# The Effect of Diethylstilbestrol and Methyltestosterone on the Growth, Carcass Characteristics, and Nitrogen Retention of Growing Swine

By
ERNEST W. LUCAS

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Abstract of Dissertation Presented to the
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# THE EFFECT OF DIETHYLSTILBESTROL AND METHYLTESTOSTERONE ON THE GROWTH, CARCASS CHARACTERISTICS, AND NITROGEN RETENTION OF GROWING SWINE

By

Ernest W. Lucas

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Chairman: H. D. Wallace
Major Department: Animal Science

Experiments were conducted to determine the effects of a combination of 2.2 mg each of diethylstilbestrol and methyltestosterone (DES + MT) per kg of feed on the feedlot performance, carcass characteristics, and nitrogen retention of growing-finishing swine. The interrelationships between hormone supplementation and dietary protein level and sex were also investigated. A total of 6 trials, involving 205 crossbred pigs, were conducted. Of these, 4 were feeding and carcass experiments and 2 were metabolism trials. Practical corn-soybean meal rations with 12, 14, or 16 percent protein were fed with and without DES + MT to growing-finishing barrows and gilts.

Hormone supplementation caused a decrease in average daily gain and average daily feed consumption, but improved feed conversion efficiency. Protein level did not significantly affect feed intake, feed efficiency, or rate of gain. Barrows ate more feed and gained faster than gilts.

Carcass leanness was markedly improved by hormone supplementation. Evidence of this was seen in an increased percentage of lean cuts, both individually and as the 4 lean primal cuts, in pigs fed DES + MT. There was also a decreased backfat thickness and increased carcass length due to hormone supplementation. In addition, pigs fed higher protein levels were leaner than those fed lower protein levels. Gilts were leaner than barrows.

Carcass subjective measurements were not affected by any treatment. There was a significantly increased incidence of boar odor and flavor in the meat of pigs fed DES + MT. This boar odor markedly decreased the eating quality of meat of treated pigs in some cases.

Chemical composition of meat was significantly but not consistently affected in 2 trials by DES + MT.

Nitrogen retention was not enhanced by feeding DES + MT in 2 experiments.

Excretion of 17-ketosteroids in urine was significantly but not consistently affected by hormone supplementation.

Interactions of hormone supplementation with both sex and protein level were observed; these obscured some main effects. Interactions affecting average daily gain, average daily feed intake, dressing percentage, yield of lean cuts, average backfat thickness, average loin eye area, and carcass length were observed.

The mode of action of DES + MT in improving carcass leanness was not clear. The effects of hormone supplementation were not consistently manifested in all trials, although there was in general a trend toward decreased feed intake and rate of gain, increased feed efficiency, and

improved carcass leanness due to DES + MT. Although DES + MT can be of significant benefit in improving feed conversion efficiency and carcass leanness, these benefits may be partially offset by the presence of boar odor and flavor in the meat of some treated pigs.

# INTRODUCTION

The use of feed additives and chemotherapeutics in animal rations for the purpose of improving performance and production is a topic of continuing interest in the nutrition field. Experiments have been conducted with all species of domestic livestock for the purpose of developing, testing, and evaluating various chemotherapeutics for use in livestock rations. Many of these compounds are in general use today.

Recent trends in consumer preference have focused attention on the need for animals which will gain efficiently and produce lean, meaty carcasses without excess fat trim.

About 20 years ago it was discovered that the addition of certain estrogenic substances to the rations of beef cattle in the feedlot produced beneficial responses in these cattle. Among the effects were improved feed efficiency and gains, heavier muscling, increased nitrogen retention and decreased fat deposition. It has become standard practice to feed or implant this material, diethylstilbestrol, to finishing cattle nearly everywhere in the U.S.

The advent of diethylstilbestrol feeding in cattle has sparked a whole field of research involving hormone feeding, using most species of domestic animals. Although the merits of diethylstilbestrol are proven in the case of ruminants, the responses in monogastric species have been somewhat varied. Several other estrogenic substances have

been investigated as potential feed additives, as well as numerous androgenic compounds. Recently, work using combinations of estrogen and androgen has been done.

Research with hormones as chemotherapeutics for swine has been conducted since the early 1950's, with varying results. Evidence pro and con has been collected for several different hormones, including diethylstilbestrol and methyltestosterone, the most widely used estrogen and androgen, respectively. Recent work indicates that a combination of these two compounds fed to growing-finishing swine is more effective in stimulating efficiency, carcass quality, and leanness than either one alone.

The purpose of this study was to investigate the effects of a dietary combination of diethylstilbestrol (DES) and methyltestosterone (MT), fed at 2.2 mg each per kg of feed, on the growth, carcass characteristics, and nitrogen retention of growing-finishing pigs.

## REVIEW OF LITERATURE

### The Effects of Sex on the Growth and Carcass Quality of Swine

Sex has been recognized for many years as a factor which affects the performance of meat animals. Differences in growth, efficiency, and carcass characteristics between the genders are common in most species. Swine are prone to show sex differences in performance and carcass quality.

Blair and English (1965) reported on an experiment designed to measure sex differences in growth and carcass quality in growing-finishing pigs. These workers fed boars, gilts, and barrows on a similar ration from weaning to market weight and measured carcass parameters and feedlot performance. They reported significant differences among sexes in the various standard carcass parameters. Boars had significantly less backfat than either barrows or gilts. In addition, boars and gilts showed a significantly larger loin eye area than barrows.

Wallace (1965) reviewed the effects of sex influences (barrows vs. gilts) on finishing swine and concluded that gilts gained more slowly but more efficiently than barrows, and that gilts were superior to barrows in all aspects relating to carcass leanness.

Kolaczyk and Kotik (1966) compared muscle properties of barrows and gilts. The meat of gilts had a significantly higher percentage of

moisture than that of barrows. Barrows exhibited significantly more fat in the meat than gilts. No significant difference was observed between barrows and gilts for nitrogen content of lean meat. Gilts, however, had a significantly higher myoglobin level in the muscle than barrows; as a result, the meat of gilts was significantly darker than that of barrows.

Hale and Southwell (1967) measured differences in swine performance and carcass characteristics due to dietary protein, sex, and breed. They fed 60 weanling pigs in a 3 x 2 x 2 factorial experiment to study effects of level of protein sequence (18 - 15%; 16 - 13%; and 14 - 11%), sex (barrow and gilt), and breed (Duroc and Hampshire), on performance and carcass traits of growing-finishing swine. Sex differences were noted by these authors. They reported that barrows gained significantly faster than gilts, but that gilts had a significantly higher dressing percentage than barrows. In addition, the carcasses of gilts were significantly longer, had less backfat, larger loin eye area, and a higher percentage of lean primal cuts than those of barrows.

Hale, Johnson, and Warren (1968) studied the effect of season, sex, and energy level on performance and carcass traits of pigs. They used 80 weanling Duroc barrows and gilts, and reported that barrows consumed significantly more feed per day and needed more feed per unit of gain than gilts. Gilts, however, yielded carcasses that were significantly longer, leaner, had a larger loin eye area, and had a higher percentage of lean primal cuts than barrow carcasses.

Swierstra and Rahnfeld (1968) studied growth, carcass measurements, and sexual development of partially or completely castrated pigs.

They reported no differences in rate of gain, age at slaughter, dressing percentage, ham weight, loin eye area, average backfat thickness, or carcass length between pigs partially castrated by Baiburtcjan's method and pigs completely castrated.

Wong, Boylon, and Stothers (1968) performed an experiment to study differences in performance and carcass traits of swine due to sex and dietary protein level. One group of pigs containing equal numbers of boars, barrows, and gilts with an initial average weight of 22.5 kg was given a growing ration (17% protein) until slaughter at an average weight of 88.6 kg. A similar group of pigs received the growing ration to a body weight of 50 kg and then a finishing ration (13% protein) until slaughter. No differences due to protein were observed, but significant differences between sexes were found for average daily gain and feed per unit of gain. Boars exceeded barrows by 7 percent and gilts by 5 percent in average daily gain. Boars required 16 percent less feed per unit of gain than barrows. Gilts exceeded boars and barrows in loin eye area. Both boars and gilts were superior to barrows in percent lean in the ham face.

