cattle were used, of which 12 were castrated at birth, 12 were allowed to remain as bulls and 12 were allowed to remain as bulls but were implanted with 12 mg. DES at birth, 24 mg. at 3 months and 36 mg. at 6 months, 8 months and 10 months of age. The cattle were started on feed at 3 months and slaughtered at 12 to 13 months of age. The average daily gain and feed required per pound of gain for the bulls, implanted bulls and steers, respectively, were: 2.61, 6.14; 2.85, 5.74; 2.38, 6.10. Steers had smaller rib-eye area, more fat cover, a greater amount of marbling, higher carcass grade, more kidney fat, less separable lean and more separable fat than did the bulls or implanted bulls. The steers were clearly fatter than the bulls or implanted bulls. This resulted, under present grading systems, in a payment of approximately $1.40 more per cwt. for the steers and cancelled
the $1.00 saving in feed cost per cwt. of gain for the implanted bulls. In general, the implanted bulls were fatter than the control bulls, but they still sold as bulls.

Arthaud (1965) studied the effects of sex on production and carcass traits in cattle. The animals were individually fed after a 30-day adjustment period following weaning. Bulls gained 22% more per day than steers who, in turn, gained 11% more than heifers. Bulls required 15% less feed per pound of gain and the steers 3% less than heifers. Bulls had less marbling and were about one-third grade lower than steers and heifers. The muscle from bulls was less tender as measured by the Warner-Bratzler shear test. However, some bulls were more tender than some of the steers and heifers. There was a greater range in tenderness among the bulls than among the steers. Bulls had the highest percentage yield of trimmed, boneless, retail cuts from the chuck, rib, loin and round (cutability) of the three groups. Bulls had 3% higher cutability than steers and 5% higher than the heifers. Market value per pound for the bull carcasses was less than that for steers and heifers. However, the net return per carcass over feed cost was higher for the bulls because of their greater efficiency. The yield of the total amount of boneless, trimmed, packaged meat was greater from the bulls. When the same retail value per pound, adjusted for quality grade, was placed on the packaged product, the bulls had a much greater return over feed costs.

In a study by Williams (1965), 45 animals were used to investigate performance, carcass characteristics and ultrasonic estimates of muscle and fat of bulls, steers and heifers. Steers were castrated after allotment and five animals of the same sex and breed were fed per lot in a 133-
day wintering period followed by a 75-day finishing period. Slaughter was by sire progeny trios at three times: (1) when all heifers averaged 750 lb.; (2) when the remaining steers averaged 875 lb.; and (3) when the remaining bulls averaged 1000 lb. During the wintering period, bulls gained more than steers or heifers on less feed per 100 lb. of gain. During the finishing period, bulls gained more than steers or heifers and steers gained more than heifers. Differences in feed required per 100 lb. of gain were significant among sexes in the following order: bulls < steers < heifers. Over both periods, feed required per 100 lb. of gain differed significantly among sexes. Bull carcasses graded lower than those of steers or heifers. Bulls and steers had lower dressing percentages than heifers. Heifers had more estimated kidney and pelvic fat and greater fat thickness than steers or bulls. Weight of trimmed round was significantly different among sexes as follows: bulls > steers > heifers. Bulls and steers had a greater percent trimmed round than heifers. There was a greater percent protein in bull meat than in heifer meat. Percent moisture and ether extract were significantly different among sexes with bulls > steers > heifers in moisture and bulls < steers < heifers in ether extract. Bull meat was less tender than steer or heifer meat by shear tests and taste panel scores. Bull meat was also darker and coarser textured than steer or heifer meat. The author reported that all of the above differences were significant at either the 1 or 5% level.

Warwick et al. (1965) individually fed twin cattle from 6 months of age to slaughter. Bulls gained 21% more on 16 to 17% less feed and reached slaughter weight 2 months sooner than twin steers. The bulls produced 1.19
lb. of beef for every pound the steers produced on the same amount of feed. In reaching the desired market weight 2 months sooner, there was a saving of 18% in feedlot labor and overhead costs for the bulls. Bulls yielded 10% more lean, 38% less fat and 9.3% more bone than steers. Bulls also compared well with the steers in the percent of desirable cuts in the carcass. A taste panel rated bull beef slightly less flavorful and tender than steer meat, and the Warner-Bratzler shear test confirmed the tenderness difference. The bull carcasses graded between high good and low choice; the steer carcasses middle choice — all within the range that consumers consider desirable. The satisfactory quality rating of bull beef was, in part, because of the bulls rapid growth and youth when slaughtered. The meat had none of the objectionable flavor or other characteristics associated with meat from older bulls.

Conrad and Neal (1965) fed an equal number of bulls, steers and heifers for 196 days. One-half of the animals in each sex group were implanted with 30 mg. DES at the start of the feeding period. The average daily gain and feed required per cwt. gain for bulls, steers and heifers, respectively, were: 2.57, 694; 2.16, 786; 2.01, 767. The 30 mg. DES implant had little or no effect on the average daily gains of bulls and heifers but increased the gain of steers 0.24 lb. over the control group. The bulls had heavier carcasses, larger rib eyes, less fat and a higher percentage of boneless cuts than either steers or heifers. However, the bull carcass did not have as much marbling nor did they grade as well as the steers or heifers. The average Warner-Bratzler shear values were 10.52, 10.49 and 9.92 for the bulls, steers and heifers, respectively.
Warner et al. (1965) fed 400-lb. weanling bull, steer and heifer calves to a constant weight of 900 or 1100 lb. Beef bulls outgained steers by 0.70 lb. and heifers by 0.78 lb. per day (P < .01). Daily gains were 2.92, 2.22 and 2.14 lb. per head and feed required per cwt. gain was 749, 876 and 900 for bulls, steers and heifers, respectively. Carcasses from bulls slaughtered at either 900 or 1100 lb. had a higher retail yield and less total carcass fat than steers or heifers at similar weights. Average retail yield was 74.6, 67.1 and 62.7% for bulls, steers and heifers, respectively. Percent total carcass fat was 15.7 for bulls, 22.4 for steers, and 29.0 for heifers. Both of the above differences between bulls and steers as well as steers and heifers were highly significant (P < .01). Bulls graded lower than steers and steers graded slightly lower than heifers, but the only significant (P < .05) difference in grade was between bulls and heifers. Shear tests of loin steaks indicated no significant differences in tenderness of beef from bulls, steers and heifers.

Hemstrom and Orme (1965) reported a significant (P < .05) difference in favor of bulls for the U.S.D.A. carcass yield grade when bulls were fed for 149 days and slaughtered at 13 months of age. A consumer preference study comparing loin steaks from bulls and steers clearly indicated no difference in preference. Warner-Bratzler shear tests for tenderness using 1-inch cores from cooked steaks also indicated that bull steaks were equally as tender as steer steaks. Prediction equations for estimating percent lean in the carcass and percent lean cuts indicated that the bull carcasses were superior in both respects.

Cmarik (1966a) fed 55 long yearling bulls and 22 long yearling steers
all in one lot for 145 days. An equal number of bulls were implanted with 0, 24, 48, 96 and 192 mg. DES and the steers were implanted with 0 or 48 mg. DES. Bulls with or without DES gained faster than steers without DES and, in most cases, as well as or better than steers treated with DES. Implanted steers gained 15.5% more than untreated steers but 13% less than bulls treated with an equal amount of DES. Bulls implanted with 24 and 48 mg. DES performed progressively better than those receiving no DES. Bulls with 24 mg. DES gained about 4% faster than bulls with none, and bulls with 48 mg. gained 4.5% faster than those with 24 mg. and 9% faster than those with none. DES implants in excess of 48 mg. per head resulted in smaller gains. Although the bull meat tended to be darker and coarser than steer meat, the differences were not significant. There was a decrease in testicle weight of the bulls receiving levels of DES at 48 mg. and higher.

Cmarik (1966b) studied the effects of various DES implant levels on the performance and carcass characteristics of yearling bulls. Equal numbers of bulls were grouped by weight and sire in four random lots and implanted with 0, 24, 48 and 96 mg. DES. The feeding period lasted 102 days. The 24, 48, and 96 mg. rates of treatment resulted in approximately 7, 6 and 4% more gain, respectively, than the untreated lot. Bulls that received 24 mg. DES utilized feed most efficiently, requiring 2% less feed than control bulls and about 6% less than bulls with 48 and 96 mg. implants. The fact that bulls implanted with 48 and 96 mg. DES required approximately 4% more feed than the untreated lot to produce a unit of gain does not agree with previous data reported by this author (1966a). None of the carcass traits differed significantly; however, testicle weights
were slightly reduced by DES implantation. The author concluded that DES implants used on this age group of bulls (yearlings) appeared to be slightly less effective than on older males (long yearlings) reported in previous literature.

Martin et al. (1966) investigated the growth and carcass characteristics of 157 Angus bull and steer calves in a 5-year study. The male calves were randomly allotted to steer and bull groups prior to weaning. Calves assigned to the steer groups were castrated at weaning and placed on a full-feed. All animals were slaughtered at or near 1000 lb. live weight. Bulls gained significantly faster ($P < .01$) than steers and were slaughtered 23 days earlier with a 57 lb. weight advantage. All carcasses were graded on steer carcass standards. Steer carcasses were significantly fatter ($P < .01$) and graded significantly higher ($P < .01$) than bull carcasses. Bull carcasses graded high good with a modest marbling score and 0.54 inch of outside fat cover. Steer carcasses graded low choice with a moderate marbling score and 0.82 inch of outside fat cover. Bulls fed to make maximum daily gain and consequently marketed at a young age were more profitable than steers under the marketing conditions experienced in the experiment. Bulls required $2.50 less feed per cwt. gain than steers. Cookery tests revealed no pronounced differences between bull and steer loin steaks with regard to tenderness and palatability characteristics.

Bailey et al. (1966a, 1966b) investigated growth rate, feed utilization, body composition and quality factors of the l. dorsi of young bulls and steers. Three experiments were conducted in which all the animals were
slaughtered at a constant weight. The effect of DES implantation on car­
cass characteristics of bulls and steers was not the same. DES implanta­
tion (24 mg.) caused a significant increase in the growth rate of steers
and a reduction in the amount of fat in the carcass. Bulls implanted with
60 mg. DES tended to gain more rapidly and were somewhat fatter than con­
trols, but the effect of the hormone on carcass characteristics of bulls
was less pronounced than with steers. There was some indication in the
third experiment of an increase in carcass grade of bulls which had re­
ceived DES. Differences in daily gain and feed efficiency of bulls and
DES-implanted steers were not significant. The l. dorsi of steers con­
tained a higher (P < .05) percent ether extract than muscle of bulls. DES
caused a decrease in percent ether extract in steers and tended to in­
crease slightly the amount of ether extract in l. dorsi of bulls. L. dorsi
from bulls in Experiment I was more acceptable in tenderness than muscle
from animals of either sex condition which were raised under less intensive
conditions and slaughtered at older ages (Experiments II and III).

Hammond (1932) found that growth rate to the age of 4 months was in­
fluenced by castration in a flock of Suffolk sheep. At this age the weights
of rams and wethers expressed as percentages of ewe weights were 124 and
110%, respectively. This author advised against castration in a flock pro­
ducing fat lambs for sale at an early age on the grounds that ram growth
rate is superior to that of the castrate. On the other hand, at 5 months
of age, carcasses of ram lambs were, in general, inferior to those of weth­
ers, the meat being coarser grained and less tender. Only slight differen­
ces in marbling existed at 5 months but, with increasing age, marbling in
the meat of the entire animal coarsened progressively.

Hunt et al. (1938), in a comparison between rams and wethers extending over 52 weeks and involving a total of 145 animals, found ram lambs to be heavier than wethers at the younger ages but at 1 year some wethers were as heavy or heavier than rams. Differences in average rate of gain on pasture or in the feedlot between rams and wethers were, however, not significant. There was no difference in carcass grade between rams and wethers at 15 weeks, but at 1 year wethers averaged one grade higher than rams. Rams had a higher percentage of lean in the rib cuts, especially at the older ages. At ages from 15 weeks to 1 year, approximately 23% more force was required to shear a piece of leg muscle from rams than from wethers. Castration was considered desirable over the age of 20 weeks on grounds that it ensured a higher quality carcass.

Reynolds et al. (1966) found that ram lambs gained faster and yielded more lean meat, but wethers were fatter, graded higher and were more tender. Richter (1961) stated that carcass quality was not affected by castration when lambs were slaughtered at an average age of 124 days.

When comparing rams and wethers at equal dressed carcass weights and at the same age (4 months) Pálsson (1955) found that wethers were earlier maturing, had higher dressing percentages and better fat development in the loin.

Walker (1951) reported on weight for age of ram lambs and wethers and considered the superiority of rams sufficient to justify a policy of non-castration of ram lambs.

In the pig, the effect of castration on growth rate is less well marked than in cattle and sheep. According to Pálsson (1955) castration
in pigs appears to have greater effects in promoting early maturity than in cattle and sheep, possibly because of differences in physiological age at castration in the three species. Winters et al. (1942) compared growth rates in 67 boar/barrow pairs from six inbred lines of Poland China pigs and in 19 pairs of Minnesota No. 1 pigs which were weighed monthly from 8 to 24 weeks of age, by which time they had reached approximately 220 lb. Poland China boars were slightly heavier than barrows at all ages, but gain differences were not significant after 16 weeks of age. In the case of the Minnesota No. 1 pigs, boars were heavier from 8 to 16 weeks and barrows thereafter.

Bratzler et al. (1954) found no significant difference in rate of gain between Poland China - Hampshire boars and male hogs castrated at 70 days or 100, 140 or 180 lb. Pork from boars slaughtered at live weights between 210 and 230 lb. was inferior to that of barrows of similar weight and had an undesirable odor on cooking. There were no significant differences between boars and barrows in feed consumption or feed efficiency. However, Wallace (1944) found barrows to be only 79% as efficient as boars in over-all conversion and 75% as efficient in protein storage. The taste of meat from boars slaughtered at 210 lb. live weight was not adversely affected. Charette (1958 and 1961) reported significantly improved feed conversion for boars when compared to male hogs castrated at various ages from birth to 20 weeks. There was no taint in pork from boars slaughtered at 205 lb. live weight. Boars had less backfat and less loin fat except when compared with pigs castrated at 12 weeks. Fat was of a softer consistency in boars. This author stated that in view of
the increased feed efficiency, carcass length, thinness of fat and area of loin, consideration should be given to the use of boars for meat production, and that castration may not be necessary when slaughter takes place before a pig is 150 days old.

The literature indicates that the pros and cons of castration must be considered not only on a species basis but also in relation to the class of meat within the species. In the final analysis the question must be one of economics. There is little point in the farmer rearing uncastrated animals if the price he is paid for them is so much less than for castrates that it cancels out the lower costs of production and even results in less profit. In those parts of the world where there are no economic restrictions against bull carcasses, or in places where the importance of efficiency of production outweighs carcass differences, there is a definite advantage in the intensive rearing of young bulls for beef. Where rearing is on range there is no evidence to suggest that abandoning the practice of castration would lead to any increase in meat production relative to food consumption. Indeed, there is a suggestion that on pasture the growth rate of steers exceeds that of bulls. In the case of swine slaughtered before 150 days, leaving boars uncastrated does not confer any great material advantage in production efficiency. Slight improvements may occur in production efficiency, carcass length and fat thickness, but these may be offset by a slight adverse shift in the balance of hind and forequarters. The question is really whether or not castration makes for material advantages, and, in the absence of non-subjective tests for taint, the meat trade and the consumer must have the last word on discrimination.
against boar carcasses. In fat lamb production castration does not appear to be essential from the quality standpoint. Increases in growth rate and efficiency of conversion resulting from raising uncastrated animals must take into consideration herd or flock management practices. The fact that the uncastrated animal requires careful segregation to prevent indiscriminate mating and may need additional measures to counteract an increased aggressiveness, must be taken into account. Drugs and hormones will no doubt play important roles in the future of the uncastrate animal. When DES is administered to uncastrated male cattle, top quality beef is produced efficiently and economically. However, the animal must be raised under intensive feeding and management systems and slaughtered at early ages.