On the basis of the previously cited experiments, it seems reasonable to conclude that there is a real sex difference in performance and carcass quality in swine. When only performance and carcass objective measurements are considered, boars rank superior to gilts, and gilts rank superior to barrows. In light of the differences observed between the sexes in performance and carcass traits, it seems logical to assume that the cause of these differences might be due to the presence or absence of the natural sex hormones produced in the gonads.

## Sex Odor in Pork

Castration of male farm animals is a practice which is nearly as old as the domestication of animals. Benefits originally sought were those of greater tractability in work animals. Physiological changes and ensuing material developmental changes occur in animals following castration. The effect of castration on growth, feed efficiency, carcass traits, and meat quality must be weighed against the inherent advantages in growing uncastrated males. Literature previously cited shows that there might be an economic advantage, in addition to breeding and selection advantages, in feeding intact boars.

In swine, however, the phenomenon known as "sex odor," "boar odor," or "taint" occurs to some degree in the fat and meat of intact males. Martin (1969), in a review of the sex odor problem in pork, documents cases of sex odor in boars as far back as 1936. This odor or flavor has caused a discrimination by packers and consumers against the meat of intact male swine. In spite of the advantages in performance and carcass traits which boars exhibit, it is not economically feasible to feed boars.

In his review, Martin (1969) notes that comprehensive studies of carcasses of pigs of all sexes, conducted at commercial slaughterhouses, showed that 17 percent of all hogs, regardless of sex, exhibited medium to strong sex odor. The problem is not confined to boars. This observation is corroborated by Williams, Pearson, and Webb (1963), who studied the incidence of sex odor in boars, sows, barrows, and gilts. Incidence of sex odor was studied using fat samples from the flank area or ham facing of 79 boars, 78 sows, 86 barrows, and 96 gilts.

Results indicated that the occurrence of sex odor was largely, but not exclusively, dependent on the sex of the animal. Boars were found to have 64 percent incidence of sex odor, significantly higher than any other group tested. No significant differences could be found between the percent incidence of sex odor in sows, barrows, and gilts, which were found to have 1 percent, 5 percent, and 5 percent incidence, respectively.

Blair and English (1965) reported significantly more boar odor in boar meat and fat than in barrow or gilt meat and fat, but were unable to demonstrate any differences in flavor.

Charette (1961) indicated little or no undesirable odor in boar carcasses.

Martin, Freden, and Stothart (1968) evaluated the quality of cooked pork from 144 pigs consisting of an equal number of barrows, boars, gilts, and ridglings which ranged from 87 to 93 kg live weight at time of slaughter. Ham steaks, prepared and cooked by a standard procedure, were evaluated for cooking aroma, tenderness, juiciness, texture, flavor, and overall preference by a panel of 6 trained judges. Samples were scored on a 1 to 10 hedonic scale with 10 representing the most favorable score. For tenderness and texture, the samples from boars ranked highest, followed by gilts, barrows, and ridglings. All sex differences were significant for these two characteristics. Ranking for overall score and overall preference by judges was in this same order. Samples from barrows and ridglings scored higher for cooking aroma than samples from boars and gilts, although only 3 boars and 1 gilt were judged unacceptable. However, the authors noted that aroma was not highly correlated with flavor, and samples which scored low on aroma were often quite acceptable for flavor.

Craig and Pearson (1959), in a preliminary study on sex odor in pork, reported that sex odor was strongest in the parotid gland, fat, testicles, penis, and preputial diverticulum. The study was conducted on the tissues of an 18 month old boar. They noted that fat or lean with intramuscular fat produced boar odor when heated to the boiling point in water. A barrow control failed to produce boar odor upon heating. Ether extraction of the freeze-dried lean tissue produced an extract which appeared to contain the odor component, which the extracted lean did not. Ether or carbon tetrachloride extracted fat did not give off sex odor when heated. This led the authors to conclude that sex odor in pork is found only in the fatty tissues and that the odor-contributing elements may be separated from the fat by a selective extraction process.

In another study, Craig (1960) was unable to detect sex odor in any aqueous distillation condensates of boar fat, although a strong sex odor was evident in the fat prior to distillation. This further demonstrated the lipophilic nature of the sex odor component. Fat from boars did not differ significantly from that of barrows with regard to nitrogen content.

Craig (1961), in a dissertation abstract, reported that the odor component of boar fat was not readily volatilized below 100° C. He was unable to isolate the component from any solvent fraction by collecting distillates.

Craig, Pearson, and Webb (1962) reported the findings of a series of experiments to fractionate the components responsible for sex odor in pork. They noted that sex odor was produced when fat, lean with

fat in it, and most organs from a boar were heated in a skillet or in hot water. Odor volatilized most greatly at 100° to 108° C, but was not entirely absent at body temperature. The sex odor component was found to be water insoluble, ether soluble and definitely associated with the fatty tissues of boars. The odor was absent in reconstituted moisture-free, fat-free lean tissue. Distillation methods were regarded as unsuccessful in collecting sex odor components in any recognizable form. No differences in distillates of boar and barrow fat were detected by heat tests or gas chromatography. Cold saponification of boar fat yielded a small amount of unsaponifiable matter which produced a concentrated, permeating sex odor on heating. The authors concluded that the agents responsible for sex odor are located in the unsaponifiable fraction of boar fat. Cholesterol and squalene were found in this fraction of both boar and barrow fat, but sex odor was not produced when either of these compounds was heated.

Patterson (1966) isolated large amounts of para-cresol, a metabolite of tyrosine, from the phenolic fraction of boar preputial fluid. It was not concluded that para-cresol was directly responsible for the characteristic sex odor of heated boar fat, although it does contribute significantly to the odor of the live boar and its immediate environment.

In a second paper, Patterson (1968a) identified a derivative of the male sex hormone as the odor component in boar fat. This substance, 5-α-androst-16-ene-3-one, is a lipophilic ketone, and is found in the fat of mature boars. This compound was found to have the empirical formula $C_{19}H_{28}O$, differing from the male hormone testosterone only by

a single oxygen atom and from androsterone by the elements of a molecule of water. The author concluded that the source of the odor component was a metabolite of the male sex hormones.

Patterson (1968b) later shed more light on the pathway of formation of the boar odor component. A musk odor compound, 3-α-hydroxy-5-α-androst-16-ene, was isolated from the submaxillary salivary glands of all boars tested, but not from the glands of barrows or gilts. This secondary alcohol is a musk odor compound distinctly different from the ketone previously isolated from boar fat. The alcohol was successfully oxidized *in vitro* to the ketone, and the odor changed from a musk to a boar taint. Since male sex hormones, the musk odor alcohol, and the boar odor ketone all are so similar in structure, the author concluded that both odor compounds were under testicular control. A pathway by which testosterone could be transformed to 3-β-hydroxy-5-α-androst-16-ene was suggested. The β epimer also possesses musk odor activity, but the α epimer is much stronger. It may be that epimerization of the β compound to the α epimer occurs, since salivary glands of boars contained almost exclusively the α substance.

Patterson (1968b) suggested an interesting hypothesis as to the means of incorporation of boar odor into the fat of boars. He observed that it was possible to detect the presence of the musk odor alcohol in the submaxillary glands of young boars before the boar odor ketone appeared in the gland or fat, and that the detection of the ketone, as well as the alcohol, in the salivary glands of older boars shows that the ketone is formed by the oxidation of the alcohol at a later stage of maturity. He noted that the concentration of androstenol was

relatively high in the salivary gland of mature boars compared to the androstenone concentration, but that in depot fat the opposite was true. This observation led him to suggest that the submaxillary salivary gland is either the site of formation of the androstenol, or that it acts as a reservoir for the substance, presumably extracting it from the bloodstream. He also noted that musk odors are known sex attractants and that either androstenol or androstenone in the saliva may act in this capacity. The sexual behavior of boars and sows suggests an attractant of some kind present in the head of the boar. Since the saliva was found to possess the odor of 5-α-androst-16-ene-3-one, ingestion of the ketone in the saliva will result in its incorporation into the body as a result of the normal digestive process. Because of its ketone structure, deposition in adipose tissue will occur preferentially to other tissues. The hydrophilic alcohol, on the other hand, will be eliminated from the body in its normal water-soluble state. This would explain the presence of the androstenone but absence of androstenol in the depot fat of mature boars.

Weir et al. (1962) reported on a study of the composition and organoleptic properties of pork chops as affected by cooking procedures. They noted an increased percentage of fat on a dry weight basis for the lean of cooked chops over the lean of raw chops. This was due to migration of external fat into the meat during cooking. The authors suggested that the phenomenon may be of some significance in the odor, flavor, and texture of cooked meat.