Effects of Age and Sex on Muscle Tenderness

Mitchell and Hamilton (1933) and Mackintosh et al. (1936) found that meat from young steers contained less collagen and was more tender than meat from older animals. Hiner and Hankins (1950) studied the effects of age on tenderness using animals of five different age groups: 3, 8, 14, 37 and 67 months. As age of the animals increased, tenderness decreased. The difference between veal (3 months old) and cows (67 months old) was highly significant, whereas that between veal and beef from 8 month old steer calves was not significant.

Wilson et al. (1954) investigated the effect of age and grade on the collagen and elastin content of beef and veal using cow, steer and veal carcasses representing various U.S.D.A. grades. Considerable variation in
The collagen and elastin content was found within grades for each age group and in no case were the differences in the measurements between grades significant. There was no difference between the collagen and elastin content of samples from steers and cows, but the samples from both of the older groups contained less collagen and elastin than veal. The authors concluded that the percentage of collagen and elastin in the l. dorsi of beef animals is not a critical measure of tenderness of meat.

Wäerbicki et al. (1955) studied the effects of castration on the biochemistry and quality of beef. Bulls and steers were well fed from birth and slaughtered at 13 to 15 months of age. The eating quality as measured by tenderness ratings (the primary attribute of quality for the consumer) indicates that the bulls yielded slightly less tender meat; this difference was found at both 3 and 15 days post-mortem. In the 1950-51 study, connective tissue, measured as hydroxyproline, showed a very high negative correlation ($P < 0.01$) with tenderness at both 3 ($r = -0.64$) and 15 ($r = -0.58$) days post-mortem. In view of the high correlation coefficient in the first year, it was a contrast to find practically no correlation the second or third years. In the first study, all animals were slaughtered at the same age, whereas in the other studies animals were slaughtered as a certain market weight was reached. All animals had comparatively low hydroxyproline values and the contribution of connective tissue to the tenderness or toughness was not pronounced. A summary of the combined data for the 3-year study showed no difference between percent hydroxyproline of bulls and steers that were well fed and slaughtered at 13 to 15 months of age.
Loyd and Hiner (1958) reported that hydroxyproline content of 26 beef muscles ranged from 0.016% of the most tender muscle to 0.160% of the toughest muscle. Contrary to existing belief, the results of this study indicate that veal muscle contains less hydroxyproline than beef and that the amount of hydroxyproline increases somewhat in older animals.

In a study involving 24 Hereford females, 18, 42 and 90 months of age, Tuma et al. (1962) reported that tenderness of l. dorsi steaks, as measured by the Warner-Bratzler shear and a taste panel, decreased significantly with increasing animal age.

Parrish et al. (1961) compared hydroxyproline values with sensory tenderness data of 92 steak samples including 32 loin steaks and 60 round steaks. The coefficient of correlation of these two indices of tenderness for all steaks examined was -.69 (P<.001). The coefficient of correlation of the mean hydroxyproline and sensory tenderness values for all steaks examined within grades and cuts was -.84 (P<.001). Hydroxyproline content was a better measure of the tenderness of less tender steaks than of tender steaks.

Using the biceps femoris muscle of 11 animals divided into four different age groups, Goll et al. (1963) found no significant differences among the age groups in the hydroxyproline content and presumably the connective tissue content. The results indicate that veal muscle tends to have a slightly higher collagen content than the other three age groups. Muscle from veal and from the oldest group (cows, 10 years) possessed less fat than muscle from the two intermediate age groups (steers 1 to 2 years and cows, 5 years). Warner-Bratzler shear-force values of cores from
biceps femoris steaks from the three oldest groups indicated that tenderness decreased with age.

McClain et al. (1965) investigated the relationship of alkali-insoluble collagen to tenderness of three bovine muscles. The l. dorsi, semimembranosus and triceps brachii muscles from the carcasses of 28 yearling steers, classified as tender or less tender on the basis of shear values of the l. dorsi muscles were utilized in the study. The l. dorsi was the only muscle studied which varied greatly in tenderness. Alkali-insoluble collagen in raw meat was found to differ significantly among muscles but did not differ significantly between tenderness groups. The less tender l. dorsi muscles in the raw state averaged 33 lb. in shear force and contained 2.2% of alkali-insoluble collagen, but the tender l. dorsi muscles averaged 18.3 lb. in shear force and had 2.5% alkali-insoluble collagen. The less tender l. dorsi muscles in the cooked state had 0.51% collagen, while the tender l. dorsi had 0.28% collagen present.

Cattle of four different age groups, 6, 18, 42 and 90 months, were used by Henrickson and Moore (1965) to study the effects of animal age on the palatability of beef. The l. dorsi and semitendinosus muscles of 40 cattle were evaluated for tenderness, juiciness and flavor by a taste panel; also, tenderness was measured by the Warner-Bratzler shear instrument. Differences in taste panel tenderness values were significant (P < .01) for age and ranked in the following order: 6 > 18 > 42 > 90. The differences in Warner-Bratzler shear values were significant (P < .01) for age and ranked in the following order: 18 < 6 < 42 < 90.

Field et al. (1966) studied the effects of age, marbling and sex on
the palatability of beef. *L. dorsi* roasts from the 12th rib section of 134 bulls and 84 steers and heifers having from traces to moderate amounts of marbling were evaluated for tenderness, juiciness and flavor. Roasts were obtained 48 hours after slaughter from Hereford, Angus and Shorthorn cattle ranging from 300 to 699 days of age. These were cooked in deep fat to an internal temperature of 74°C. No significant differences were found between bulls or steers and heifers 300 to 399 days old. Steers and heifers 400 to 499 days old had slightly higher palatability ratings than bulls which were similar with respect to age and marbling. Sensory tenderness and shear scores indicated that bulls 500 to 599 and 600 to 699 days old were tougher (P < .01) than steers and heifers of comparable ages. Sensory flavor and juiciness scores for roasts from steers and heifers were also more (P < .01) desirable than from bulls 600-699 days of age. Simple correlation coefficients indicated that sensory quality factors in all roasts were closely interrelated. Correlations between shear and sensory tenderness were -.65 and -.77 for bulls and for steers and heifers, respectively. Least-squares estimates of the influence of age and marbling on shear and sensory tenderness showed that bulls under 400 days old were more (P < .01) tender than older bulls when marbling was held constant. Age of steers and heifers did not affect any palatability characteristics when marbling was held constant. When age was held constant, higher marbling scores in bulls were more closely associated with higher sensory ratings than were higher marbling scores in steers and heifers.

Hydroxyproline as a measure of the collagen (connective tissue) in beef muscle seems to be of controversial value. Scientists have searched
for ways to evaluate amounts of collagen in muscle and in turn this value has been used as a measure of the desirability or tenderness. The results from the majority of the research reports indicate that muscle from the young (veal) animal contains larger amounts of hydroxyproline than muscle from older animals. The muscle becomes less tender with the increase in chronological age of the animal. This could possibly indicate a structural change in collagen as the animal matures.
EXPERIMENTAL PROCEDURE

Pre-weaning Phase

A 4-year study with beef calves was conducted to investigate the possible growth promoting effects of diethylstilbestrol (DES) implants and various methods of creep feeding during the pre-weaning period. The pre-weaning experimental design for each of the 4 years is presented in table 1. Male calves raised in the commercial beef herd at the Beef Nutrition Farm at Ames, Iowa, were randomly assigned to one of two treatment groups (table 1) for the pre-weaning phase (summer studies). The calves were all dehorned at 2 months of age and a portion of the male calves were castrated between 2 and 3 months of age. All the calves were born within a 70-day calving period. Each summer treatment group was assigned the same number of calves of each sex providing numbers permitted. The heifer calves for the corresponding year were used as the control group, thus receiving no creep or DES implant. The weaning weight of the heifer calves was adjusted for sex by multiplying the actual weaning weight times 1.05 which is the adjustment factor recommended by the United States Beef Cattle Records Committee (1965). At 3 months of age the calves were implanted with the desired level of DES and at the same time they were given access to a creep ration consisting of 60% cracked corn, 30% rolled oats and 10% molasses. At the end of 1 month on the above creep mixture the calves were gradually switched over to an all cracked corn ration. The DES was implanted subcutaneously in the mid-portion of the ear with a conventional implant gun.
Table 1. Design of experimental treatments on 4-year pre-weaning study with beef calves

<table>
<thead>
<tr>
<th>Year</th>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963-64</td>
<td>No. animals</td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DES implant</td>
<td>12 mg</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-weaning treatment</td>
<td>No creep</td>
<td>Free-choice creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1964-65</td>
<td>No. animals</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DES implant</td>
<td>12 mg, 24 mg</td>
<td>12 mg, 24 mg</td>
<td>12 mg, 24 mg</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-weaning treatment</td>
<td>No creep</td>
<td>Limited creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1965-66</td>
<td>No. animals</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DES implant</td>
<td>12 mg, None</td>
<td>12 mg, 48 mg</td>
<td>12 mg, None</td>
<td>12 mg, 48 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-weaning treatment</td>
<td>No creep</td>
<td>Limited creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1966-67</td>
<td>No. animals</td>
<td>4</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Sex</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>DES implant</td>
<td>None, 12 mg</td>
<td>None, 48 mg</td>
<td>None, 12 mg</td>
<td>None, 48 mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pre-weaning treatment</td>
<td>Limited creep</td>
<td>Free-choice creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The two methods of creep feeding employed in this study were (1) free-choice creep and (2) limited-creep. The calves that were assigned to the free-choice creep treatments were allowed to consume as much creep feed as they desired; the creep feeder in the pasture was never allowed to get empty. The calves that were assigned to the limited-creep treatments were hand-fed the creep ration once daily in an enclosed creep feeder. They were never fed more than 2 lb. of creep ration per head per day, and the creep feed was added to the feeder every morning by 7:30 a.m.

All treatment groups were provided summer pasture consisting of bromegrass, orchardgrass, bluegrass and either alfalfa or birdsfoot trefoil. The stocking rate was 1 acre per cow and calf unit. During the summer season of 1965 and 1966 rainfall was short so the cattle from various pastures were rotated every 2 weeks on sudangrass pasture to help supplement the original pasture.

Cow and calf weights were taken at 28-day intervals throughout the trials. Initial and final weights each represent an average of two consecutive days' weights. The calves were weaned at approximately 7 months of age. After a 2 week adjustment period they were assigned to the post-weaning phase of the study to further test the effects of DES (fed orally and implanted) and creep feeding on the feedlot performance and carcass characteristics of male cattle.

Post-weaning and Carcass Evaluation Phase

Experiment I

Twenty-two calves from the no-creep pre-weaning treatment group were
assigned to lots 1 thru 4 and 21 calves from the free-choice creep pre-
weaning treatment were assigned to lots 5 thru 8 (table 2). The calves
were brought to full feed as rapidly as possible. Daily ration per animal
consisted of 1 lb. of 42% soybean meal protein supplement, 5 lb. of corn
silage, 2 lb. of alfalfa hay and a full feed of cracked corn. The cracked
corn was used to increase the nutrient level as the feeding period pro-
gressed while the other components remained constant throughout the feed-
ing period.

Weights were taken at 28-day intervals throughout the trial. Initial
and final weights each represent the average of two consecutive days' weights. The animals were slaughtered as they reached a weight of approxi-
ately 1050 lb.

Data obtained at the packing plant Animals were individually
weighed at the packing plant and each carcass was tagged for identifica-
tion before the hide was removed. The testicles from the bulls were col-
lected, identified, trimmed and weighed to the nearest ounce on a scale
at the packing plant. Individual hot carcass weights were recorded after
the carcasses were split but before they were washed and shrouded. Chilled
carcass weights were taken 24 to 36 hours following slaughter. Personnel
from the Iowa State University Meats Laboratory collected the following
carcass information: weight of the rear quarters of the carcass, weight
of the kidney knob and suet fat, U.S.D.A. carcass grade, Iowa State Uni-
versity carcass grade and maturity, marbling and conformation scores. The
fat thickness over the l. dorsi muscle between the 12th and 13th rib was
measured at a point three-fourths the longitudinal distance of the l. dorsi
### Table 2. Post-weaning experimental design

<table>
<thead>
<tr>
<th>Lot number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>No. animals</strong></td>
<td>5</td>
<td>6</td>
<td>6</td>
<td>5</td>
<td>6</td>
<td>5</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td><strong>1963-64</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td>Steers</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DES oral</strong></td>
<td>10 mg.</td>
<td>10 mg.</td>
<td>10 mg.</td>
<td>None</td>
<td>10 mg.</td>
<td>None</td>
<td>10 mg.</td>
<td>None</td>
</tr>
<tr>
<td><strong>DES implant</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1964-65</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. animals</strong></td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td>Steers</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DES oral</strong></td>
<td>10 mg.</td>
<td>20 mg.</td>
<td>20 mg.</td>
<td>None</td>
<td>20 mg.</td>
<td>None</td>
<td>20 mg.</td>
<td>None</td>
</tr>
<tr>
<td><strong>DES implant</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>1965-66</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>No. animals</strong></td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td><strong>Sex</strong></td>
<td>Steers</td>
<td>Bulls</td>
<td>Steers</td>
<td>Bulls</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>DES oral</strong></td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td><strong>DES implant</strong></td>
<td>12 mg.</td>
<td>12 mg.</td>
<td>48 mg.</td>
<td>12 mg.</td>
<td>None</td>
<td>12 mg.</td>
<td>48 mg.</td>
<td></td>
</tr>
</tbody>
</table>
from the medial end. A tracing of the cross section of the \textit{1. dorsi} muscle was taken on acetate paper at the same location. The \textit{1. dorsi} tracing was measured with a compensating polar planimeter and fat thickness was measured on the tracing corresponding to the location of the measurement taken on the carcass. The wholesale round and rib section (6 to 12) from the left side of each carcass were returned to the Iowa State University Meats Laboratory for detailed cutting and analyses.

\textbf{Data obtained at the Iowa State University Meat Laboratory} Each wholesale round was weighed, trimmed to approximately 3/8 in. of external fat, and weighed again without the fat trim. The round was then divided into two parts by cutting perpendicular to the outside surface of the round and at right angles to the longitudinal axis of the \textit{semitendinosus} muscle. This cut severed the femur and exposed the cross sectional area of the \textit{semitendinosus}. A steak 1 \textfrac{1}{4} in. thick was cut from the exposed cross-sectional area, and 7 days post-slaughter the steak was cooked in a Hotpoint deep fat fryer to an internal temperature of 60°C. After cooking and prior to shearing, the steak was allowed to cool and remain at room temperature for 24 hours. Three 1 in. cores (following a circular pattern) were cut as nearly parallel with the fibers as possible using a metal cylinder attachment in a mounted electric drill. Two Warner-Bratzler shear force readings were obtained for each core giving a total of six per steak. The average of these six values was used in the statistical treatment of the data.