From the evidence presented in the papers previously cited several conclusions regarding sex odor may be drawn.

Research has shown that boar odor appears to be sex-limited and associated with the presence of a ketone derivative of testosterone, found in the fatty tissues of tainted carcasses.

All factors affecting the incidence of boar odor are not yet known, but stage of maturity is very important. Incidence of boar odor is high in mature boars and very low or nil in boars slaughtered at 70 kg live weight or in boars which reach conventional slaughter (90 kg) at a young age.

The assumption that all boar carcasses contain taint is invalid, as well as the assumption that all barrow and gilt carcasses do not contain taint.

## The Effects of Estrogens on the Growth and Carcass Quality of Swine

Diethylstilbestrol (DES), a synthetic estrogen, came into vogue as a feed additive for cattle in the late 1940's and early 1950's. During this period a number of workers began feeding or implanting estrogens and other humoral substances in several species of domestic livestock in an attempt to realize benefits similar to those obtained in cattle supplemented with DES.

Woehling et al. (1951) were among the first workers to study the effects of DES on swine. These workers fed 42 growing-finishing pigs on a standard ration. Treatment was applied by subcutaneously implanting 2 lots of 7 pigs each with 12 mg of DES at the start of the experiment and again at 12 weeks. Pigs averaged 19.5 kg at the start of the experiment and were slaughtered as they reached 95 kg.

Average daily gain, average daily feed intake, feed required for each unit of gain, dressing percentage, carcass length, weight of ham, loin eye area, and backfat thickness were among the characteristics studied. These workers reported no significant differences due to DES in any of these parameters.

Dinusson, Klosterman, and Buchanan (1951) implanted 12 or 25 mg of DES in barrows and gilts. Average initial weight was 20 or 45 kg. These workers did not observe any response in rate of gain or carcass parameters due to DES. They did report, however, that DES implanted hogs required 5 to 14 percent less feed per unit of gain than control hogs.

Pearson et al. (1952) conducted 3 experiments to determine the effects of DES implants on average daily gain, feed efficiency, and carcass characteristics of growing-finishing swine of different sexes. Barrows, gilts, and boars weighing 16 or 42 kg initially were subcutaneously implanted with DES. Level of dosage used was 25 mg initially, 25 mg again at 1 month, and 50 mg at 2 months. These workers reported no significant difference in rate of gain of barrows or gilts caused by implanting DES, but there was a growth depression in young implanted boars. No effect on feed efficiency due to DES was observed. No differences in backfat thickness, carcass grade, or tenderness were apparent. DES had little or no influence on acceptability ratings of pork loin roasts and did not appear to increase the eating qualities of boar meat.

Beeson et al. (1955) conducted an investigation with barrows and gilts weighing 20 kg initially, and fed a practical ration containing

DES in a quantity to supply 2 mg per animal per day. The treatment did not improve growth rate or feed efficiency. There was a trend toward leaner carcasses in the pigs fed DES, but no significant differences were observed.

Taylor et al. (1955) studied the effects of orally administered stilbestrol at levels of 0, 22, 44, 88, 176, 352, 704, 1408, or 2816 µg of DES per kg of feed on the growth, carcass traits, and organ development of growing-finishing pigs. A total of 120 pigs averaging 15 kg initially was finished to a terminal weight of 91 kg. No differences in average daily gain or feed conversion were observed due to feeding DES. Carcass differences were not significant. Stimulation of female secondary sexual characteristics was observed in the development of certain organs in both barrows and gilts.

Heitman and Clegg (1957) used 136 barrows and gilts in 4 experiments and compared untreated pigs with pigs implanted with 30 or 60 mg of DES. Implanted pigs showed reduced gains, improved feed efficiency, less backfat, and a greater percentage of lean primal cuts than untreated pigs. The authors postulated that a possible protein anabolic effect due to stilbestrol implantation could be causing the increased carcass leanness.

Sewell, Warren, and O'Mary (1957) fed barrows and gilts averaging 18 kg initially to determine the effects of DES supplied orally at levels 0, 1.1, 4.4, or 5.5 mg per kg of feed. They reported that gains were not affected consistently in 3 different trials by DES supplementation.

Cahill et al. (1959) studied the influence of implanting stilbestrol on the carcass composition of boars, barrows, and gilts at 3 stages of maturity. They reported that stilbestrol implants of 1.5, 3.0, or 6.0 mg at 68 kg body weight had little effect on growth rate or feed conversion ratio. They noted that a positive correlation existed between level of DES implanted and both size of loin eye and percentage of lean primal cuts.

Day et al. (1960) conducted a trial to determine the effects of diethylstilbestrol and a combination of progesterone and estradiol on growing-finishing swine. Poland China barrows were fed to market weight on a practical diet. Treatments were administered by implanting 6 mg of DES, 166.7 mg of progesterone plus 3.3 mg of estradiol benzoate, or 500 mg of progesterone plus 10 mg of estradiol benzoate. Differences in rate and efficiency of gain among the 4 treatment groups were not statistically significant. Backfat thickness was generally reduced by the hormone treatments, with both levels of the progesterone-estradiol combination showing a significant effect. Backfat probes for the 4 treatments averaged 3.91, 3.76, 3.56, and 3.45 cm respectively for the control, DES, low level progesterone-estradiol, and high level progesterone-estradiol treatments. Carcasses of pigs administered the high level of progesterone-estrogen treatment had the lowest percentage of fat and highest yield of lean, evidenced by a significantly higher percentage of lean primal cuts, larger loin eye area, and lower backfat thickness than other treatment groups.

Beacom (1963) studied the effect of stilbestrol and estradiol-testosterone implants on performance and carcass traits of market swine fed different finishing diets. He reported no differences in growth rate between control pigs and implanted pigs, but hormone implants significantly decreased average daily feed intake. Carcass parameters exhibited no significant differences between control and implanted pigs.

Gorrill, Bell, and Williams (1964) reported on an experiment designed to measure the effects of DES implantation on the performance of pigs on a restricted feeding regimen. Pigs weighing 50 kg initially were implanted with 12 mg of DES and finished to 91 kg. Implantation with DES reduced barrow average daily gain from 0.69 kg to 0.62 kg, but had no effect on gilt average daily gain. Feed intake of barrows was reduced from 2.72 kg to 2.41 by DES, but gilt feed intake was affected in the reverse manner, going from 2.27 kg to 2.45 kg. Implanted gilts digested protein better than did control gilts, but the opposite was true for barrows. Loin eye area and backfat thickness were only slightly affected by DES, although the trend was favorable in both cases.

Teague et al. (1964) conducted 7 trials to determine the effectiveness of implanting boars with DES as a method for overcoming or delaying the development of the odor or flavor commonly associated with boar meat, and for retaining or further improving the favorable performance and muscling characteristics of the boar. The feedlot performance and carcass traits of market barrows, boars, and boars implanted with 48 mg of DES at 70 kg or 96 mg of DES at 65, 70, or

75 kg were compared. Boars implanted with 96 mg of DES at 70 kg had a significantly faster rate of gain than other groups. Feed conversion was also favorably affected in this same group. The authors found that carcasses of barrows were significantly shorter and fatter than those of either boars or implanted boars. Sex odor and flavor in the 10th rib chops were significantly reduced by implantation with DES. In addition, no carcasses of boars implanted with DES were condemned for odor or flavor.

Plimpton (1966) implanted boars with 96 mg of DES at 70 kg and fed them to 136 kg to determine the effects of the drug during extended growth on carcass composition, muscle quality, and palatability of meat. Average daily gain and percentage of lean primal cuts were significantly increased in implanted boars. Sex odor in meat of implanted boars was significantly reduced. No differences were observed in marbling or color of the loin eye. Chemical evaluation of the loin eye muscle showed no difference due to DES except percentage of moisture and fat. Implanted pigs had significantly more moisture and less fat in the lean of the longissimus dorsi muscle.