The \textit{1. dorsi} muscle was removed from the wholesale rib and three 1 \textfrac{1}{4} in. steaks were cut from the caudal portion of the muscle and used in the following manner. The steaks were identified and stored in plastic bags at
3°C. for approximately 7 days post-slaughter. Steak number one was cooked in a Hotpoint deep fat fryer to an internal temperature of 60°C. After cooking and prior to shearing, the steak was allowed to cool and remain at room temperature for 24 hours. Three 1 in. cores (medial, center, lateral) were taken for shear force readings using the same conditions and procedure as for the wholesale round. Steaks number two and three were evaluated for flavor, juiciness, initial tenderness and residual tenderness by a trained taste panel consisting of six members. Two l. dorsi steaks were freed of any remaining intermuscular fat and a thermometer was inserted into each steak so that the bulb was in the geometric center of the steak. Two General Electric ovens were set on broil and preheated approximately 20 minutes with doors open in broiling position. When the internal temperature of the steaks was 30°C. the steaks were turned and broiled to an internal temperature of 60°C., at which time they were removed from the oven. The cooked steaks were trimmed at least ½ in. around the edges, and beginning at the medial end, ½ in. slices were cut using a mitre box. The slices were numbered consecutively and served to the taste panel judges in the following manner: on test day 1, judge 1 received slice number 1; on test day 2, judge 1 received slice number 2; etc. until each judge had received samples from every anatomical position. Then the pattern was repeated. On any day, a judge received the corresponding anatomically positioned sample from all the animals tested. Flavor, juiciness, initial and residual tenderness were scored on a 10 point hedonic scale (table 3) with 10 being the highest rating. The sensory values used in the statistical data are an average of the six taste panel
Table 3. Adjectives used in scoring beef

<table>
<thead>
<tr>
<th>Score</th>
<th>Initial tenderness</th>
<th>Friability of muscle fibers</th>
<th>Tenderness of residue of connective tissue</th>
<th>Flavor intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>Extremely juicy</td>
<td>Extremely friable</td>
<td>No tissue left</td>
<td>Very full, rich</td>
</tr>
<tr>
<td>9</td>
<td>Very juicy</td>
<td>Very friable</td>
<td>Tiny amount of tissue</td>
<td>Full, rich</td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Juicy</td>
<td>Soft</td>
<td>Small amount of fairly soft</td>
<td>Full</td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Neither juicy nor</td>
<td>Neither friable</td>
<td>Small amount of firm</td>
<td>Moderately full</td>
</tr>
<tr>
<td></td>
<td>dry nor hard nor</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>soft</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Dry</td>
<td>Hard</td>
<td>Medium amount of firm</td>
<td>Slightly weak</td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Very dry</td>
<td>Very slightly friable</td>
<td>Large amount of hard</td>
<td>Weak</td>
</tr>
<tr>
<td>0</td>
<td>Too dry to swallow</td>
<td>Too hard to chew</td>
<td>Not friable</td>
<td>Residue very hard</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
judges scores for each of the organoleptic components. The score card used to score and record the judges findings is shown in table 4.

The following three prediction equations were used to estimate carcass yields:

1. Iowa State University Method (Henderson et al., 1966): percent boneless lean as a percent of the carcass = 52.340 - 61.24 (single fat thickness measurement over 1. dorsi at 12th rib, in./cwt. cold carcass) + 6.556 (1. dorsi area at 12th rib, sq. in./cwt. cold carcass).

2. Iowa State University Method (Henderson et al., 1966): percent retail yield as a percent of the carcass = 64.832 - 63.999 (single fat thickness measurement over 1. dorsi at 12th rib, in./cwt. cold carcass) + 5.134 (1. dorsi area at 12th rib, sq. in./cwt. cold carcass).

3. Wisconsin Method (Brungardt and Bray, 1963): percent retail yield = 16.64 + 1.67 (percent trimmed round) - 4.94 (single fat thickness measurement over 1. dorsi at 12th rib, in.).

**Experiments II and III**

The post-weaning experimental design for Experiments II and III is presented in table 2. The procedures for Experiments II and III were similar to Experiment I, with the following exceptions.

1. The animals in Experiments II and III were slaughtered as they reached an age of approximately 14 months versus a constant weight in Experiment I.

2. In Experiment III the animals were all fed in one lot so feed
Table 4. Score card for beef

<table>
<thead>
<tr>
<th>Sample Number</th>
<th>Flavor Intensity</th>
<th>Juiciness</th>
<th>Initial Tenderness</th>
<th>Residual Tenderness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Rate each characteristic from 0 (lowest) to 10 (highest). See descriptive adjectives posted in the booth.

Comments:
consumption and efficiency data were not available.

3. Chilled carcass weights were determined by shrinking the bull and steer hot carcass weights 2.45% and 2.30%, respectively, whereas, actual weights were obtained for chilled carcasses in Experiment I.

4. Weight of the rear quarters and kidney knob and suet fat were not obtained for the carcasses evaluated from Experiments II and III.

5. Only the left wholesale rib was returned to the Iowa State University Meats Laboratory for detailed cutting and analysis.

6. The prediction equation involving the use of the trimmed round weight variable (Brungardt and Brey, 1963) was omitted from Experiments II and III.

7. Steaks number one in Experiments II and III were allowed to cool 5 minutes prior to shearing compared to 24 hours in Experiment I; steak number four in Experiment II was allowed to cool 24 hours.

**Experiment IV**

This experiment has been completed for the pre-weaning phase only and the post-weaning and carcass evaluation phase will not be complete in time to be included in this dissertation.

**Effects of Age and Sex on Muscle Tenderness**

**Experiment V**
Twenty male Hereford calves born within a 30-day period and of similar genetic background were purchased from a South Dakota ranch. One-half of the calves were randomly selected for castration at 3½ months of age. The calves were paired for size and age with one bull and one steer composing each pair. They were purchased when the average age for the group was 6 months. Two bulls and two steers were slaughtered at 6, 9, 12, 15 and 18 months of age. After the first group (6 months old) was slaughtered the remaining cattle were fed the same daily fattening ration and the same method of feeding was employed as reported for Experiment I.

Weights were taken at 28-day intervals throughout the trial. Initial and final weights each represent an average of two consecutive days' weights taken at the beginning and end of the feeding period for each respective slaughter group.

Data obtained at the Iowa State University Meats Laboratory All animals were slaughtered and individually weighed at the Iowa State University Meats Laboratory. Individual hot carcass weights were recorded after the carcasses were split, washed and shrouded. The carcasses were ribbed after a 48-hour chill and the right and left wholesale rib sections (6 to 12) were removed from each carcass. A tracing of the cross section of the l. dorsi muscle was taken on acetate paper between the 12th and 13th rib. The l. dorsi tracing was measured with a compensating polar planimeter and fat thickness was measured over the l. dorsi between the 12th and 13th rib at a point three-fourths the longitudinal distance of the l. dorsi from the medial end.

The l. dorsi muscle was removed from the right wholesale rib and
four one and one-fourth inch steaks were cut from the caudal portion of the muscle and used in the following manner. The steaks were identified and stored in plastic bags at 3°C. for approximately 7 days post-slaughter. Steak number 1 was cooked in a Hotpoint deep fat fryer to an internal temperature of 60°C. The steak was allowed to cool 5 minutes after cooking and Warner-Bratzler shear values were determined and evaluated in the same manner as in Experiments II and III. Steaks number 2 and 3 (four if needed) were evaluated for flavor, juiciness, initial tenderness and residual tenderness by the same six judges that served on the taste panel during Experiments I, II and III. The sensory values used in the treatment of the statistical data are an average of the six taste panel judges scores for each of the organoleptic components.

Isolation and analysis of connective tissue residues The l. dorsi muscle was removed from the left wholesale rib, identified and stored in saran wrap at 3°C. for approximately 7 days post-slaughter. The intermuscular fat and epimesium (connective tissue) were trimmed from the l. dorsi muscle and the entire muscle (rib section 6 to 12) was minced in a Hobart silent cutter (model 8141) for 5 minutes. A 250 gm. sample of the minced l. dorsi muscle was weighed into a 4 l. polyethylene beaker. The remainder of the minced l. dorsi muscle was put into a plastic bag, identified, frozen and stored.

Extraction of the muscle protein from the 250 gram sample of minced l. dorsi was according to Helander's Method (1957) as modified by Goll et al. (1963). The extraction was performed in the cold room at 4°C. with precooled 1.1M KI buffered at pH 7.4 with 0.1M potassium phosphate
(0.09M K₂HPO₄ and 0.01M KH₂PO₄). Solvent to tissue ratios of 10:1 (v/w) were used. The tissue was extracted three times with continuous stirring, the first two times for 3 hours each, and a final extraction of 2 hours. After each extraction the KI solution was strained through cheesecloth. After the third extraction, the tissue residue was placed in 10 volumes of distilled water two times for 2 to 3 hours each time at 4°C. The water was strained through cheesecloth after each washing, and 10 volumes of acetone were added to the residue after the last water washing and stirred for 12 hours. The acetone was also removed through cheesecloth and 10 volumes of 3:1 chloroform-methanol solution added to this residue. The chloroform-methanol extraction continued for 4 hours at 4°C. After being filtered through cheesecloth, the residue was treated with acetone three times, the first two times for 2 hours each and the third time for 12 hours at 4°C. The acetone was strained through cheesecloth after each treatment. After the last acetone extraction, the residue was washed thoroughly with distilled water three times for 2 to 3 hours each time. The water was strained through cheesecloth after each washing and following the final washing the sample was lyophilized. Lyophilization required 24 to 36 hours for completion. Then the lyophilized samples were finely ground in a small precooled Wiley mill in a 0°C cold room. The samples were stored in wide mouth glass jars at -21°C. Samples were taken of the powdered residue for dry matter, micro-Kjeldahl nitrogen and hydroxyproline determinations.

Hydroxyproline analyses on the collagenous residues isolated from the minced L. dorsi were performed according to the procedure outlined by
Woessner (1961) and modified by Goll et al. (1963). Samples of 30 mg. were hydrolyzed for 10 hours with 6N HCl at 15 lb. pressure (122 to 126°C). No humin formation was observed in the flasks because of the lack of tryptophan in the residues. Therefore, the acid hydrolysates were neutralized with NaOH to the phenolphthalein end point and made up to 1 l. An aliquot was taken and stored in a 125 ml. Erlenmeyer flask. A 2 ml. sample was transferred to a 16 x 150 mm. test tube. Using an automatic pipette, 0.5 ml. of pH 6.0 buffer was added separately to all samples followed by the addition of 0.5 ml. of 3.00% chloramine T solution in 2-methoxyethanol (oxidant). The samples were allowed to stand for 20 minutes. Then 1 ml. of 1.49N perchloric acid was added and the samples were allowed to stand 5 minutes. One ml. of p-dimethylaminobenz-aldehyde (PDBA) (color reagent) was added and the samples placed in a water bath for 20 minutes at 60°C. The samples were cooled in tap water and allowed to stand at room temperature for 1 hour. Optical density was read at 5570Å in a Beckman spectrophotometer. The hydroxyproline values were determined directly from the standard curve. The hydroxyproline content of the collagenous residues was converted to collagen by using a factor of 7.25.

Statistical Analysis

The least-squares analysis for unequal subclass numbers, as described by Harvey (1960), was used in the analysis of these data. Subclass means were used for the analysis of the data from all experiments. The "t" test was used to test for differences between treatment levels within a class (treatment). Standard correlation coefficients were calculated for the
right hand sides of the least-squares model according to the procedures outlined by Snedecor (1956).
EXPERIMENTAL RESULTS AND DISCUSSION

Pre-weaning Phase

The over-all arithmetic mean and standard deviation of average daily gain and weaning weight for the four experiments are presented in table 5. The standard deviations for both average daily gain and weaning weight were comparatively large indicating a considerable degree of variation in the data collected.

Least-squares means for average daily gain by sex, DES implant levels, creep, and years for Experiments I, II, III and IV are presented in table 6. There was no significant difference between the average daily gain of bulls and steers during the pre-weaning treatment period. There was a non-significant response to the various DES implant levels that were tested; however, the 48 mg. implant level gave a consistent positive response in the bull calves. Creep-fed calves (limited-fed and free-choice-fed) grew more (\( P < .005 \)) rapidly during the pre-weaning phase of the experiments than calves that were not creep-fed. A significant (\( P < .01 \)) response was found between years, which would indicate that the different years were an important source of variation in the over-all study. Interactions involving the various factors studied were nonsignificant. A highly significant (\( P < .01 \)) correlation coefficient of 0.90 was found between average daily gain and weaning weight of male calves over the 4-year period.

A summary for the 4-year test period of creep vs. no-creep for male beef calves is presented in table 7. The highly significant (\( P < .005 \)) weight gains of the creep-fed calves ranged from a 38 to 112 lb. advantage
Table 5. Over-all arithmetic mean and standard deviation of average daily gain and weaning weight for the four experiments

<table>
<thead>
<tr>
<th></th>
<th>Arithmetic mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average daily gain</td>
<td>1.73</td>
<td>0.27</td>
</tr>
<tr>
<td>Weaning weight</td>
<td>424</td>
<td>45</td>
</tr>
</tbody>
</table>
Table 6. Least-squares means by sex, DES implant, creep and year for average daily gain (Experiments I, II, III, and IV)

<table>
<thead>
<tr>
<th>Item</th>
<th>Av. daily gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>1.74</td>
</tr>
</tbody>
</table>

Sex:

<table>
<thead>
<tr>
<th>Sex</th>
<th>Av. daily gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steers</td>
<td>1.73</td>
</tr>
<tr>
<td>Bulls</td>
<td>1.74</td>
</tr>
</tbody>
</table>

DES Implant:

<table>
<thead>
<tr>
<th>DES Implant</th>
<th>Av. daily gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>1.69</td>
</tr>
<tr>
<td>12 &amp; 24 mg.</td>
<td>1.70</td>
</tr>
<tr>
<td>48 mg.</td>
<td>1.82</td>
</tr>
</tbody>
</table>

Creep:

<table>
<thead>
<tr>
<th>Creep</th>
<th>Av. daily gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>No creep</td>
<td>1.56</td>
</tr>
<tr>
<td>Creep</td>
<td>1.91</td>
</tr>
</tbody>
</table>

Year:

<table>
<thead>
<tr>
<th>Year</th>
<th>Av. daily gain</th>
</tr>
</thead>
<tbody>
<tr>
<td>1963-64</td>
<td>1.94</td>
</tr>
<tr>
<td>1964-65</td>
<td>1.80</td>
</tr>
<tr>
<td>1965-66</td>
<td>1.68</td>
</tr>
<tr>
<td>1966-67</td>
<td>1.52</td>
</tr>
</tbody>
</table>

* * * Means bearing the same superscript within a subgroup are not significantly different at the P < .05 level. The subgroups were tested for the following levels of significance: sex and DES implant (P < .05), creep (P < .005) and year (P < .01).
Table 7. A 4-year summary for creep feeding male calves

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Year</th>
<th>Steers</th>
<th>Sex</th>
<th>Bulls</th>
<th>Total</th>
<th>Days on creep</th>
<th>Weaning wt.</th>
<th>Creep cost/calf</th>
</tr>
</thead>
<tbody>
<tr>
<td>No creep</td>
<td>1963</td>
<td>47</td>
<td>11</td>
<td>58</td>
<td>None</td>
<td>None</td>
<td>377</td>
<td>None</td>
</tr>
<tr>
<td>Free-choice creep</td>
<td>1963</td>
<td>--</td>
<td>22</td>
<td>22</td>
<td>119</td>
<td>489</td>
<td>$7.63</td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>1964</td>
<td>45</td>
<td>12</td>
<td>57</td>
<td>None</td>
<td>397</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Limited creep</td>
<td>1964</td>
<td>--</td>
<td>24</td>
<td>24</td>
<td>134</td>
<td>461</td>
<td>$2.31</td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>1965</td>
<td>44</td>
<td>15</td>
<td>59</td>
<td>None</td>
<td>393</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Limited creep</td>
<td>1965</td>
<td>5</td>
<td>15</td>
<td>20</td>
<td>129</td>
<td>459</td>
<td>$3.13</td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>1966</td>
<td>36</td>
<td>--</td>
<td>36</td>
<td>None</td>
<td>364</td>
<td>None</td>
<td></td>
</tr>
<tr>
<td>Limited creep</td>
<td>1966</td>
<td>9</td>
<td>10</td>
<td>19</td>
<td>126</td>
<td>430</td>
<td>$3.42</td>
<td></td>
</tr>
<tr>
<td>Free-choice creep</td>
<td>1966</td>
<td>10</td>
<td>10</td>
<td>20</td>
<td>126</td>
<td>402</td>
<td>$5.59</td>
<td></td>
</tr>
</tbody>
</table>

*The creep-fed calves were significantly heavier (P < .005) each year at weaning than the non-creep-fed calves.*
for creep feeding periods of 119 to 134 days in length. A comparison of creep feeding methods and the monetary advantage due to creep feeding are presented in table 8. Total creep feed costs per calf ranged from $7.63 (free-choice creep) in 1963 to $2.31 (limited-creep) in 1964. Calves fed creep free-choice consumed more total pounds of creep feed than limited-creep-fed calves. On the average, the limited-creep-fed calves showed a 65 lb. advantage due to creep feed, and the free-choice creep-fed calves showed a 75 lb. advantage; however, the free-choice calves required about twice the amount of creep feed. Creep-fed calves showed a positive monetary advantage over non-creep-fed calves each year the study was conducted. When the additional gain due to creep feed was valued at 25 cents per pound, the creep-fed calves showed an advantage of $3.91 to $20.37 per calf. The data indicated that limited-creep feeding was the most effective method in promoting increased weight gains of suckling male beef calves.

The calves from each experiment were weaned at approximately 7 months of age, given a 2 week adjustment period, and then assigned to various treatments for the post-weaning feedlot and carcass studies. Table 9 shows the average weight change of creep-fed and non-creep-fed calves during the 2 week stress period, as well as some performance and carcass traits for the respective treatment groups. Creep-fed calves gained from 6 to 12 lb. during the 2-week stress period compared with essentially no gain for the non-creep-fed calves.

Least-squares means by sex, DES implant level, creep, and year for the total gain during the 2 week adjustment period, days in the feedlot,
Table 8. A comparison of creep feeding methods

<table>
<thead>
<tr>
<th></th>
<th>1963</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Free-choice</td>
<td>Limited</td>
<td>Limited</td>
<td>Free-choice</td>
<td>Limited</td>
</tr>
<tr>
<td>No. of head</td>
<td>22</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td>19</td>
</tr>
<tr>
<td>Av. daily gain</td>
<td>2.22</td>
<td>1.97</td>
<td>1.77</td>
<td>1.64</td>
<td>1.70</td>
</tr>
<tr>
<td>Days on creep</td>
<td>119</td>
<td>134</td>
<td>129</td>
<td>126</td>
<td>126</td>
</tr>
<tr>
<td>Creep feed consumed/calf, lb.</td>
<td>398</td>
<td>125</td>
<td>169</td>
<td>310</td>
<td>187</td>
</tr>
<tr>
<td>Creep feed consumed/calf/day, lb.</td>
<td>3.35</td>
<td>.93</td>
<td>1.31</td>
<td>2.46</td>
<td>1.48</td>
</tr>
<tr>
<td>Cost of creep/calf</td>
<td>$7.63</td>
<td>$2.31</td>
<td>$3.13</td>
<td>$5.59</td>
<td>$3.42</td>
</tr>
<tr>
<td>Cost of creep/day/calf</td>
<td>6.4¢</td>
<td>1.7¢</td>
<td>2.4¢</td>
<td>4.4¢</td>
<td>2.7¢</td>
</tr>
<tr>
<td>Weaning wt. advantage&lt;sup&gt;a&lt;/sup&gt; from creep feeding, lb.</td>
<td>112</td>
<td>64</td>
<td>66</td>
<td>38</td>
<td>66</td>
</tr>
<tr>
<td>Value of extra gain @ 25 cents/lb.</td>
<td>$28.00</td>
<td>$16.00</td>
<td>$16.50</td>
<td>$9.50</td>
<td>$16.50</td>
</tr>
<tr>
<td>Added value/calf with creep feeding</td>
<td>$20.37</td>
<td>$13.69</td>
<td>$13.37</td>
<td>$3.91</td>
<td>$13.08</td>
</tr>
</tbody>
</table>

<sup>a</sup>Weaning weight advantage from creep feeding was significantly (P < .005) higher for each of the four years.
Table 9. The ability of creep-fed calves to withstand weaning stress and maintain their weight gain advantage in the feedlot

<table>
<thead>
<tr>
<th>Sex</th>
<th>1963</th>
<th>1964</th>
<th>Non-creep</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>B</td>
<td>S</td>
<td>B</td>
<td>S</td>
</tr>
<tr>
<td>Weaning wt.</td>
<td>389 407</td>
<td>398 401</td>
<td>353 377</td>
<td>428 410</td>
<td>415</td>
</tr>
<tr>
<td>On test wt. (2 weeks later)</td>
<td>385 401</td>
<td>393 399</td>
<td>355 377</td>
<td>432 410</td>
<td>416</td>
</tr>
<tr>
<td>Days in feedlot</td>
<td>281 250</td>
<td>265 224</td>
<td>222 223</td>
<td>217 214</td>
<td>215</td>
</tr>
<tr>
<td>Av. daily gain in feedlot</td>
<td>2.36 2.63 2.50 2.18 2.48 2.33 2.40 2.38 2.38</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lb. feed/ 100 lb. gain</td>
<td>825 738 782 855 732 790</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lb. carcass/ day of age</td>
<td>1.29 1.40 1.34 1.19 1.24 1.22 1.27 1.22 1.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Creep-fed

<table>
<thead>
<tr>
<th></th>
<th>1963</th>
<th>1964</th>
<th>Non-creep</th>
<th>1965</th>
<th>1966</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>S</td>
<td>B</td>
<td>S</td>
<td>B</td>
<td>S</td>
</tr>
<tr>
<td>Weaning wt.</td>
<td>- 489 489</td>
<td>- 461 461 474 453 459 403 428 416</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>On test wt. (2 weeks later)</td>
<td>- 501 501</td>
<td>- 475 475 485 463 468 412 435 424</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Days in feedlot</td>
<td>214 214</td>
<td>211 211 206 205 205</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Av. daily gain in feedlot</td>
<td>2.66 2.66 2.37 2.37 2.27 2.40 2.37</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lb. feed/ 100 lb. gain</td>
<td>720 720 784 784</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lb. carcass/ day of age</td>
<td>1.50 1.50 1.37 1.37 1.26 1.32 1.30</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)S = Steers  \(B=\) Bulls
average daily gain in the feedlot, pounds of feed per pound of gain, and pounds of chilled carcass per day of age are presented in table 10. The creep-fed calves gained significantly faster ($P < .005$) than non-creep-fed calves during the 2 week adjustment period. When the male cattle were slaughtered at a constant weight (Experiment I, 1963), the creep-fed animals required fewer days in the feedlot. The trend existed throughout Experiments II and III even though the animals were slaughtered at a constant age of approximately 14 months. There was no significant difference between creep-fed and non-creep-fed cattle for average daily gain in the feedlot. Bulls grew more rapidly in the feedlot than steers ($P < .07$). Year differences were an important source of variation in average daily gain in the feedlot ($P < .01$), in pounds of feed required per 100 lb. of gain ($P < .05$) and pounds of carcass per day of age ($P < .001$). Bulls required significantly ($< .005$) less feed per 100 lb. of gain than steers. Creep-fed animals produced more ($P < .05$) pounds of chilled carcass per day of age than animals that did not receive creep feed during the suckling period. Cattle that received a 48 mg. DES implant during the suckling period produced significantly ($P < .05$) more pounds of chilled carcass per day of age. The 48 mg. DES implant level was used just in Experiment III and was implanted only in intact male (bull) calves.

The data presented in table 11 represent the effects of creep feeding the calf on the weight change of the cow. There were no significant differences between the weight of dams of creep-fed calves and dams of non-creep-fed calves during the suckling period. The 4 year average of
Table 10. Least-squares means by sex, DES implant, creep and year for factors related to the effects of the pre-weaning treatments

<table>
<thead>
<tr>
<th>Item:</th>
<th>Total gain for 2-week adjustment period</th>
<th>Days in feedlot</th>
<th>Average daily gain in feedlot</th>
<th>Lb. feed/lb. gain</th>
<th>Lb. carcass/day of age</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>7.02</td>
<td>222</td>
<td>2.39</td>
<td>7.97</td>
<td>1.33</td>
</tr>
<tr>
<td>Sex:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steers</td>
<td>9.08&lt;sup&gt;a&lt;/sup&gt;</td>
<td>229&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.30&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.50&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.30&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bulls</td>
<td>4.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>216&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.35&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>DES implant:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>7.94&lt;sup&gt;a&lt;/sup&gt;</td>
<td>229&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.28&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.26&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>12 &amp; 24 mg.</td>
<td>3.56&lt;sup&gt;a&lt;/sup&gt;</td>
<td>224&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.40&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.31&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>48 mg.</td>
<td>9.56&lt;sup&gt;a&lt;/sup&gt;</td>
<td>213&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-----</td>
<td>1.41&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creep:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>0.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>235&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.36&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.27&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creep</td>
<td>13.77&lt;sup&gt;c&lt;/sup&gt;</td>
<td>209&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.42&lt;sup&gt;a&lt;/sup&gt;</td>
<td>8.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.38&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Year:</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963-64</td>
<td>7.77&lt;sup&gt;a&lt;/sup&gt;</td>
<td>237&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.54&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.43&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1964-65</td>
<td>10.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>217&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.30&lt;sup&gt;c&lt;/sup&gt;</td>
<td>8.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>1.30&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1965-66</td>
<td>7.27&lt;sup&gt;a&lt;/sup&gt;</td>
<td>212&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.33&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-----</td>
<td>1.26&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1966-67</td>
<td>3.02&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
</tbody>
</table>

<sup>a</sup>Means bearing the same superscript within a subgroup are not significantly different at the P < .05 level.

<sup>b</sup>Means bearing this superscript are significant at the P < .05 level.

<sup>c</sup>Means bearing this superscript are significant at the P < .01 level.
Table 11. Effect of creep feeding the calf upon the weight change of the cow

<table>
<thead>
<tr>
<th>Year</th>
<th>1963</th>
<th>1964</th>
<th>1965</th>
<th>1966</th>
<th>4-year av.</th>
</tr>
</thead>
<tbody>
<tr>
<td>No creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. cows</td>
<td>58</td>
<td>56</td>
<td>59</td>
<td>36</td>
<td>209</td>
</tr>
<tr>
<td>Starting wt.lb.</td>
<td>970</td>
<td>955</td>
<td>937</td>
<td>1041</td>
<td>969</td>
</tr>
<tr>
<td>Final wt.lb.</td>
<td>996</td>
<td>1015</td>
<td>994</td>
<td>1021</td>
<td>1005</td>
</tr>
<tr>
<td>Wt. change lb.</td>
<td>26+</td>
<td>60+</td>
<td>57+</td>
<td>20-</td>
<td>36+</td>
</tr>
<tr>
<td>Free-choice creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. cows</td>
<td>22</td>
<td>24</td>
<td>20</td>
<td>20</td>
<td>42</td>
</tr>
<tr>
<td>Starting wt.lb.</td>
<td>969</td>
<td>954</td>
<td>1001</td>
<td>1012</td>
<td>989</td>
</tr>
<tr>
<td>Final wt.lb.</td>
<td>1032</td>
<td>1084</td>
<td>1029</td>
<td>991</td>
<td>1012</td>
</tr>
<tr>
<td>Wt. change lb.</td>
<td>63+</td>
<td>130+</td>
<td>28+</td>
<td>23-</td>
<td>23+</td>
</tr>
<tr>
<td>Limited-creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. cows</td>
<td></td>
<td>24</td>
<td>20</td>
<td>19</td>
<td>63</td>
</tr>
<tr>
<td>Starting wt.lb.</td>
<td></td>
<td>954</td>
<td>1001</td>
<td>1060</td>
<td>1001</td>
</tr>
<tr>
<td>Final wt.lb.</td>
<td></td>
<td>1084</td>
<td>1029</td>
<td>1050</td>
<td>1056</td>
</tr>
<tr>
<td>Wt. change lb.</td>
<td></td>
<td>130+</td>
<td>28+</td>
<td>10-</td>
<td>55+</td>
</tr>
</tbody>
</table>

4-year No. av. creep cows = 209

Creep cows = 105
314 cows showed that dams of creep-fed calves were 7 lb. heavier, but there was considerable variation from year to year.

Calves used in all the experiments were from the same herd and were handled in a similar manner throughout the post-weaning and carcass evaluation phase; therefore, data on the post-weaning performance, carcass evaluation and tenderness measures were combined.

Post-weaning Phase

The purpose of the post-weaning experiments was to determine the effects of sex, age and levels of DES on the feedlot performance, carcass characteristics and muscle tenderness of young bulls and steers under intensive rearing conditions. In Experiment I, the cattle were slaughtered at a constant weight of approximately 1050 lb., and in Experiments II and III, the animals were slaughtered at a constant age of approximately 14 months. During Experiments I and II, the cattle were fed in individual lots according to their respective treatments. The animals in Experiment III were all fed in one large lot; hence, feed cost and efficiency data are available for only the first two trials.