Plimpton et al. (1967) studied the performance, carcass traits, and carcass composition of barrows, boars, and boars implanted with 96 mg of DES measured from live weight of 70.4 kg to 136.1 kg. Carcass measurements were related to treatment, age, time of slaughter, and carcass weight. Implantation of boars with 96 mg of DES at 70.4 kg increased rate of gain and rate of lean primal cut deposition. The rate of deposition of lean cuts was increased in implanted boars, compared to control boars, for 10 of the 12 weeks following

implantation. This period also coincided with the time during which DES significantly repressed sex odor in treated boars. All boars, regardless of treatment, had carcasses significantly longer, leaner, and with a higher yield of lean primal cuts than the carcasses of littermate barrows of the same weight. A trend toward increased loin eye area due to DES was observed. The yield of edible portion of ham from boars was significantly more than that from barrows, and the percentage of fat in the ham was also significantly lower for boars. Measures of growth such as loin eye area, carcass length, and percentage of lean primal cuts were observed to increase in a linear fashion with increasing age and weight. Differences in carcass composition were related to changes in weight.

Echternkamp et al. (1969) studied the relationship between intensity of boar odor and flavor and glandular development in normal and DES implanted boars. They reported that implanting 96 mg of DES at 70.3 kg significantly reduced the incidence of boar odor and flavor to a live weight of 127 kg. In addition, DES significantly increased average daily gain up to 104 kg and decreased the weight of accessory sex glands. These authors also reported that there was a high correlation between odor and flavor scores. They concluded that DES prevented or delayed the development of boar odor and flavor.

Hale and Johnson (1970) fed 144 weanling Duroc barrows individually to study the effects of season (summer vs. winter), energy concentration (high vs. low), and orally administered hormones (none, diethylstilbestrol, or methyltestosterone), on performance in the feedlot and on carcass characteristics of the pigs. The only

significant effect of feeding 2 mg of DES per day was a 2 percent increase in the weight of the lean primal cuts.

The papers previously cited provide a general picture of the effect of estrogens, notably diethylstilbestrol, on the performance and carcass characteristics of swine. Although different workers have observed conflicting results in some cases, an overall trend is apparent. Treatment with DES generally reduces feed intake and improves feed conversion. Growth is usually depressed in barrows and gilts, but may be increased in boars. There seems to be a definite improvement in carcass leanness in all sexes. DES has also shown ability to suppress or delay the development of boar odor or flavor, at least up to 100 kg of body weight. Benefits in feed efficiency and leanness due to DES are not apparent in younger pigs, but in pigs from 45 kg to market weight, DES can be of some value in improving efficiency and leanness.

## The Effects of Androgens on the Growth and Carcass Quality of Swine

Researchers have long known that males generally produce leaner, more heavily muscled carcasses than do females or castrate males. Literature previously cited documents sex differences in growth and carcass quality in swine. Researchers have attempted to produce this increased leanness and muscling in females and castrated males by replacement therapy with testosterone since the early 1950's.

Woehling et al. (1951) implanted 30 mg of testosterone in 20 kg barrows and gilts at the start of the experiment and again at 12 weeks.

They were unable to demonstrate a response in any performance or carcass parameter due to testosterone therapy.

Noland and Burris (1956) fed methyltestosterone (MT) at a level of 0, 0.015, 0.15, or 1.5 mg per kg of body weight to boars, barrows, gilts, and castrated gilts. They noted that the rate of body weight gain of females was slightly depressed by 0.15 mg of MT per kg of body weight, but gains of males were not affected. All sexes fed MT had leaner carcasses, evidenced by a higher percentage yield of lean primal cuts, compared to control pigs. The authors noted that boars fed the highest level of MT exhibited markedly depressed spermatogenesis, and interstitial tissue development in all boars fed MT was depressed. They concluded that the levels of MT fed were not effective in inducing any growth stimulus.

Bratzler et al. (1954) made carcass comparisons of boars, testosterone implanted barrows (193 mg of testosterone per pig), and barrows castrated at 18, 45, 64, or 82 kg. Boars and 82 kg castrates had a higher percent of lean in the rough loin, less backfat, longer carcasses, and a higher live weight and lean primal cut yield. Quality of boar pork was judged unacceptable in palatability tests for odor and flavor, but no difference in palatibility of chops between control barrows and barrows implanted with testosterone propionate was observed.. In this trial no differences due to testosterone or castration were observed in rate or gain or feed conversion.

Beeson et al. (1955) administered 20 mg of MT per pig per day in a practical ration to barrows and gilts fed from 23 kg to market

weight. Growth rate and feed efficiency were unaffected, but carcasses from testosterone fed pigs contained heavier lean cuts (ham, loin, Boston butt, picnic shoulder) and lighter fat cuts (fat backs, bellies, jowls) than carcasses from control pigs. The percentage yield for lean primal cuts was 62.4 percent for testosterone fed pigs and 58.8 percent for control pigs. Chemical analysis of carcass composition showed 5 percent less fat and 5 percent more lean in testosterone fed pigs than in control pigs.

Perry et al. (1956) tested the effect of various levels of orally administered MT (0 to 62 mg of MT per pig per day) on the growth and carcass composition of growing-finishing barrows and gilts fed from 23 kg to market weight. They reported that a daily intake of 27 mg or more of MT resulted in a highly significant growth depression, but also resulted in decreased fat deposition evidenced by decreased backfat thickness.

Johnston, Zeller, and Hiner (1957) fed MT to swine at levels of 20 or 33 mg of MT per kg of feed. In 5 experiments they noted that MT decreased rate of gain, average daily feed intake, backfat thickness, and feed efficiency. There was no odor or flavor problem reported in the meat of testosterone supplemented pigs. The authors concluded that MT increased the ratio of lean to fat in the carcasses of swine.

Whiteker et al. (1959) studied the effects of various androgens at different levels on growth and carcass traits of pigs. They fed 96 barrows and gilts in 3 trials on practical diets containing either methyltestosterone, methylandrostenediol, thyroprotein, or a combination

of the latter two. Rate of gain was not significantly affected by any of these additives. Pigs fed the combination of methylandrostenediol and thyroprotein produced significantly leaner carcasses than did those pigs fed either drug singly. Pigs fed MT produced carcasses that had a significantly higher percentage of lean than did pigs fed the basal ration. None of the treatments caused an adverse flavor or odor in the meat. Loin protein content was not significantly affected by any of the treatments. Masculine behavior and characteristics were noted in the animals receiving MT.

Thrasher et al. (1959) conducted 3 experiments to determine the effects of various testosterone analogs, combinations of testosterone and stilbestrol, and late castration on the performance and carcass quality of swine. No differences due to treatment were observed in any parameter tested, although there was a trend toward increased leanness in pigs fed MT singly or in combination with DES.

Baird and McCampbell (1959) reported no differences in feedlot performance or carcass quality in pigs fed 0.55 mg of hydroxyzine per kg of feed. Another test comparing androgenic compounds with DES, estradiol-progesterone, and a basal ration failed to show any significant differences due to any treatment. Other combinations of hormones and tranquilizer substances were tested and they also failed to produce any changes in growth or carcasses of swine.

Cantwell, Johnston, and Tabler (1962) fed swine methyltestosterone and 17-ethyl-19-nortestosterone under various experimental conditions to determine their effects on growth and carcass characteristics, with special emphasis on glands and internal organs.

Methyltestosterone and 17-ethyl-19-nortestosterone fed at 20 to 33 mg per kg of feed singly and in combination with stilbestrol at 13 mg per kg of feed caused highly significant increases in weight of liver, kidney, heart, and thymus gland. Average daily gain was decreased significantly, as was adrenal gland weight. The authors reported that methylstestosterone was more potent than 17-ethyl-19-nortestosterone.

Mente et al, (1962) studied the effect of 9-fluoro-11-hydroxy-17-methyltestosterone (Halotestin), a testosterone analog of great potency. Barrows and gilts weighing 32 to 57 kg were fed 0 to 27.5 mg of Halotestin per kg of diet. They reported a significant decrease in backfat thickness, and an increase in percent yield of lean primal cuts due to Halotestin. Gains were depressed in pigs fed the hormone compared to gains of those fed the basal diet.

Hale and Johnson (1970) fed weanling pigs methyltestosterone at a level of 20 mg per day. They reported that MT decreased rate of gain, daily feed intake, dressing percentage, and backfat thickness, but increased carcass length, area of loin eye, and weight of the 4 lean cuts. They concluded that methyltestosterone had a potent anabolic action in swine, evidenced by the increased leanness in carcasses of pigs fed MT.

The previously cited papers present a review of the effects of androgenic compounds on the growth and carcass characteristics of swine. Of all androgens in use, methyltestosterone is probably one of the most practical and anabolically potent. There seems to be rather strong evidence that MT is capable of inducing in swine

measurable carcass changes in a favorable direction. These papers indicate that pigs fed methyltestosterone gain more efficiently, and produce leaner, meatier carcasses than do pigs fed normal rations. There is some evidence that high level testosterone therapy may produce significant odor or flavor problems in pork.

## The Effects of Combinations of Androgens and Estrogens on the Performance and Carcass Quality of Swine

Research has indicated that there is some benefit to be derived from feeding or implanting estrogens or androgens in growing swine of all sexes. Although changes in performance and carcass are not always great or drastic, there is nevertheless a definite trend toward decreased feed consumption and increased carcass leanness due to hormone therapy. Since estrogen supplementation has shown particular usefulness with regard to boars, some workers feel that using the combination of androgen and estrogen in barrows and gilts would prove more beneficial than either compound used singly. Work has been done using combinations of estrogenic and androgenic drugs to determine if the effects of the two substances used together are additive.

Thrasher et al. (1959) studied combinations of testosterone and stilbestrol and their effects on carcass quality and feedlot performance in growing-finishing pigs. In 3 trials involving a total of 180 pigs they reported a non-significant trend toward increased carcass leanness.

Beacom (1963) implanted finishing pigs with a combination of estradiol and testosterone. He observed no difference in growth rate between controls and treated pigs, but there was a significant decrease in average daily feed consumption caused by the estradiol-testosterone implant combination. Beacom also reported an increase in loin eye area in treated pigs fed a low energy diet. Other indices of carcass leanness were favorably improved.

Wallace et al. (1967) conducted a 2 x 2 x 2 factorial experiment involving protein level, sex, and supplementation with a combination of DES and MT. The trial involved 48 pigs which averaged 59 kg initially. The pigs were slaughtered as they reached 95 kg. Feedlot performance and carcass characteristics were studied. Hormone supplementation with DES + MT significantly decreased average daily gain, average daily feed intake, and average backfat thickness. In addition, there was a significant interaction between protein level and hormone supplementation for average feed conversion ratio, which was interpreted as evidence that hormone supplementation favored improved feed conversion in the presence of increased protein. Secondary sex glands in barrows (Cowper's gland, prostate gland, and seminal vesicles) and ovaries and uteri in gilts were markedly affected by hormone supplementation. All these organs exhibited hypertrophy in hormone supplemented pigs. Loin roasts were checked for any indication of boar odor or flavor. A strong influence on odor and flavor of pork was exerted by DES + MT. The meat from some hormone fed pigs had a very undesirable odor and flavor when cooked. Both gilts and barrows were affected to the same degree. The authors concluded that the odor was probably due to methyltestosterone.

Baker et al. (1967) fed 448 finishing pigs in 3 trials to evaluate the effects of a dietary combination of DES + MT. The effects of sex and dietary protein level on hormone response were also studied. Regardless of sex or protein level, carcass leanness was improved by DES + MT. Improved feed efficiency due to hormone, however, resulted only at higher levels of protein. These workers also observed that feed efficiency and carcass leanness response to DES + MT was greater in barrows than in gilts. Growth rate and feed conversion efficiency were greatest at a dietary protein level of 12 percent in barrows and 14 percent in gilts, but for maximum carcass leanness response, barrows needed 14 percent protein and gilts required 16 percent. Protein level did not appear to affect backfat thickness in any of the trials, but the remainder of carcass leanness parameters were improved additively by both DES + MT and increased protein level.

Baker, Diller, and Jordan (1968) observed that DES + MT caused a lowering of serum triglycerides level when fed to gilts. This decrease did not occur in barrows. Serum cholesterol and free fatty acids were not affected by hormone treatment. The mechanism by which DES + MT decreased serum triglycerides in gilts was not elucidated.

Doornenbal and Frankenham (1969) studied growth, feed conversion ratio and chemical composition in market weight barrows and gilts fed DES + MT plus tylosin. They reported a trend toward increased gains, improved feed efficiency and a reduction in age to market. Carcass measurements within sex were not significantly different between controls and hormone fed animals. There was a trend toward increased

leanness in barrows, but toward increased fat deposition in gilts. The authors concluded that different proportions of sex steroid hormones would be required for barrows and gilts to achieve equally beneficial effects on carcass composition.

Meyer et al. (1968) evaluated the effects of a dietary combination of DES + MT on the reproductive performance of gilts fed 2.2 or 4.4 mg each of DES and MT per kg of diet during the finishing phase only, or continuously through finishing to breeding. A total of 136 gilts was used in 5 experiments. These workers reported that feeding the hormonal combination through breeding inhibited estrus. Some gilts conceived after termination of hormone feeding. Gilts which received the hormone only during the finishing phase had normal estrus cycles and conception was reduced in only 1 of 3 experiments. In 4 out of 5 experiments, DES + MT reduced litter size. It was noted that gilts fed the hormone supplement during finishing farrowed smaller litters at the first two farrowings. Litter size increased to that of the control group by the third parturition. The authors concluded that inhibition of the normal reproductive function by DES + MT treatment during the finishing period did not seem to be permanent. The lower level of hormone addition was not as inhibiting to reproduction as the high level.

Evidence accumulated by various researchers whose work was reviewed in the foregoing section indicates that there may be some additive performance and carcass improvement when estrogens and androgens are fed or implanted in combination. The overall trend is much the same as that observed when either type of drug is fed or implanted

alone. Combining the two substances seems to produce a more powerful stimulus to the metabolism of the animal, resulting in the changes in feedlot performance and carcass composition reported. The entire picture is unclear as yet regarding the mechanism of action of these potent humoral substances. Also, observed responses to these drugs are not always consistent in swine. It does appear, however, that there may be some benefit to be derived in feedlot performance increase and in favorable changes in carcass characteristics by supplementing growing-finishing pigs with a combination of estrogen and androgen.

There do not appear to be any permanent adverse effects on reproductive capacity of gilts fed DES + MT through the finishing phase.

## The Effects of Androgens on Protein Anabolism in Animals

The influence of androgens on nitrogen retention has been known since 1935 (Dorfman and Shipley, 1956) when it was discovered that extracts of urine containing androgenic material stimulated nitrogen retention in dogs.

Drill and Saunders (1956) used rats to test the ratio of anabolic to androgen activity in a number of steroids. Of the testosterone analogs tested, 17-ethyl-19-nortestosterone was found to be the most potent anabolically and also to have the highest ratio of anabolic to androgen activity. This compound was reported to be 5 times more anabolically active than 17-α-methyltestosterone when administered

orally to rats, while the androgenic activity of methyltestosterone was relatively high.

Leathem (1956), in a rat experiment, found that the state of body protein stores at the time of hormone administration determined in large part whether or not an anabolic response was observed. Older rats and protein depleted rats exhibited a marked increase in nitrogen retention when testosterone or other anabolic steroids were administered. Very little response in young, healthy rats fed high protein diets was observed. Leathem concluded that in many instances nutrition appears to be dominant over anabolic hormones, even though steroids are known to be involved in protein anabolic processes.

Applezweig (1962) reported on radioisotope studies in which rats were fed $^{15}N$-labeled glycine with and without androgen therapy. An increase in amount of $^{15}N$-labeled glycine retained was apparent for the treated group. The author concluded that androgen influenced the reaction of amino acids $\leftrightarrow$ proteins and caused the reaction to proceed in favor of protein synthesis. He postulated that either an inhibition of protein catabolism or a stimulation of anabolism could be the mechanism of action. In addition, Applezweig stated that when body protein stores were filled, little or no anabolic response to androgen treatment was observed.

Robinson and Singleton (1966) tested the effects of norbolethone, an anabolic steroid, on the performance and body composition of barrows. They used 24 Large White barrows fed two levels of protein with and without 0.1 mg of steroid per kg of body weight. On the low protein diet, steroid therapy increased growth, but the opposite

was true for the high protein diet. This interaction was significant. In addition, there was a significant improvement in percentage of lean in the carcass and loin eye area, but a decrease in carcass length.

Evidence presented in the papers previously cited indicates that there is a definite protein anabolism in animals following therapy with certain steroid hormones. Response varies according to species, age, nutritional status, and sex of the animal. In general, steroid anabolism is most marked in those animals in a state of protein depletion.