Least-squares means according to sex, DES levels, pre-weaning creep treatment and year are given for post-weaning feedlot performance factors in table 12. There was no difference in animal response to 10 or 20 mg. of DES fed orally in Experiments I and II or the 12 mg. implant used in Experiment III; hence, lots receiving the above levels will be referred to as the low level DES treatments. Bulls grew more rapidly (P < .07) than steers during the feedlot period and required less (P < .005) feed per unit of gain, which resulted in a lower (P < .005) feed cost per pound.
Table 12. Least-squares means by sex, DES, creep and year for various post-weaning performance traits of young male cattle

<table>
<thead>
<tr>
<th>Item</th>
<th>AGE</th>
<th>DIFL</th>
<th>GN/DFL</th>
<th>GN/DA</th>
<th>LWTB</th>
<th>RA</th>
<th>FDPPG</th>
<th>FCPPG</th>
<th>TFCPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>440</td>
<td>222</td>
<td>2.39</td>
<td>2.23</td>
<td>21.79</td>
<td>211</td>
<td>7.97</td>
<td>13.2</td>
<td>31.9</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steers</td>
<td>448&lt;sup&gt;b&lt;/sup&gt;</td>
<td>228&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.19&lt;sup&gt;b&lt;/sup&gt;</td>
<td>24.13&lt;sup&gt;b&lt;/sup&gt;</td>
<td>232&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.50&lt;sup&gt;b&lt;/sup&gt;</td>
<td>14.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.1&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Bulls</td>
<td>431&lt;sup&gt;b&lt;/sup&gt;</td>
<td>216&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.48&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.27&lt;sup&gt;b&lt;/sup&gt;</td>
<td>19.45&lt;sup&gt;c&lt;/sup&gt;</td>
<td>190&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.44&lt;sup&gt;c&lt;/sup&gt;</td>
<td>12.3&lt;sup&gt;c&lt;/sup&gt;</td>
<td>31.7&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>DES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>444&lt;sup&gt;b&lt;/sup&gt;</td>
<td>229&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.28&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>213&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>12&amp;24 mg.</td>
<td>439&lt;sup&gt;b&lt;/sup&gt;</td>
<td>224&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.40&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.22&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>209&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.2&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>48 mg.</td>
<td>436&lt;sup&gt;b&lt;/sup&gt;</td>
<td>213&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.49&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.33&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>a</sup>AGE= Days of age at slaughter; DIFL= Days in the feedlot; GN/DFL= Average daily gain per day in the feedlot; GN/DA= Average daily gain per day of age; LWTB= Live-weight bid per cwt.; RA= Total returns on live-weight basis; FDPPG= Pounds of feed per pound of gain; FCPPG = Feed cost per pound of gain; TFCPD= Total feed costs per day in the feedlot.

<sup>b</sup>Means bearing the same superscript within a subgroup are not significantly different at the P< .05 level.

<sup>c</sup>Means bearing this superscript are significant at the P< .01 level.
Table 12. (Continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>AGE</th>
<th>DIFL</th>
<th>GN/DFL</th>
<th>GN/DA</th>
<th>LWTE</th>
<th>RA</th>
<th>FDPPG</th>
<th>FCPPG</th>
<th>TFCPD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>448&lt;sup&gt;b&lt;/sup&gt;</td>
<td>235&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.36&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.14&lt;sup&gt;b&lt;/sup&gt;</td>
<td>22.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>210&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.92&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.3&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creep</td>
<td>431&lt;sup&gt;b&lt;/sup&gt;</td>
<td>209&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.42&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.32&lt;sup&gt;b&lt;/sup&gt;</td>
<td>21.55&lt;sup&gt;b&lt;/sup&gt;</td>
<td>212&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>31.5&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963-64</td>
<td>452&lt;sup&gt;b&lt;/sup&gt;</td>
<td>237&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.54&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.35&lt;sup&gt;b&lt;/sup&gt;</td>
<td>20.82&lt;sup&gt;b&lt;/sup&gt;</td>
<td>216&lt;sup&gt;b&lt;/sup&gt;</td>
<td>7.76&lt;sup&gt;b&lt;/sup&gt;</td>
<td>13.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.9&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1964-65</td>
<td>430&lt;sup&gt;b&lt;/sup&gt;</td>
<td>217&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.30&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.18&lt;sup&gt;c&lt;/sup&gt;</td>
<td>22.76&lt;sup&gt;c&lt;/sup&gt;</td>
<td>206&lt;sup&gt;b&lt;/sup&gt;</td>
<td>8.18&lt;sup&gt;d&lt;/sup&gt;</td>
<td>13.3&lt;sup&gt;b&lt;/sup&gt;</td>
<td>30.9&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>1965-66</td>
<td>436&lt;sup&gt;b&lt;/sup&gt;</td>
<td>212&lt;sup&gt;b&lt;/sup&gt;</td>
<td>2.33&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2.16&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

<sup>d</sup> Means bearing this superscript are significant at the P < .05 level.
of gain. Prior to slaughter, steers received a higher ($P < .005$) evaluation per cwt. by a packer buyer, which would have resulted in a greater ($P < .005$) return per steer if they had been sold on a liveweight basis.

Bulls required fewer days in the feedlot to meet the desired slaughter standards, and this resulted in the bulls being slaughtered at young ages; however, these differences were not significant. Animals that received the low level of DES treatment had a lower ($P < .005$) daily feed cost than animals that did not receive DES during the feedlot period. Animals that were fed a pre-weaning creep ration required consistently fewer days in the feedlot to meet the desired slaughter standards; however, this difference was not highly significant ($P < .20$). Year (Experiment) differences were an important source of variation in many of the post-weaning performance traits that were analyzed. Interactions involving the various post-weaning performance factors studied were not statistically significant.

Carcass Evaluation Phase

Least-squares means classified by sex, DES treatment, pre-weaning creep treatment and year for carcass traits of young male cattle are reported in table 13. Carcasses of steers graded higher ($P < .005$), had higher ($P < .005$) marbling scores, greater ($P < .005$) backfat thickness over the 12th rib, and heavier ($P < .07$) hind quarters. Steer carcasses also had greater amounts of kidney and suet fat; however, the difference was not significant at the 5% level. Carcasses of bulls had larger ($P < .05$) rib eyes, higher ($P < .005$) estimated yield of retail cuts, higher ($P < .005$) estimated lean yield and higher ($P < .05$) estimated yield of chuck, rib, loin and round. Steer carcasses were valued at more ($P < .005$) per cwt.,
Table 13. Least-squares means by sex, DES, creep and year for some carcass traits of young male cattle

<table>
<thead>
<tr>
<th>Item</th>
<th>CCWTE</th>
<th>RC</th>
<th>USDA®</th>
<th>MBSf</th>
<th>TW,oz.</th>
<th>RE/cwt</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>37.32</td>
<td>216</td>
<td>6.15</td>
<td>4.32</td>
<td>15.40</td>
<td>2.08</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steers</td>
<td>39.31a</td>
<td>227a</td>
<td>7.09a</td>
<td>5.05a</td>
<td></td>
<td>2.01a</td>
</tr>
<tr>
<td>Bulls</td>
<td>35.33c</td>
<td>205b</td>
<td>5.21c</td>
<td>3.59c</td>
<td></td>
<td>2.15b</td>
</tr>
<tr>
<td>DES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>36.81a</td>
<td>205a</td>
<td>5.66a</td>
<td>4.11a</td>
<td>17.9a</td>
<td>2.15a</td>
</tr>
<tr>
<td>12 &amp; 24 mg.</td>
<td>36.49a</td>
<td>208a</td>
<td>5.63a</td>
<td>4.04a</td>
<td>14.9a</td>
<td>2.06a</td>
</tr>
<tr>
<td>48 mg.</td>
<td>38.66a</td>
<td>235a</td>
<td>7.16a</td>
<td>4.81a</td>
<td></td>
<td>2.03a</td>
</tr>
<tr>
<td>Creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>37.91a</td>
<td>214a</td>
<td>6.02a</td>
<td>4.11a</td>
<td>15.0a</td>
<td>2.08a</td>
</tr>
<tr>
<td>Creep</td>
<td>36.73a</td>
<td>218a</td>
<td>6.28a</td>
<td>4.53a</td>
<td>15.8a</td>
<td>2.08a</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963-64</td>
<td>34.48a</td>
<td>220a</td>
<td>6.59a</td>
<td>4.96a</td>
<td>16.3a</td>
<td>1.88a</td>
</tr>
<tr>
<td>1964-65</td>
<td>37.73c</td>
<td>209a</td>
<td>5.44b</td>
<td>4.06c</td>
<td>13.3a</td>
<td>2.15c</td>
</tr>
<tr>
<td>1965-66</td>
<td>39.75c</td>
<td>218a</td>
<td>6.42a</td>
<td>3.94c</td>
<td>16.6a</td>
<td>2.21c</td>
</tr>
</tbody>
</table>

*a* Means bearing the same superscript within a subgroup are not significantly different at the P < .05 level.

*b* Means bearing this superscript are significant at the P < .05 level.

*c* Means bearing this superscript are significant at the P < .01 level.

*d* CCWTE = Chilled carcass value per cwt.; RC = Total returns on chilled carcass basis; USDA® = U.S.D.A. carcass grade; MBS = Marbling score; TW = Testes weight; RE/cwt. = Square inches of ribeye per cwt. chilled carcass; BF/cwt. = Backfat thickness per cwt. chilled carcass; C/DA = Pounds of chilled carcass per day of age; PCHQ = Percent of the chilled carcass weight in the hind quarters; WTKKS = Weight of the kidney knob and suet fat; RY = Estimated percent retail yield of chuck, rib, loin and round; Estimated percent of lean yield of total carcass = TLY; TRY = Estimated percent retail yield of total carcass.

*e* Based on a 1-9 scale, 1 = low standard, 9 = high choice.

*f* Based on a 1-9 scale, 1 = practically devoid, 9 = abundant.
Table 13. (Continued)

<table>
<thead>
<tr>
<th></th>
<th>BF/cwt.</th>
<th>C/DA</th>
<th>PCHQ</th>
<th>WTKKS</th>
<th>RF</th>
<th>TLY</th>
<th>TRY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>0.07</td>
<td>1.33</td>
<td>47.47</td>
<td>108</td>
<td>49.32</td>
<td>61.68</td>
<td>71.01</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steers</td>
<td>0.09a</td>
<td>1.30a</td>
<td>48.06a</td>
<td>120a</td>
<td>46.95a</td>
<td>60.24a</td>
<td>69.62a</td>
</tr>
<tr>
<td>Bulls</td>
<td>0.05c</td>
<td>1.35a</td>
<td>46.88a</td>
<td>96a</td>
<td>51.69b</td>
<td>63.12c</td>
<td>72.40c</td>
</tr>
<tr>
<td>DES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>0.06a</td>
<td>1.26a</td>
<td>47.32a</td>
<td>113a</td>
<td>48.73a</td>
<td>62.45a</td>
<td>71.69a</td>
</tr>
<tr>
<td>12 &amp; 24 mg.</td>
<td>0.06a</td>
<td>1.31a</td>
<td>47.62a</td>
<td>103a</td>
<td>49.91a</td>
<td>61.85a</td>
<td>71.23a</td>
</tr>
<tr>
<td>48 mg.</td>
<td>0.08a</td>
<td>1.41b</td>
<td>47.55a</td>
<td>103a</td>
<td>49.21a</td>
<td>61.80a</td>
<td>71.13a</td>
</tr>
<tr>
<td>Creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>0.07a</td>
<td>1.27a</td>
<td>47.39a</td>
<td>113a</td>
<td>49.43a</td>
<td>61.56a</td>
<td>70.89a</td>
</tr>
<tr>
<td>Creep</td>
<td>0.07a</td>
<td>1.38b</td>
<td>47.55a</td>
<td>103a</td>
<td>49.21a</td>
<td>61.80a</td>
<td>71.13a</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963-64</td>
<td>0.08a</td>
<td>1.43a</td>
<td></td>
<td></td>
<td>59.45a</td>
<td>69.01a</td>
<td></td>
</tr>
<tr>
<td>1964-65</td>
<td>0.07c</td>
<td>1.30c</td>
<td></td>
<td></td>
<td>62.21c</td>
<td>71.45c</td>
<td></td>
</tr>
<tr>
<td>1965-66</td>
<td>0.06c</td>
<td>1.26c</td>
<td></td>
<td></td>
<td>63.38c</td>
<td>72.56c</td>
<td></td>
</tr>
</tbody>
</table>
which resulted in greater (P < .025) total return per steer carcass. Animals receiving the high DES implant level (bulls, only) produced higher (P < .06) grading carcasses, more (P < .05) pounds of carcass per day of age and returned more (P < .06) total dollars per carcass when sold on a grade and yield basis. There was no significant difference between the U.S.D.A. carcass grade for steers and the U.S.D.A. carcass grade for the high level DES implant bulls. Testicle weights of the implanted bulls were consistently lower than those from the untreated bulls; however, the differences were not significant.

Cattle that received a creep ration during the pre-weaning treatment period produced significantly more (P < .05) pounds of carcass per day of age than cattle that were not provided creep rations prior to weaning. Year (Experiment) differences were significant for many of the carcass traits studied. There were no significant interactions involving the various carcass traits that were analyzed from these data. The data in table 14 show simple correlation coefficients between different post-weaning performance traits and carcass characteristics of young male beef cattle.

Warner-Bratzler shear values and taste panel observations of various quality factors of muscle from young male beef animals are presented by sex, DES treatment, pre-weaning creep treatment and year in table 15. Shear values on hot (taken 5 minutes after cooking) or cold (taken 24 hours after cooking) l. dorsi muscle show a significant difference in muscle tenderness between bulls and steers. However, shear values on the semitendinosus (taken 24 hours after cooking) muscle only tends to approach
Table 14. Simple correlation coefficients between different post-weaning performance traits\(^a\) and carcass characteristics\(^a\) of young male beef cattle

<table>
<thead>
<tr>
<th></th>
<th>AGE</th>
<th>DIFL</th>
<th>USDAG</th>
<th>MABS</th>
<th>RC</th>
<th>GN/DFL</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIFL</td>
<td>0.95**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDAG</td>
<td>0.55**</td>
<td>0.41*</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MABS</td>
<td>0.67**</td>
<td>0.64**</td>
<td>0.77**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td>0.61**</td>
<td>0.45*</td>
<td>0.75**</td>
<td>0.73**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>GN/DFL</td>
<td>-0.30</td>
<td>-0.25</td>
<td>-0.16</td>
<td>-0.06</td>
<td>-0.18</td>
<td>1.00</td>
</tr>
<tr>
<td>RE/cwt</td>
<td>-0.66**</td>
<td>-0.70**</td>
<td>-0.39</td>
<td>-0.77**</td>
<td>-0.45*</td>
<td>-0.17</td>
</tr>
<tr>
<td>BF/cwt</td>
<td>0.61**</td>
<td>0.62**</td>
<td>0.62**</td>
<td>0.86**</td>
<td>0.58**</td>
<td>-0.16</td>
</tr>
<tr>
<td>C/DA</td>
<td>-0.33</td>
<td>-0.27</td>
<td>-0.22</td>
<td>0.08</td>
<td>-0.06</td>
<td>0.83**</td>
</tr>
<tr>
<td>TRY</td>
<td>-0.66**</td>
<td>-0.69**</td>
<td>-0.54**</td>
<td>-0.86**</td>
<td>-0.55**</td>
<td>0.01</td>
</tr>
<tr>
<td>RA</td>
<td>0.83</td>
<td>0.75**</td>
<td>0.73**</td>
<td>0.82**</td>
<td>0.95**</td>
<td>-0.43</td>
</tr>
<tr>
<td>FDPPG</td>
<td>0.48</td>
<td>0.48</td>
<td>0.41</td>
<td>0.42</td>
<td>0.58*</td>
<td>-0.91**</td>
</tr>
<tr>
<td>FCPPG</td>
<td>0.61*</td>
<td>0.56*</td>
<td>0.63**</td>
<td>0.66**</td>
<td>0.79**</td>
<td>-0.71**</td>
</tr>
</tbody>
</table>

\(^a\) AGE = Days of age at slaughter; DIFL = Days in the feedlot; USDAG = U.S.D.A. carcass grade; MABS = Marbling score; RC = Total returns on chilled carcass basis; GN/DFL = Average daily gain per day in the feedlot; RE/cwt. = Square inches of ribeye per cwt. chilled carcass; BF/cwt. = Backfat thickness per cwt. chilled carcass; C/DA = Pounds of chilled carcass per day of age; TRY = Estimated percent retail yield of total carcass; RA = Total returns on a live-weight basis; FDPPG = Pounds of feed per pound of gain; FCPPG = Feed cost per pound of gain.