## The Effects of Diethylstilbestrol on Protein Anabolism in Animals

Researchers have attempted to determine the mechanism of action of diethylstilbestrol in stimulating growth. There is a general agreement that increased nitrogen retention due to protein anabolism occurs in ruminants consistently, and to a more variable degree in monogastrics. The exact means by which DES causes this remain unclear.

Clegg (1952) reported on the use of DES to increase nitrogen retention in steers. The nitrogen retention of steers implanted with 60 mg of DES was more than twice that shown by control animals.

Jordan and Bell (1952) studied nitrogen retention in lambs implanted with 12 mg of DES. Hormone implantation did not appear to alter digestion of feed or nitrogen retention.

Whitehair, Gallup, and Bell (1953) implanted lambs with 24 mg of DES to study the effects on calcium, phosphorus, and nitrogen balance. There was no difference in the digestibility of feed between implanted and control lambs, but DES caused a significant increase in the amount of calcium, phosphorus, and nitrogen retained. DES implanted lambs also showed faster rates of gain than control lambs.

Tillman and Brethour (1955) fed lambs 6 or 10 percent protein with and without 3 mg of DES per day to study the effects on calcium, phosphorus, and nitrogen metabolism. Nitrogen retention and average daily gain were decreased by DES in the 6 percent protein ration, but the reverse was true for the 10 percent protein ration. The authors concluded that the effects of DES were not consistent.

Struempler and Burroughs (1955) studied the effects of growth hormone and DES on nitrogen retention in lambs fed low or high energy and low or high protein diets. Growth hormone or DES alone resulted in increased nitrogen retention, regardless of dietary energy or protein level. When administered together, however, growth hormone and DES did not produce an additive response. The authors concluded that DES may cause an increase in secretion of growth hormone in the animal.

Sell and Balloun (1961) studied nitrogen retention of growing cockerels as influenced by DES or MT. DES resulted in decreased nitrogen retention, while MT did not significantly alter nitrogen balance.

Carew and Hill (1967) studied the effect of DES on protein utilization in chicks fed diets containing glucose or corn oil as the major energy component. Nitrogen retention was markedly decreased by DES in the high fat diet at restricted levels of energy intake, but not on the glucose diet. The authors concluded that in chicks the effect of DES on certain metabolic processes was influenced by the form in which dietary energy was supplied.

Lassiter et al. (1956) studied the minimum protein intake for pigs for maximum nitrogen retention. They also investigated the precision of 3, 5, and 7 day collection periods for estimating nitrogen balance. With 23 kg pigs, nitrogen retention increased with increasing protein levels up to 18 percent. With 68 kg pigs, protein levels from 10 to 22 percent did appear to affect nitrogen balance, but the difference was not significant. These workers also reported that after a 10 day preliminary period, the 7 day collection period offered only a slight advantage over the 3 day collection period with 23 kg pigs and even less advantage with 68 kg pigs.

The anabolic effects of DES vary markedly with species, age, sex, diet, and status of body protein stores, as shown by evidence in work cited in this section.

## The Mechanisms of Anabolic Action of Androgens and Diethylstilbestrol

The means by which certain steroid hormones and diethylstilbestrol stimulate anabolism have been the subject of intense scrutiny by researchers as long as the anabolic effect has been known. There

has been no clarification of the exact mechanism by which these substances stimulate protein anabolism.

Dorfman (1961), at a symposium on the mechanism of action of steroids, proposed a working hypothesis for androgens which places the mechanism of action of androgens at the level of regulation of rate of biosynthesis of specific enzyme systems (protein synthesis). The action of androgen is visualized as producing the necessary critical enzyme concentrations which result in growth of tissue. Androgen may act as an inhibitor of catabolism or an inducer of anabolism in this capacity.

Wilson (1962) studied protein synthesis in rat seminal vesicle tissue as influenced by testosterone. Radioisotope $^{14}C$-labeled amino acids were used to study protein biosynthesis rate in tissue following testosterone administration. Protein synthesis was doubled 12 hours after testosterone administration and reached a maximum (5 to 6 fold) within 24 to 48 hours. There was evidence that this enhancement of protein synthesis was independent of either amino acid transport or synthesis, but was secondary to the acceleration of a specific step in protein synthesis, the conversion of soluble ribonucleic acid - amino acid complexes to microsomal ribonucleoprotein.

Further work should serve to elucidate more clearly the exact mechanisms involved in anabolic action of androgens.

Several theories concerning the mechanism of action of diethylstilbestrol in stimulating nitrogen retention have been advanced by various workers. The most promising hypothesis concerns the effect

of stilbestrol on growth hormone secretion. Struempler and Burroughs (1955) reported that both DES and growth hormone increased gains and nitrogen retention in lambs. When both substances were administered together, however, no additive effect was observed. This observation led them to conclude that DES may cause an increase in secretion of growth hormone from the pituitary gland.

Davis, Garrigus, and Hinds (1970) studied the metabolic effects of DES and growth hormone in lambs. They also observed very similar responses to DES and growth hormone administration, and also concluded that secretion of growth hormone might be increased by DES.

Generally, however, the mechanism of anabolic action of DES remains unclear. Even less is known about this substance than is known about anabolic steroids. It does appear that DES stimulates nitrogen retention more markedly and more consistendly in ruminants than in nonruminants.

No direct evidence for an increase in secretion of growth hormone caused by DES has been presented, although there are indications that this may be the mechanism by which DES improves growth and nitrogen retention.

# EXPERIMENTAL

## General Objectives

These experiments were conducted to investigate the effects of hormone supplementation (DES + MT at 2.2 mg each/kg of feed) and the interrelationships with protein level (12 to 16%) and sex (barrow or gilt) in swine. Treatment effects were measured by feedlot performance, carcass parameters, and nitrogen balance studies.

## General Experimental Methods

### Records

The experiments reported herein are on file in the Swine Nutrition section of the Animal Science Department, Institute of Food and Agricultural Science, University of Florida, Gainesville, Florida, 32601. Six trials were conducted between February 1967 and October 1969 and the series designated as Swine Experiment 178. Individual trials were numbered as Experiments 178-A through F.

### Animals

Animals used were Landrace x Duroc 2 way and (Landrace x Duroc) x Hampshire 3 way cross-bred pigs. They were raised at the University of Florida Swine Unit and were fed a typical practical fortified

corn-soybean meal ration from weaning to the time they were placed on experiment. Sound management practices in raising the baby pigs were followed to ensure healthy experimental animals. Male pigs were castrated at approximately 7 to 10 days of age. All pigs had their ears notched at birth for identification and were vaccinated against swine erysipelas at approximately 6 weeks of age. The pigs in the first two experiments (178-A and B) were vaccinated against hog cholera as well.

Allotment, Feeding, and Weighing

Outcome groups were chosen on the basis of sex, weight, and litter, and these groups were randomly assigned to treatments.

Pigs in all feeding trials were fed ad libitum from self feeders. Pigs in the metabolism trials were full-hand-fed twice daily. Water was supplied ad libitum from automatic water fountains. All pigs were fed in confinement on concrete or steel mesh floors. All feed used was in a dry meal form. Hormone feeding was discontinued for 72 hours prior to slaughter. Feed was weighed back every 2 or 4 weeks and a final weighback was taken at the termination of the feeding trial. Compositions of the diets, level of hormone supplementation, and compositions of the mineral and vitamin premixes are shown in Tables 1 through 5.

Animals were weighed initially, and at 1 or 2 week intervals thereafter until slaughter. A platform scale was used for weighing.

Slaughter Procedure and Carcass Evaluation

As live weight of the pigs reached 100 kg, they were slaughtered at the University of Florida Meats Laboratory. Carcasses were dressed packer style (head off) for study. All carcass weights and measurements were taken after the carcasses had been chilled for 48 hours at 2° - 5° C. The length of carcass was measured from the anterior edge of the aitch bone (pelvis) to the anterior edge of the first rib. Average backfat thickness was calculated from measurements taken at the first rib, last rib, and last lumbar vertebra. Loin eye area was determined as an average of the left and right sides. The loins were cut perpendicular to the vertebral column between the 10th and 11th rib to expose the longissimus dorsi. Tracings of the perimeter of the loin eye were made, and their area determined by the use of a compensating polar planimeter. The carcasses were broken down by standard procedure and weight of wholesale cuts was determined. In addition, the loin eye muscle was scored for marbling, color, and firmness (Tables 6, 7, and 8). Blade loin roasts and loin chops were wrapped for freezing and were frozen and stored at -15° C. Before cooking, roasts and chops were thawed overnight at 10° C. Roasts were cooked in covered Pyrex dishes in an oven preheated to 175° C. The same cooking temperature was used for chops as for roasts. Chops were cooked in Pyrex Petri dishes covered with watch glasses. Roasts were cooked 60 to 80 minutes per kg to an internal temperature of 175° C; chops were cooked for approximately 30 minutes. Aroma and flavor were determined by a trained 6 member panel. Degree of boar odor and flavor were the only palatibility factors considered. Table 9 shows the code used for scoring samples.