\(^*\) \(P < .05\)

\(^{**}\) \(P < .01\)
Table 14. (Continued)

<table>
<thead>
<tr>
<th></th>
<th>RE/cwt</th>
<th>BF/cwt</th>
<th>C/DA</th>
<th>TRY</th>
<th>RA</th>
<th>FDPPG</th>
<th>FCPPG</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGE</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DIFL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>USDAG</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MABS</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>GN/DFL</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE/cwt</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>BF/cwt</td>
<td>-.76**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C/DA</td>
<td>-.24</td>
<td>-.06</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TRY</td>
<td>0.91**</td>
<td>-.95**</td>
<td>-.09</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RA</td>
<td>-.68**</td>
<td>0.80**</td>
<td>-.37</td>
<td>-.79**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FDPPG</td>
<td>-.20</td>
<td>0.53*</td>
<td>-.72**</td>
<td>-.42</td>
<td>0.64**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>FCPPG</td>
<td>-.45</td>
<td>0.73**</td>
<td>-.55*</td>
<td>-.66**</td>
<td>0.81**</td>
<td>0.90**</td>
<td>1.00</td>
</tr>
</tbody>
</table>
Table 15. Least-squares means by sex, DES, creep and year for Warner-Bratzler shear force values\(^{de}\) and some organoleptic measures\(^{df}\) of muscle from young male cattle

<table>
<thead>
<tr>
<th>Item</th>
<th>CSTSV</th>
<th>CLDSV</th>
<th>HLDSV</th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>28.78</td>
<td>19.05</td>
<td>14.98</td>
<td>7.65</td>
<td>7.71</td>
<td>7.41</td>
</tr>
<tr>
<td>Sex</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Steers</td>
<td>27.11(^a)</td>
<td>16.12(^a)</td>
<td>13.32(^a)</td>
<td>7.82(^a)</td>
<td>7.80(^a)</td>
<td>8.17(^a)</td>
</tr>
<tr>
<td>Bulls</td>
<td>30.45(^a)</td>
<td>21.98(^c)</td>
<td>16.64(^b)</td>
<td>7.48(^a)</td>
<td>7.62(^a)</td>
<td>6.65(^c)</td>
</tr>
</tbody>
</table>

\(^a\)Means bearing the same superscript within a subgroup are not significantly different at the P < .05 level.

\(^b\)Means bearing this superscript are significant at the P < .05 level.

\(^c\)Means bearing this superscript are significant at the P < .01 level.

\(^d\)CSTSV = Warner-Bratzler shear values on cold Semitendinosus muscle; CLDSV = Warner-Bratzler shear values on cold Longissimus dorsi muscle; HLDSV = Warner-Bratzler shear values on hot Longissimus dorsi muscle; FLV = Taste panel flavor values; JUIC = Taste panel juiciness values; TEND = Taste panel tenderness values.

\(^e\)Expressed in pounds, the greater the number of pounds, the less tender the steak.

\(^f\)Rated on a hedonic scale of 10 being extremely desirable and 1 equaling extremely undesirable.
Table 15. (Continued)

<table>
<thead>
<tr>
<th>Item</th>
<th>CSTSV</th>
<th>CLDSV</th>
<th>HLDSV</th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
</tr>
</thead>
<tbody>
<tr>
<td>DES</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>None</td>
<td>28.80&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.20&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.47&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.68&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.11&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>12 &amp; 24 mg.</td>
<td>28.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.90&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.74&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.63&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.79&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.27&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>48 mg.</td>
<td>-</td>
<td>-</td>
<td>13.52&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.85&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.66&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.85&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creep</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No creep</td>
<td>28.60&lt;sup&gt;a&lt;/sup&gt;</td>
<td>18.34&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.87&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.45&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Creep</td>
<td>28.96&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.76&lt;sup&gt;a&lt;/sup&gt;</td>
<td>15.09&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.61&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.69&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.37&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Year</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1963-64</td>
<td>-</td>
<td>20.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-</td>
<td>7.18&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.45&lt;sup&gt;a&lt;/sup&gt;</td>
<td>6.80&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>1964-65</td>
<td>-</td>
<td>17.92&lt;sup&gt;a&lt;/sup&gt;</td>
<td>14.71&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.80&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.70&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.68&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>1965-66</td>
<td>-</td>
<td>-</td>
<td>15.25&lt;sup&gt;a&lt;/sup&gt;</td>
<td>7.97&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.98&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.75&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>
significance \( (P < .09) \) for sex differences. \textit{L. dorsi} of steers was rated higher \( (P < .01) \) in tenderness by the trained taste panel than muscle from bulls, but there were no significant sex differences at the 5\% level for flavor or juiciness. \textit{L. dorsi} muscle from the older animals in Experiment I was scored lower \( (P < .005) \) in flavor, lower \( (P < .01) \) in juiciness and less \( (P < .05) \) tender by the taste panel.

Simple correlation coefficients for some objective and subjective measures of muscle tenderness and quality of young male beef cattle are reported in table 16. Subjective measures of tenderness and quality of beef muscle were highly \( (P < .01) \) correlated. Warner-Bratzler shear values and taste panel scores for tenderness were negatively \( (P < .01) \) correlated. Cold \textit{L. dorsi} shear values and hot \textit{L. dorsi} shear values were highly \( (P < .01) \) correlated, but cold \textit{L. dorsi} shear values and cold semitendinosus shear values were not significantly related at the 5\% level.

Arithmetic means and standard deviations for hot and cold Warner-Bratzler shear values on \textit{L. dorsi} steaks are reported in table 17. There was more than 3 lb. difference in shear force between steaks tested 5 minutes after cooking and those tested 24 hours following cooking. The smaller standard deviation for the shear values on the hot \textit{L. dorsi} steaks indicates that there was less variation between samples evaluated shortly after cooking.

\textbf{Evaluation of Factors Affecting Tenderness and Quality of Beef Muscle}

Least-squares means by sex and age for various factors related to muscle tenderness and quality of male beef cattle are reported in table 18.
Table 16. Simple correlation coefficients between some objective\(^d\) and subjective\(^d\) measures of muscle tenderness and quality of young male beef cattle

<table>
<thead>
<tr>
<th></th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
<th>CLDSV</th>
<th>HLDSV</th>
<th>CSTSV</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLV</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUIC</td>
<td>0.83(^c)**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEND</td>
<td>0.82(^c)**</td>
<td>0.79(^c)**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CLDSV</td>
<td>-0.74(^b)**</td>
<td>-0.48(^b)</td>
<td>-0.86(^b)**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLDSV</td>
<td>-0.52(^b)*</td>
<td>-0.78(^b)**</td>
<td>-0.84(^b)**</td>
<td>0.92(^a)**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>CSTSV</td>
<td>-0.84(^a)**</td>
<td>-0.80(^a)*</td>
<td>-0.83(^a)*</td>
<td>------</td>
<td>0.53(^a)</td>
<td>1.00</td>
</tr>
</tbody>
</table>

\(^a\)Correlation coefficients calculated from data involving 1 year.

\(^b\)Correlation coefficients calculated from data involving 2 years.

\(^c\)Correlation coefficients calculated from data involving 3 years.

\(^d\)FLV = Taste panel flavor values; JUIC = Taste panel juiciness values; TEND = Taste panel tenderness values; CLDSV = Warner-Bratzler shear values on cold \(1. \text{dorsi}\) muscle; HLDSV = Warner-Bratzler shear values on hot \(1. \text{dorsi}\) muscle; CSTSV = Warner-Bratzler shear values on cold \(1. \text{semitendinosus}\) muscle.

\(^*\)P < .05

\(^**\)P < .01
Table 17. Arithmetic means and standard deviations for hot and cold 1. dorsi Warner-Bratzler shear values (Experiment II)

<table>
<thead>
<tr>
<th></th>
<th>Arithmetic mean</th>
<th>Standard deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold 1. dorsi</td>
<td>19.81</td>
<td>2.39</td>
</tr>
<tr>
<td>Hot 1. dorsi</td>
<td>16.36</td>
<td>2.14</td>
</tr>
</tbody>
</table>

Table 18. Least squares means by sex and age for various factors related to muscle tenderness and quality of male cattle

<table>
<thead>
<tr>
<th></th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
<th>HLDSV</th>
<th>RE/cwt.</th>
<th>BF/cwt.</th>
<th>Moisture</th>
<th>Collagen^a</th>
<th>Protein^b</th>
<th>Collagen^c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Over-all mean</td>
<td>7.80</td>
<td>7.90</td>
<td>7.57</td>
<td>16.19</td>
<td>2.19</td>
<td>0.08</td>
<td>6.27</td>
<td>49.27</td>
<td>85.19</td>
<td>58.89</td>
</tr>
<tr>
<td>Sex: Steers</td>
<td>8.00^d</td>
<td>8.02^d</td>
<td>8.11^d</td>
<td>14.74^d</td>
<td>2.12^d</td>
<td>0.09^d</td>
<td>6.72^d</td>
<td>51.90^d</td>
<td>83.50^d</td>
<td>62.91^d</td>
</tr>
<tr>
<td>Bulls</td>
<td>7.60^d</td>
<td>7.76^d</td>
<td>7.03^e</td>
<td>17.63^h</td>
<td>2.26^e</td>
<td>0.07^d</td>
<td>5.82^d</td>
<td>46.64^d</td>
<td>86.88^e</td>
<td>54.87^e</td>
</tr>
</tbody>
</table>

^a Expressed on dry weight basis of total sample.

^b Kjeldahl nitrogen multiplied by a weighted mean of 5.55 and 6.25 depending on collagen content (see text).

^c Expressed on a protein-content basis (see footnote b).

^d,e,f,g Means bearing the same superscript within a subgroup are not significantly different at the P < .05 level.

^h Means bearing this superscript within a subgroup are significant at the P < .01 level.

^i FLV = Taste panel flavor values; JUIC = Taste panel juiciness values; TEND = Taste panel tenderness values; HLDSV = Warner-Bratzler shear values on hot L. dorsi muscle; RE/cwt. = Square inches of ribeye per cwt. chilled carcass; BF/cwt. = Backfat thickness per cwt. chilled carcass.
Table 18. (Continued)

<table>
<thead>
<tr>
<th>Age</th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
<th>HLDSV</th>
<th>RE/cwt.</th>
<th>BF/cwt.</th>
<th>Moisture</th>
<th>Collagen(^a)</th>
<th>Protein(^b)</th>
<th>Collagen(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6 mo.</td>
<td>7.48(^d)</td>
<td>8.32(^d)</td>
<td>7.95(^d)</td>
<td>12.67(^e)</td>
<td>2.81(^d)</td>
<td>0.06(^d)</td>
<td>8.52(^e)</td>
<td>66.07(^d)</td>
<td>80.07(^e)</td>
<td>82.68(^d)</td>
</tr>
<tr>
<td>9 mo.</td>
<td>8.11(^d)</td>
<td>8.27(^d)</td>
<td>7.82(^d)</td>
<td>20.01(^d)</td>
<td>2.30(^e)</td>
<td>0.05(^d)</td>
<td>13.47(^d)</td>
<td>66.67 (^d)</td>
<td>82.50(^e)</td>
<td>81.07(^de)</td>
</tr>
<tr>
<td>12 mo.</td>
<td>7.67(^d)</td>
<td>7.40(^d)</td>
<td>7.17(^d)</td>
<td>18.71(^d)</td>
<td>2.12(^f)</td>
<td>0.06(^d)</td>
<td>4.59(^ef)</td>
<td>48.90(^de)</td>
<td>84.56(^e)</td>
<td>57.67(^ef)</td>
</tr>
<tr>
<td>15 mo.</td>
<td>7.69(^d)</td>
<td>7.55(^d)</td>
<td>7.37(^d)</td>
<td>15.93(^ef)</td>
<td>1.93(^e)</td>
<td>0.11(^e)</td>
<td>3.32(^f)</td>
<td>36.44(^ef)</td>
<td>93.62(^d)</td>
<td>39.83(^f)</td>
</tr>
<tr>
<td>18 mo.</td>
<td>8.05(^d)</td>
<td>7.96(^d)</td>
<td>7.54(^d)</td>
<td>13.63(^fg)</td>
<td>1.79(^e)</td>
<td>0.12(^e)</td>
<td>1.45(^f)</td>
<td>28.27(^f)</td>
<td>85.20(^e)</td>
<td>33.20(^f)</td>
</tr>
</tbody>
</table>
Bull carcasses had larger (P < .05) ribeyes and a higher (P < .05) percent protein in the connective tissue residue that was isolated from the l. dorsi muscle. L. dorsi steaks from steer carcasses received a tenderness rating of 8.11 from a trained taste panel compared to a rating of 7.03 for similar steaks from bull carcasses. Sex differences in taste panel scores for tenderness were significant at the P < .05 level. Warner-Bratzler shear values were significantly (P < .01) lower for cooked l. dorsi steaks from steer carcasses. Sex differences in taste panel scores for flavor and juiciness were nonsignificant at the 5% level. Analysis of connective tissue residues from bull and steer l. dorsi showed no significant sex differences in moisture and collagen levels.

Duncan's (1955) multiple range test was used in the statistical analysis of the least-squares means for the five different age groups.

Age differences in taste panel scores for flavor, juiciness and tenderness were nonsignificant (P < .05). A summary of the taste panel scores for the organoleptic components of l. dorsi muscle from bull and steer carcasses is presented in figure 1. Flavor scores were lowest for the 6 month old group, and juiciness and tenderness values were lowest for the 12 month old group. Simple correlation coefficients between the organoleptic components indicate that flavor, juiciness and tenderness are highly (P < .01) related (table 19).

Warner-Bratzler shear values for the 9 month age group were significantly higher (P < .05) than for the 6, 15 and 18 month age groups. Shear values for the 12 month age group were higher (P < .05) than for the 6 and 12 month age groups and the 6 month group required less (P < .05) shear
Figure 1. Taste panel values for flavor, juiciness and tenderness of L. dorsi steaks from bulls and steers of different ages.
Table 19. Simple correlation coefficients between various factors related to muscle tenderness and quality of male cattle slaughtered at different ages

<table>
<thead>
<tr>
<th></th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
<th>HLDSV</th>
<th>RE/cwt.</th>
<th>BF/cwt.</th>
<th>Moisture</th>
<th>Collagen(^a)</th>
<th>Protein(^b)</th>
<th>Collagen(^c)</th>
</tr>
</thead>
<tbody>
<tr>
<td>FLV</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>JUIC</td>
<td>0.66(^**)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TEND</td>
<td>0.68(^**)</td>
<td>0.79(^**)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>HLDSV</td>
<td>-0.06</td>
<td>-0.30</td>
<td>-0.44(^*)</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RE/cwt.</td>
<td>-0.32</td>
<td>0.27</td>
<td>0.01</td>
<td>-0.02</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

\(^a\)Expressed on dry weight basis of total sample.

\(^b\)Kjeldahl nitrogen multiplied by a weighted mean of 5.55 and 6.25, depending on collagen content (see text).

\(^c\)Expressed on a protein-content basis (see footnote b).

\(^d\)FLV= Taste panel flavor values; JUIC= Taste panel juiciness values; TEND= Taste panel tenderness values; HLDSV= Warner-Bratzler shear values on hot l. dorsi muscle; RE/cwt.=Square inches of ribeye per cwt. chilled carcass; BF/cwt.= Backfat thickness per cwt. chilled carcass.

\(^*\)P < .05

\(^{**}\)P < .01
Table 19. (Continued)

<table>
<thead>
<tr>
<th></th>
<th>FLV</th>
<th>JUIC</th>
<th>TEND</th>
<th>HLDSV</th>
<th>RE/cwt.</th>
<th>BF/cwt.</th>
<th>Moisture</th>
<th>Collagen\textsuperscript{a}</th>
<th>Protein\textsuperscript{b}</th>
<th>Collagen\textsuperscript{c}</th>
</tr>
</thead>
<tbody>
<tr>
<td>BF/cwt.</td>
<td>0.46*</td>
<td>0.10</td>
<td>0.32</td>
<td>-0.52*</td>
<td>-0.68**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Moisture</td>
<td>0.03</td>
<td>0.17</td>
<td>0.14</td>
<td>0.44*</td>
<td>0.46*</td>
<td>-0.59**</td>
<td>1.00</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Collagen\textsuperscript{a}</td>
<td>-0.10</td>
<td>0.21</td>
<td>0.12</td>
<td>0.21</td>
<td>0.62**</td>
<td>-0.56**</td>
<td>0.80**</td>
<td>1.00</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Protein\textsuperscript{b}</td>
<td>-0.10</td>
<td>-0.39</td>
<td>-0.35</td>
<td>0.04</td>
<td>-0.49*</td>
<td>0.42</td>
<td>-0.52*</td>
<td>-0.62**</td>
<td>1.00</td>
<td></td>
</tr>
<tr>
<td>Collagen\textsuperscript{c}</td>
<td>-0.08</td>
<td>0.24</td>
<td>0.16</td>
<td>0.18</td>
<td>0.65**</td>
<td>-0.58**</td>
<td>0.80**</td>
<td>1.00**</td>
<td>-0.68</td>
<td>1.00</td>
</tr>
</tbody>
</table>
force than the 15 month group. A summary of the Warner-Bratzler shear values for tenderness of the l. dorsi muscle from bull and steer carcasses is presented in figure 2. Shear values were higher (less tender) for the 9 and 12 month age groups and lower (more tender) for the 6 and 18 month age groups. Taste panel scores for tenderness were different than the Warner-Bratzler shear values. This supports the belief of many in the research field that shear instruments and taste panels do not measure the same tenderness qualities. A significant (P < .05) correlation coefficient (table 19) of -.44 was obtained between shear values and taste panel tenderness measures.

Ribeye area per cwt. of chilled carcass was significantly higher (P < .05) for the 6 month age group than for the other four age groups. Ribeye area per cwt. decreased proportionately from the youngest to the oldest age group. This is a trait commonly found in livestock and the data from this study are in agreement.

Backfat thickness per cwt. was lower (P < .05) for the 6, 9 and 12 month age groups than for the 15 and 18 month groups. This helps explain the decrease in ribeye area per cwt. The highly significant (P < .01) correlation coefficient (-.68) between ribeye area and backfat thickness per cwt. tends to lend more support to this fact (table 19).

Analysis of the connective tissue residue from the l. dorsi showed that the 6 and 9 month age groups contained a significantly higher (P < .05) percent moisture than the two oldest age groups. The percent moisture in the connective tissue residue was higher (P < .05) for the 9 month age group than for the other four groups. Percent protein in the connective
Figure 2. Warner-Bratzler shear values for tenderness of 1. dorsi steaks from bulls and steers of different ages
tissue residue was significantly ($P < .05$) higher for the 15 month old group than for the other four age groups. This difference is partly due to a very high protein value (99.67) for one animal in the 15 month age group.

The factor used to convert Kjeldahl nitrogen to protein was a weighted mean of the factors used to convert collagen nitrogen to protein (5.55) and non-collagenous nitrogen to protein (6.25). This procedure was necessary because the nitrogen content of collagen has been reported to be 18% (Eastoe and Leach, 1958).

The hydroxyproline content of the samples was used as a measure of their collagen content. The hydroxyproline content of the tissue was converted to collagen using a factor of 7.25, assuming that the hydroxyproline content is 13.3% on a weight basis (Eastoe and Leach, 1958). The collagen value was converted to protein (5.55) and the collagen protein value was subtracted from the actual protein value received from the Kjeldahl nitrogen (6.25) analysis. The difference was called non-collagenous nitrogen and the common conversion factor (6.25) was used to convert the value to protein. The protein value reported in this study is obtained by using a weighted mean of the two conversion factors for the different types of nitrogen.

The collagen values for the five age groups are presented on a dry weight total sample basis and on a protein-content basis. The 6 and 9 month age groups had significantly greater ($P < .05$) amounts of collagen, expressed on either total sample or protein-content basis, than for the two older age groups. Neither taste panel tenderness measures nor Warner-
Bratzler shear values were related to collagen content of the connective tissue residue (table 19).

All first order interactions involving the information collected in this study were nonsignificant at the 5% level.
GENERAL DISCUSSION

There is considerable evidence that bull calves grow more rapidly than steers during the pre-weaning period (Klosterman et al., 1954; Marlowe and Gaines, 1958; Pilkington et al., 1959; Field et al., 1964). Brinks et al. (1961) found that selection was the major factor determining sex differences in daily gain. When random groups of male calves were castrated at about 3.2 months of age, Bailey et al. (1966) found that bulls and steers were similar in growth rate to weaning. In our study with random groups of male calves castrated between 2 and 3 months of age, the growth rate to weaning of bulls and steers was similar.

Diethylstilbestrol implants failed to increase the average daily gain of bull or steer calves during the pre-weaning period. Meiske et al. (1960), Ewing and Burroughs (1961), Nelson and Kuhlman (1962) and Nesler et al. (1966), using 6 and 12 mg. DES implants, reported increased gains in steer and heifer calves. Bradley et al. (1962) found that steer and heifer calves implanted with 12 mg. of DES gained 20 to 30 lb. more than calves which had not been implanted. The following year, however, implanted steers gained less than steers which had not been implanted. Melton and Riggs (1965) observed a weight increase in DES-implanted calves ranging from 2 lb. less to 29 lb. more than non-implanted calves during a 4-year study. These workers found that DES implants were most effective in increasing weaning weights of calves when range feed conditions were best. The feed conditions experienced in the experiments reported herein were quite variable and could account for the lack of a consistent response of DES-implanted male calves during the suckling period.
The literature is less plentiful regarding the response of bull calves to DES implants during the suckling period. Bull calves showed a consistent but nonsignificant response to the high level (48 mg.) implant. Pilkington et al. (1959) observed that bulls implanted with 12 mg. DES at 3½ and 24 mg. at 6½ months of age made greater gains than steer calves implanted with 12 mg. DES at 3 months of age but somewhat less than bull calves that were not implanted. Bull calves implanted with 12 mg. DES at birth (Ralston, 1965) were heavier at weaning than bull calves implanted at 3 months of age or bull calves that did not receive any implant. The data from our experiments and that available in the literature indicate that bull calves respond best to DES implants shortly after birth or to extremely high levels (48 mg.) at approximately 3 months of age.

There is considerable evidence that creep feeding beef calves is a very controversial practice. Black and Trowbridge (1930), Bray (1934), Johnson and Fenn (1943), Duncan et al. (1949), Cunningham et al. (1958) and Woods et al. (1958) reported increased gains of 50 to 100 lb. when steer calves were creep-fed 100 to 150 days during the suckling period. Nelson et al. (1955) and Burns et al. (1966) observed a more conservative increase in weaning weights of 30 lb. for calves that were creep-fed. Black and Trowbridge (1930), Johnson and Fenn (1943), Nelson et al. (1955) and Burns et al. (1966) found that non-creep-fed calves were more profitable in the feedlot than calves that received creep feed during the pre-weaning period. Our results appear to be consistent in most respects to the reported evidence, except there was no difference in feedlot performance between creep-fed and non-creep-fed calves. However, creep-fed ani-
mals maintained their pre-weaning weight advantage throughout the feeding period. This could have been due to the fact that the majority of the cattle that were on the pre-weaning creep-fed treatments were bulls. Bulls gained more rapidly ($P < .07$) than steers in the feedlot on less ($P < .005$) feed.

Both methods of creep feeding (limited-creep and free-choice-creep) were equally responsible for the highly significant ($P < .005$) creep response that resulted from this study. The free-choice method of creep feeding beef calves is the conventional method that is used extensively throughout this country. There were no reports in the literature of research on limited-creep feeding beef calves. The data obtained from this study concerning limited-creep feeding indicate that it was a profitable practice that consistently improved the weaning weights of beef calves. These results may suggest that the limited amount of creep feed provided by this practice tends to stimulate the appetite of the young calf, and it grazes and nurses more often and more vigorously to satisfy the demands of its appetite. On the other hand, free-choice creep feeding tends to more completely satisfy the appetite requirements of the young animal, and it becomes lazy and complacent. This could be partly responsible for the high costs and low returns that most workers report when calves are creep-fed by the free-choice method.

The difference ($P < .005$) between the gain of creep-fed and non-creep-fed calves during the 2-week adjustment period following weaning is not only significant from the statistical point of view but also from the monetary standpoint. The ability of the creep-fed calves to withstand the stress
conditions that were encountered at weaning was an important factor influencing the length of time that the creep-fed animals required to achieve the constant slaughter weight in Experiment I. Animals that received creep feed during the suckling period consistently required fewer days to reach the requirements for slaughter. This difference was not highly significant \( P < .20 \). From the economical standpoint, the non-creep-fed cattle were in the feedlot approximately 1 month longer which would greatly increase the feedlot cost for these animals. Johnson and Fenn (1943) and Nelson et al. (1955) found that animals that were creep-fed during the suckling period required a shorter feedlot period to reach the U.S.D.A. choice carcass grade at slaughter.

No differences were found in average daily gain and feed conversion between cattle that were creep-fed or not creep-fed before entering the feedlot. However, various workers (Johnson and Fenn, 1943; Nelson et al., 1955) have reported that cattle that received creep feed before weaning made slower gains and required more feed per unit of gain than cattle that had not received creep prior to the feedlot period.

Creep-fed cattle produced more \( (P < .05) \) pounds of chilled carcass per day of age than cattle that were not creep-fed. The fact that the creep-fed animals gained more during the suckling period, continued to gain during the 2-week adjustment period following weaning, and made gains similar to or above the non-creep-fed cattle in the feedlot would help to explain the significant response in pounds of chilled carcass per day of age. Calves that received the high level implant (48 mg.) during the pre-weaning period produced more \( (P < .05) \) pounds of chilled carcass per day of age. The only
animals that received the high level implants were intact males (bulls). This situation does not allow the high level implant and sex interaction to be treated statistically. However, the fact that only bulls received the high level implant could probably account for the significant response received in this particular instance.

Information relating to the effect of creep feeding the calf on the weight of the dam (Black and Trowbridge, 1930; Jones and Jones, 1932; Nelson et al., 1955; Ewing et al., 1959; Burns and Koger, 1963) suggest that dams of creep-fed calves are heavier at weaning than dams nursing calves that are not creep-fed. In the present study, dams nursing creep-fed calves gained, on the average, 7 lb. more than dams whose calves were not creep-fed. This trait is probably influenced more by environmental conditions other than creep feeding.

Bulls gained more rapidly ($P < .07$) under feedlot conditions than steers and were more efficient ($P < .005$) in converting feed to body weight when animals of each sex condition were slaughtered at either a constant weight or a constant age. Carcasses of steers graded higher, had higher marbling scores for the l. dorsi, greater backfat thickness at the 12th rib and larger amounts of kidney and suet fat. These responses would indicate that at least some of the apparent advantages in growth rate and efficiency of intact male cattle may be associated with greater lean tissue growth. Estimated retail yield of the carcass was 2.78% ($P < .005$) higher for the bulls than the steers. These findings are in agreement with results reported by Field et al. (1964) and Warner et al. (1965). The high level implant bulls were fatter and the estimated retail
yield of the carcass was about 0.5% higher than the corresponding average yield for all steers. All of the carcass measurements involving finish were significantly in favor of the steers, but retail value estimated by 3 prediction equations was significantly in favor of the bulls. It is interesting to note that age at slaughter, marbling score, backfat thickness, total chilled carcass returns, total liveweight returns and feed cost per pound of gain were all positively (P < .01) correlated with U.S.D.A. carcass grade. However, U.S.D.A. carcass grade was negatively (P < .01) correlated with estimated carcass retail value. These results tend to support the previous findings of Klosterman et al. (1954); Koger et al. (1960); Brown et al. (1962); Aitken et al. (1963); Field et al. (1964); Warwick et al. (1965) and Bailey et al. (1966).

In Experiments I and II, DES fed orally had no appreciable effect on feedlot performance of carcass characteristics of bulls or steers. In Experiment III, bulls that were implanted with 48 mg. DES produced more (P < .05) pounds of carcass per day of age, returned more (P < .06) total dollars on a chilled carcass basis and yielded carcasses that graded slightly above the average for the steers. Bulls that were treated with the high level of DES were fatter than the control bulls and graded higher; however, these differences were only significant at the 6% level because the number of animals in each subclass was too small. These data indicate that bulls creep-fed and implanted at early ages can produce high grading, desirable carcasses when they are re-implanted upon entering an intensive post-weaning feeding period and slaughtered at young ages. DES treatment, especially the high level, caused a reduction in testicle weight and mini-
mized some of the bullish characteristics of the animals on hoof and in the carcass. The results of this study appear to be consistent in most respects with other information which is available (Klosterman et al., 1955; Cahill et al., 1956; Matsushima and Sprague, 1963; Bailey et al., 1966; Cmarik, 1966) concerning the effect of DES on secondary sex characteristics of bulls. The definite trend of an increase (P < .06) in the carcass grade of bulls implanted with high levels of DES is in agreement with results reported by Klosterman et al. (1955). Cattle that were creep-fed during the pre-weaning phase produced more (P < .05) pounds of chilled carcass per day of age and gained slightly faster than animals that were not creep-fed prior to entering the feedlot. Trial differences were an important source of variation in many of the factors analyzed.

In Experiment III steers and bulls were fed together in one lot without management problems. This observation is in agreement with that reported by Matsushima and Sprague (1963).

Warner-Bratzler shear values of either hot or cold l. dorsi of steers were significantly lower than values for bulls. Similarly, the trained taste panel favored (P < .005) steer steaks in terms of tenderness. In other studies, Bocsor et al. (1955); Koger et al. (1960) and Brown et al. (1962) and (1963) observed that differences in tenderness between bulls and steers slaughtered at approximately 13 months of age were minimal. Klosterman et al. (1954) found in one experiment that tenderness of carcasses of young bulls and steers was similar. In a subsequent experiment, tenderness differed significantly. Results given by Adams and Arthaud (1963); Wipf et al. (1964) and Field et al. (1966)
suggest that an age gradient may exist in quality factors of bulls. In our study, the \textit{l. dorsi} from bulls in Experiment I was less acceptable in tenderness, juiciness and flavor than muscle from animals of either sex condition which were slaughtered at younger ages (Experiments II and III).