Tissue Sampling and Preparation

Loin chops 2.5 cm thick taken between the 10th and 13 rib were wrapped for freezing and frozen and stored at -15° C for subsequent chemical analysis. To prepare the sample chop for analysis, a band saw was used to isolate the longissimus dorsi while the chop was still frozen. All external fat and bone were removed. The remaining frozen longissimus dorsi section was quartered with the band saw, placed in a coded plastic bag, and returned to the freezer for pulverizing. Longissimus dorsi sections were pulverized in the freezer room at -15° C by placing each sample individually in a commercial duty, rotary-blade blender with a 1 liter stainless steel container, along with 200 g of dry ice (approximately twice the sample volume). The blender was cooled to -15° C in the freezer prior to use. The cover was placed on the blender, held in place firmly by hand, and the blender was switched on to high speed. After approximately 60 seconds the blender was switched off, the pulverized, frozen composite of meat and dry ice was placed in a coded plastic bag, and the bag was closed loosely with a rubber band.

The pulverized samples were stored in the freezer at -15° C for at least 24 hours prior to weighing out aliquots for analysis. This storage interval was necessary to allow time for all of the pulverized dry ice to sublime, leaving only the pulverized frozen meat in the sample bag. Sample aliquots of powdered meat were weighed while frozen in a cool room (2° - 4° C) as quickly as possible to prevent thawing.

Feed Sampling and Preparation

Feed samples were taken from each mixing batch and pooled at the end of the feeding trial. A sample of this composite was retained for chemical analysis. Following drying, the sample of feed was ground in a Wiley mill with a 1 mm screen. The ground sample was stored in a coded glass screw-top bottle for chemical analysis.

Feces Sampling and Preparation

In the metabolism trials (Experiments 178-E and F) total collection of feces from each pig for each 24 hours of the 6 day collection period was performed. The feces were put in coded plastic bags, weighed to the nearest 0.1 g on a single pan balance, frozen, and stored at -15° C for later analysis. Preparation for analysis was begun by thawing the frozen feces. The entire amount of feces from each pig for each day of the collection period was placed individually in a commercial duty rotary-blade blender with a stainless steel container having a 4 liter capacity. An amount of distilled water equal in weight to the original weight of the feces sample was added, and the blender was switched on to high speed. The resulting slurry was a completely homogeneous mixture from which a truly representative sample aliquot could be taken easily. Following drying, each sample was ground in a Wiley mill with a 1 mm screen and stored in a coded glass screw-cap bottle.

Urine Sampling and Preparation

In the metabolism trials (Experiments 178-E and F), total collection of urine from each pig for each 24 hours of the 6 day collection

period was performed. The total volume of the daily urinary output was measured to the nearest 5 ml in a 2 liter graduated cylinder. From the total daily urinary output of each pig, an aliquot of approximately 250 ml was filtered through cheesecloth into a coded polyethylene screw cap bottle to which 1.0 ml of concentrated hydrochloric acid was added as a preservative. The pH was tested with pHydrion paper to be sure it was in the range of 1.5 to 2.0. If it was not, concentrated hydrochloric acid was further added, drop by drop, until the desired pH was obtained. Samples were then frozen and stored at -15° C.

## Analytical Methods

### Weighing Samples

All samples for analysis were weighed on a single pan analytical balance to 4 decimal places. Aluminum foil weighing dishes were used for all samples except those on which nitrogen was to be determined; those samples were weighed on small squares of glassine paper and folded quantitatively within the paper for analysis.

### Moisture Determination

Moisture was determined on all feed, feces, and meat samples taken during the course of the investigation. Feed and feces samples were dried prior to grinding as previously described and the moisture was determined at this initial drying. The general procedure for determination of moisture was similar for feed, feces, and meat.

Duplicate samples of the material being analyzed were quantitatively weighed into numbered aluminum foil weighing dishes of known weight and placed in a 100° C drying oven. Feed samples were dried for 24 hours, but feces and meat samples required 48 to 72 hours before a complete removal of water was accomplished.

The dried samples were cooled to room temperature in desiccators and weighed to determine the loss of moisture. In the case of feces samples it was necessary to correct for the water added during homogenization. Sample size for feed was approximately 50 g. Between 100 and 200 g of feces slurry was used for the moisture determination on the feces samples. Meat sample size was between 5 and 15 g. Dried samples of feed and feces were ground and stored as previously described. Meat samples remained in their small (6 x 1.5 cm) aluminum foil weighing dishes and were stored in desiccators for later analysis.

Ether Extract Determination

The ether extract determination was performed on the same meat samples used in the moisture determination. The small foil pans containing the dried meat samples were carefully rolled up to quantitatively enclose the samples; then the rolled pans with samples were placed in numbered Whatman cellulose extraction thimbles (25 x 80 mm). The weight of each thimble, pan, and sample was quantitatively determined. Samples were then extracted for 24 hours with petroleum ether on a Goldfisch apparatus. Following extraction, the samples were dried and the weight of the thimble, pan, and extracted sample was quantitatively determined. The difference was reported as fat.

Nitrogen Determination

A modified Kjeldahl process (W.V. Stradtmann, personal communication) was used for nitrogen determination. Feed, feces, and meat samples for this determination were quantitatively weighed onto small squares of glassine paper (approximately 8 x 10 cm).

The papers were then carefully folded to quantitatively enclose the samples, and the papers with samples were put into coded 100 ml Pyrex semi-micro digestion flasks. Sample size was approximately 0.4 g for feed and feces and 1.0 to 1.5 g for meat samples. Urine samples were pipetted into the digestion flasks. Sample volume for urine was 4.0 or 5.0 ml. After the sample was in the digestion flask, 5 or 6 glass beads were added to prevent bumping during digestion. Concentrated sulfuric acid (5 ml) was used to char the samples for digestion.

The flasks containing samples, beads, and acid were then boiled over a free flame until sulfur trioxide fumes appeared in the necks of the flasks, and acid was refluxing down the necks and sides of the flasks. The flasks were then removed from heat and allowed to cool in the air for about 1 minute. Superoxol (30% hydrogen peroxide) was added drop by drop to the hot acid digests until the blackish-brown mixture turned clear, indicating complete oxidation of organic matter. The digested sample was then cooled in the air to ambient temperature and quantitatively transferred from the semi-micro digestion flasks to 500 ml macro distillation flasks. Three washes with distilled water were used to accomplish the transfer. The sample was then treated as in the normal Kjeldahl process (A.O.A.C., 1960). Mossy zinc and

concentrated sodium hydroxide were added and the alkaline mixture was distilled to drive off ammonia into receiving flasks containing 50.00 ml of dilute sulfuric acid of known normality. Following distillation, the acid remaining in the receiving flasks was titrated to the methyl red end point with 0.1000 normal sodium hydroxide. The percent nitrogen in the samples was then calculated, and in the case of feed samples and meat samples it was multiplied by a factor of 6.25 to convert to percent protein. A blank and a standard (ammonium sulfate) determination were run with every group of 24 samples.

Determination of 17-ketosteroids in Urine

A determination of the urinary 17-ketosteroids (Sigma Tentative Technical Bulletin No. 17-KS) was performed on composite samples of urine from each pig in the metabolism trials (Experiments 178-E and F). In order to compensate for variation in daily urine output volume, samples from each pig for each day of the collection period were pooled in a ratio comparable to the daily urine volume. Duplicate determinations of 17-ketosteroids were run on the composite samples and the results were reported as average excretion of 17-ketosteroids in mg per day. The Zimmerman reaction (Dorfman and Shipley, 1956) was used to determine concentration of 17-ketosteroids in urine. Filtered urine samples of 5.0 ml were acid hydrolyzed (to free conjugated steroids) in a boiling water bath for 15 minutes, cooled, and transferred to separatory funnels. The hydrolyzed samples were then extracted with approximately 20 ml of ethyl ether and washed with

2.0 normal sodium hydroxide. The washed extracts were filtered into large test tubes, evaporated to dryness, and redissolved in 0.20 ml of absolute methanol. The alcoholic solutions were incubated at room temperature for 20 minutes following the addition of 0.20 ml of meta-dinitro-benzene and 0.20 ml of 8.0 normal potassium hydroxide to each sample. Following incubation, 1.0 ml of distilled water and 5.0 ml of methylene chloride were added to each sample and the solutions were shaken to mix thoroughly. Approximately 5 minutes after shaking, the top aqueous layer was aspirated off the solutions and 1.50 ml of absolute methanol was added to allow development of the purplish color characteristic of the steroid-dinitrobenzene complex. Solutions were transferred to cuvettes and the percent transmittance was read in a colorimeter with the blank solution as a reference for 100 percent transmittance. Maximum absorbency occurred at a wavelength of 540 mμ.