Cahill \textit{et al.} (1956) and Wierbicki \textit{et al.} (1956) reported that carcasses of treated and untreated bulls were similar in tenderness. In the present study, DES-treated animals tended to be more desirable from the standpoint of flavor and tenderness than untreated animals. There was also a difference between DES-treated bulls in Experiment III and the controls in tenderness of the \textit{l. dorsi} muscle, but the difference was non-significant at the 5\% level.

Simple correlation coefficients between objective and subjective measurements of tenderness of the \textit{l. dorsi} muscle were highly significant, which would indicate that either measure would yield equally accurate data under the conditions set forth in these experiments. Moe \textit{et al.} (1964) reported a correlation of -.70 between Warner-Bratzler shear values and final tenderness scores of a taste panel. The high relationship between the shear value of hot and cold \textit{l. dorsi} suggest that both values are equally accurate as a measure of muscle tenderness within a given set of data. Comparisons between groups of data should take into consideration the more than 3 lb. difference in shear force between the two values.

The data obtained from Experiment V involving a detailed study of the effects of sex and age on muscle tenderness and quality lend close support to the results reported for Experiments I, II and III. Warner-Bratzler shear values of the \textit{l. dorsi} of steer carcasses were lower (P < .01) than
values for bulls. Similarly, a trained taste panel favored ($P < .05$) steers in terms of tenderness.

Bull carcasses had larger ($P < .05$) ribeyes and a greater ($P < .05$) percent protein in the connective tissue residue. The fact that bull carcasses contain more lean would help explain both factors.

Taste panel scores for flavor, juiciness and tenderness for the different age groups were nonsignificant at the 5% level. Shear values for the 9 and 12 month age groups were significantly less ($P < .05$) tender than for the 6 and 18 month groups. Both measures of tenderness yielded similar results in that the youngest and oldest age groups were usually more tender than the 9, 12 and 15 month groups. The relationship of the two measures of tenderness is further expressed by their significant ($P < .05$) correlation coefficient. This pattern of age related change in muscle tenderness is difficult to explain, but it indicates that a structural change in collagen takes place as an animal matures. The data reported from this study are in general agreement with the majority of the reports in the research literature pertaining to the effects of age on tenderness of muscle; the literature reports involve a much wider range in age, however. Hiner and Hankins (1950) studied the effects of age on tenderness using animals of 3, 8, 14, 37 and 67 months. As age of the animal increased, tenderness decreased. The difference between veal (3 months old) and cows (67 months old) was highly significant ($P < .01$), whereas that between veal and beef from 8 month old steer calves was not significant at the 5% level. Tuma (1962) and Goll (1963) reported that tenderness decreased significantly with increasing animal age.
Ribeye area per cwt. of chilled carcasses decreased significantly (P < .05) with increasing age. Backfat thickness per cwt. of chilled carcass of the 6, 9 and 12 month age groups was significantly lower than for the 15 and 18 month age groups. As an animal reaches maturity, the capacity for muscle growth and development decreases and the animal tends to deposit greater amounts of body fat. The highly significant (P < .01) correlation coefficient (-.68) between ribeye area and backfat thickness per cwt. further emphasizes the effect of age on these two factors.

The 6 and 9 month age groups contained a significantly higher (P < .05) percentage of moisture in the connective tissue residue than the two oldest groups. The moisture percentage was higher (P < .05) for the 9 month age group than for the other four groups. The connective tissue residues from the younger age groups had been isolated and stored for a longer period of time than the tissues from the older age groups. The samples could have collected moisture while storing or the samples may not have been thoroughly lyophilized at the time of isolation. Young animals normally have a high moisture content in intact muscle tissue which tends to decrease as they increase in age.

Percentage protein in the connective tissue residue was significantly (P < .05) higher for the 15 month old group than for the other four age groups. This difference is partly due to a very high protein value (99.67) for one animal in the 15 month age group. If the other values for the 15 month age group are assumed to be more characteristic of the collagen content of connective tissue from bovine animals of this age, it would appear that the protein content in the connective tissue residue increases grad-
ually as the animal increases in age. Goll (1963) found that veal (40 to 49 days old) and cows (56 to 65 months old) had a higher (P < .01) protein content in the connective tissue residue than steers (13 to 18 months old). The data from our experiment and that available in the literature indicate that connective tissue residues from extremely young and old bovine contain more protein than similar tissue from animals of intermediate ages.

The isolated connective tissue of the 6 and 9 month age groups had significantly greater (P < .05) amounts of collagen, expressed on either a dry weight basis of the total sample or on a protein-content basis. Neither taste panel tenderness nor Warner-Bratzler shear values were related to collagen content of the connective tissue residue. Hydroxyproline as an indicator of collagen in the l. dorsi of beef animals was not a critical measure of tenderness in this study. These results are in agreement with findings of Wilson et al. (1954); Wierbicki et al. (1955) and McClain et al. (1965); however, Mitchell and Hamilton (1933); Mackintosh et al. (1936), Loyd and Hiner (1958) and Parrish et al. (1961) have reported opposite results. The variation in the hydroxyproline content of beef muscle is difficult to explain. The muscle from the older animals may be more difficult to extract, accounting for the lower collagen values found in the older animals, or the older animals may have greater amounts of reticulin present, which has a lower hydroxyproline content than collagen. There may be a structural change in collagen that takes place as the animal matures and this in turn could account for some of the variation. More information is needed to properly evaluate the hydroxyproline
method of collagen determination as a critical measure of tenderness in
beef.

The results of this study are in general agreement with those avail­
able in the literature. A few points from this investigation do stand out
as important findings. They are: (1) The use of the limited method of
creep feeding as a possible tool to increase weaning weights of beef calves
at minimal costs, (2) The weight gain advantage that creep-fed calves ex­
hibited during the 2-week stress period following weaning, (3) The use of
96 mg. DES (48 mg. pre-weaning and 48 mg. post-weaning) implants to maxi­
mize performance and carcass quality and minimize masculine characteristics
of young beef bulls and (4) The finding that hydroxyproline as an indi­
cator of collagen content in the I. dorsi of beef animals was not a criti­
cal measure of muscle tenderness.

The demand for more red meat may exceed our supply because of popu­
lation growth and other factors. If the beef industry is interested in
efficiently producing a maximum of total retail product from beef car­
casses, then feeding and slaughtering of young bulls will be a common
practice. However, such programs at present would almost of necessity
have to utilize special direct market outlets, because of the discrimina­
tion in price against bulls on the open market.

Packer acceptability or consumer demands which indicate price remain
to be the limiting factor in feeding bulls. In addition steers have more
marbling which is an important factor in deriving present day federal grades
for carcasses and may not be important to shelf life and palatability.

These data suggests that using bulls in intensive production programs
of young slaughter cattle might be advantageous. Bull calves that are implanted with 48 mg. DES and creep-fed during the pre-weaning period should be reimplanted with 48 mg. DES following weaning at which time they enter the feedlot. Bulls managed in this fashion will yield carcasses comparable to those of steers if they are slaughtered at 14 months of age or younger.
SUMMARY

Experiments involving 314 beef calves were conducted over a 4-year period to investigate the effects of diethylstilbestrol (DES) implants and creep feeding on growth during the pre-weaning period. Calves were implanted and started on creep treatments at 2½ to 3½ months and weaned at 7 to 8 months of age. The carry-over effects of pre-weaning treatments on subsequent feedlot performance and carcass characteristics were studied.

There were no significant differences (P < .05) between bulls and steers or DES implant levels during the pre-weaning period. The high (48 mg.) implant level in bull calves gave the most consistent positive response. Creep-fed calves receiving either free-choice creep or limited-creep gained significantly (P < .005) faster during the pre-weaning period than non-creep-fed calves. Creep feeding beef calves was profitable during each year the experiments were conducted. Calculated on a $0.25 per pound sale price received at weaning, creep feeding increased the value per calf $3.91 to $20.38 over and above the cost of the creep feed. The limited-creep feeding method produced a more consistent weight increase in beef calves than the free-choice method for about one-half the cost. Creep-fed calves gained significantly faster (P < .005) during the 2-week adjustment period following weaning.

Pre-weaning treatments did not adversely affect feedlot performance and carcass characteristics. Cattle that were previously creep-fed required fewer days to reach the slaughter requirements. This difference was significant at the 20% level. Creep-fed cattle in Experiments I, II and III produced more (P < .05) pounds of chilled carcass per day of age.
than cattle that did not receive a creep ration during the pre-weaning period.

During the post-weaning phase bulls gained more rapidly ($P < .07$) in the feedlot than steers, were more efficient in feed conversion ($P < .005$) and produced leaner, more muscular carcasses. Steers graded higher, had higher marbling scores, more backfat and returned more total dollars on both a liveweight or chilled carcass basis. These differences were significant at the $2.5\%$ level or lower.

Oral feeding of DES to steers and bulls did not show any appreciable differences in Experiments I and II. However, DES implantation (48 mg.) caused a significant ($P < .06$) increase in the carcass grade of bulls. Bulls receiving the high implant level tended to grow faster and were fatter than either steers or non-implanted bulls at slaughter, which resulted in a lower estimated retail yield for the treated bulls.

Shear values of $l.\ dorsi$ of steers were significantly ($P < .025$) lower, and trained taste panel participants significantly ($P < .005$) favored steers in terms of tenderness. There was a consistent but non-significant difference between DES-treated bulls (48 mg. implant) in Experiment III and the controls in tenderness of the $l.\ dorsi$ muscle. The $l.\ dorsi$ from bulls in Experiment I was less acceptable in tenderness, juiciness and flavor than muscle from animals of either sex condition which were slaughtered at younger ages (Experiments II and III). Warner-Bratzler shear values were highly correlated ($-.85$) with the final tenderness scores of the trained taste panel. Shear values on $l.\ dorsi$ muscle taken 5 minutes and 24 hours after cooking were significantly ($P < .01$)
correlated.

The effects of sex and age on quality, tenderness and collagen content of bovine $1. \text{dorsi}$ muscle were studied in 20 male calves selected from the same herd and slaughtered at 6, 9, 12, 15 and 18 months of age. Sex and age were of equal importance in affecting muscle tenderness. Steaks from the 6 and 18 month age groups were generally more tender than steaks from the 9, 12 and 15 month age groups when evaluated by the Warner-Bratzler shear instrument or a trained taste panel. Younger animals had significantly larger ribeyes and less backfat per cwt. of chilled carcass than older animals.

Connective tissue residues isolated from the $1. \text{dorsi}$ of the 6 and 9 month age groups contained a higher ($P < .05$) percentage moisture than similar residues from the 15 and 18 month age groups. Protein content of the connective tissue residue increased gradually with increasing age of the animal. The 6 and 9 month age groups had a higher ($P < .05$) collagen content in the connective tissue residue than the two oldest (15 and 18 months) groups. A low correlation was found between tenderness measures and collagen content of bovine beef muscle from the various age groups. Collagen, measured as hydroxyproline, was not a critical measure of $1. \text{dorsi}$ tenderness.
BIBLIOGRAPHY


Amschler, J. W. and R. Meinx.

Andreae, U.

Arizona Annual Report.

Arizona Annual Report.

Arthaud, V. H.

Bailey, C. M., C. L. Probert and V. R. Bohman.

Bailey, C. M., C. L. Probert, P. Richardson, V. R. Bohman and J. Chancerelle.
1930. Beef from calves fed grain before and after weaning. U.S.D.A.

1955. Ádatok a növendékek bikák és tinók hízlalásához. Állattenyésztés.
4:121.

1962. Effect of stilbestrol implants during the pre-weaning period
on post-weaning feedlot performance of steers and heifers
116.

Brännäng, E.
1960. Kastrationsförsök på SRB-tvillingar. Lantmannen. (Stockh.)
71:46.

1954. The effect of testosterone and castration on the growth and

Bray, C. I.
1934. Feeding grain to beef calves on pasture before weaning. La.


Brinks, J. S., R. T. Clark, F. J. Rice and N. M. Kieffer.
1961. Adjusting birth weight, weaning weight and pre-weaning gain
20:363.

Brown, C. J., J. D. Bartee and P. K. Lewis, Jr.
1962. Relationships among performance records, carcass cut-out data,
Bul. 655.

Brown, C. J., P. K. Lewis, Jr., and N. C. Heck.
1963. Relationships between performance test information and carcass
cut-out data and eating quality of steaks from beef bulls.

Brungardt, V. H. and R. W. Bray.
1963. Estimate of retail yield of the four major cuts in the beef
Burns, W. C., R. E. Deese and M. Koger.

Burns, W. C. and M. Koger.
1963. Response of different breed groups to creep feeding.


Casas, M. and N. S. Raun.


Charette, L. A.

Charette, L. A.


Cmarik, C. F.

Cmarik, C. F.

Conrad, B. E. and E. M. Neal.
Cundiff, L. V.  


Duncan, D. B.  


Eastoe, J. E. and A. A. Leach.  

Ewing, S. A. and W. Burroughs.  


Foster, J. E., H. H. Biswell and E. H. Hostetler.  


1965. Cutability of bull, steer and heifer carcasses. (Abstract)  

Kirillov, M. and V. Gorbačev.  

Klosterman, E. W., V. R. Cahill, L. E. Kunkle and A. L. Moxon.  

Klosterman, E. W., V. R. Cahill, L. E. Kunkle and A. L. Moxon.  


Kuhlman, L. R., A. B. Nelson and W. D. Campbell.  


Marlowe, T. J. and J. A. Gaines.  

Martin, T. G., J. L. Albright and M. Stob.  

Martin, T. G., L. W. Douglass and V. A. Garwood.  


Matsushima, J. K. and J. I. Sprague.  


Melton, A. A. and J. K. Riggs.  

Migda, I. and A. Močalovský.  


Nelson, A. B., L. R. Kuhlman and W. D. Campbell.  

Nelson, A. B., L. R. Kuhlman, R. D. Furr, W. D. Campbell and G. R. Waller, Jr.  

Nesler, R. J., H. W. Essig and W. A. Fend.  

Pálsson, H.  


Pícha, J. and Z. Župka.  


Ralston, A. T.  

Ralston, A. T., D. C. Church and W. H. Kennick.  

Richter, K.

Rostovcev, N. F.

Snedecor, G. W.


Temple, R. S.


Tyleček, J.

United States Beef Cattle Records Committee Report.

Walker, D. E.
Wallace, L. R.  


Warwick, E. J., R. J. Hiner and R. E. Davis.  

Watson, W. P.  


Wierbicki, E., L. E. Kunkle, V. R. Cahill and F. E. Deatherage.  

Williams, J. N., II.  


Wilson, L. L., C. J. Kaiser and K. Hawkins.  


Woessner, J. F.  

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to:

Dr. Wise Burroughs for his guidance and encouragement throughout these studies;

Dr. Richard Vetter for his inspiration, his helpful suggestion in all phases of this work and his valuable assistance in the preparation of this dissertation;

Dr. Edwin Kline for his suggestions and guidance in the taste panel evaluation phase of the dissertation;

Mr. Gary D. Harter for his advice and assistance in conducting the statistical analysis of these studies;

Mr. F. H. McGuire and co-workers at the Iowa State University Beef Nutrition Farm for feeding and care of experimental animals;

He also wishes to thank his wife, Carole, and son, Brad, for their personal assistance and encouragement throughout his graduate studies.