A standard solution was also carried through the extraction process with every 8 determinations. The percent transmittance values of a series of solutions of known concentration were plotted on semi-logarithmic graph paper to produce a linear standard curve from which the concentration of 17-ketosteroids in unknown solutions could be determined directly. The concentration of 17-ketosteroids in mg per liter was multiplied by the mean daily urine output in liters to give the value in mg of 17-ketosteroids excreted per day.

## Statistical Methods

All data collected from the experiments were analyzed statistically using the methods of Steel and Torrie (1960). Analysis of variance was used to determine significant effects. Wherever significant main effects were not complicated by interaction, pooled means for the main effects are presented in the figures. Any reference to statistical significance regarding main effects refers to the probability level of 5 percent or less.

Wherever significant 3 factor interaction occurred, means for the treatments were tested for significant differences by Tukey's $\omega$ procedure using the upper 10 percentage points of the studentized range. Wherever a significant 2 factor interaction occurred in the 3 factor experiments (178-A and B) data were summed and averaged across the independent factor. The 2 factor simple effects were then tested for significant difference by Tukey's $\omega$ procedure using the upper 10 percentage points of the studentized range. Treatment means in the 2 factor experiment (178-D) were tested in a similar manner where interaction occurred.

Since Tukey's procedure is so conservative, Steel and Torrie (1960) suggest that the experiment-wise error rate can be relaxed to 10 percent without danger of committing a large number of Type I errors (declaring observed differences falsely significant). Because of this, the 10 percent level was used to test for significant differences in these experiments where interaction occurred.

The standard deviation of a treatment mean ($s_{\bar{x}}$) was estimated by

$\sqrt{\frac{\text{error mean square}}{\text{no. of observations in mean}}}$ for calculating $\omega$. The value of $\omega = q^{\alpha}_{p,n_2} \cdot s_{\bar{x}}$, where $\alpha = 0.10$, $p$ = number of means being compared, and $n_2$ = error degrees of freedom. The q values were obtained from tables of the upper percentage points of the studentized range (Beyer, 1966).

## Experiment 178-A

### Experimental

A group of 72 carefully selected crossbred pigs was placed on experiment at an initial average weight of 45 kg. This first trial was begun on February 16, 1967. Pigs were group fed in concrete confinement from a self feeder to an average weight of 95.3 kg, at which time the entire group was slaughtered for carcass study. The termination of the feeding trial was on April 22, 1967, 66 days after the starting date. The design of the experiment was a 2 x 2 x 2 factorial design (Table 10) which involved sex (barrow and gilt), protein level (16 and 12% protein), and hormone supplementation (basal and DES + MT, each at 2.2 mg/kg of feed). Compositions of the rations used are shown in Table 1.

### Results

The summaries, analysis of variance plans, and observed mean squares for Experiment 178-A are presented in Tables 11 through 16 and Figures 1 through 12. Table 13 presents an overall summary of all the responses measured in Experiment 178-A. Significant mean

squares are presented in Tables 14 through 16. Figures illustrate all significant interactions and main effects.

Table 11 presents a summary of the feedlot performance of the 4 treatment groups. Table 12 shows the combined protein and hormone treatment means and the appropriate standard deviations of treatment means. The t test did not reveal any significant differences in feedlot performance due to hormone or sex. Treatment means of total gain from initial to market are shown in Table 13. There were no significant differences in total gain between any treatments.

Carcass responses are shown in Table 13. There was a significant protein x hormone x sex interaction which affected dressing percentage. This interaction is illustrated in Figure 1. Gilts showed an increased dressing percentage on the basal ration as protein was increased, and a decreased dressing percentage was noted when protein was increased on the hormone supplemented ration. The reverse effect was seen in barrows. Hormone increased dressing percentage with increasing protein. Increasing protein on the basal ration did not affect barrow dressing percentage. The effect of hormone supplementation in reducing dressing percentage was significant only at the 16 percent protein level in gilts and at the 12 percent protein level in barrows. Due to this interaction, no inferences can be made about the main effects on dressing percent.

There were two significant interactions which influenced percent lean primal cut yield. The 2 factor hormone x sex interaction was disregarded since there was also a significant 3 factor interaction. The 3 factor protein x hormone x sex interaction illustrated in

Figure 2 shows that gilts responded nearly the same on the basal and hormone rations to increased protein. There was an increased lean primal cut yield in gilts fed either diet (basal or DES + MT) when protein was increased. Barrows showed increased lean primal cut yield in response to hormone supplementation at both protein levels. Barrows fed the 16 percent diet had a higher lean cut yield than those fed the 12 percent protein regardless of hormone level. None of these differences were significant (Table 13).

Percent ham was not affected by any factor except sex (Figure 3). Gilts had significantly larger hams than barrows.

Percent loin was influenced by a significant 2 factor interaction. This hormone x sex interaction is shown in Figure 4. Percent loin was slightly decreased in gilts by hormone, but barrows showed a significant increase in yield of loin in response to DES + MT. In addition, gilts fed the basal diet yielded significantly higher percentages of loin than basal barrows.

Percent yield of picnic shoulder was influenced by both hormone and protein. There was a significant increase in percent picnic shoulder in response to increased protein (Figure 5) and to hormone supplementation (Figure 6).

Percent Boston butt was significantly increased by hormone supplementation (Figure 7). In addition, there was a significant protein x sex interaction influence on yield of Boston butt. Barrows showed a slight decrease in yield of Boston butt with increased protein, but gilts showed a moderate increase. Although this interaction was significant, none of the differences between means were significant (Figure 8).

Backfat thickness was decreased significantly by both increasing protein and DES + MT (Figures 9 and 10). No interactions were observed to influence backfat thickness in this trial.

Loin eye area was not significantly affected by any of the treatments in this experiment.

No significant differences in carcass length due to treatment were observed.

Loin eye marbling score was significantly reduced by increased protein (Figure 11).

No differences due to treatment were observed in loin eye color score or firmness score.

Loin roast aroma and flavor scores for boar odor incidence were significantly increased by DES + MT in this trial. A graphic presentation of this difference is shown in Figure 12.

## Experiment 178-B

### Experimental

Experiment 178-B was the second trial performed in the series, and was designed in 2 parts. The first phase consisted of a completely random design (Table 17) with sex of the pigs (barrow or gilt) as the treatment factor. A carefully chosen group of 60 young crossbred pigs with each sex represented equally was placed on experiment on May 15, 1967. The average initial weight was 9.8 kg. The pigs were

segregated by sex and group fed on a 16 percent protein ration in confinement on concrete to an average weight of 56.3 kg. The first phase ended on July 25, 1967. The feedlot performance data collected were analyzed to determine if there was any performance difference in early life due to sex.

The second phase of the experiment was a 2 x 2 x 2 factorial design similar to Experiment 178-A. This trial was designed to further investigate the effects of sex, protein level and hormone supplementation on growing-finishing pigs. The design of the experiment is shown in Table 18. In this experiment it was decided to use a lower level of protein (14%) than the 16 percent ration used in the first trial, to see if a response to protein still occurred, and to see if response to hormone remained the same at the lower level of protein. Pigs in this trial were individually fed from self feeders in concrete confinement pens. Compositions of the diets used are shown in Table 1. The 48 pigs used in this second phase were selected from the 60 pigs used in the first phase on a sex, weight, and littermate basis. Starting date for the factorial trial was July 25, 1967. All pigs were slaughtered (for carcass study) on an individual basis as terminal weight reached approximately 100 kg.

## Results

The summaries of treatment means and analysis of variance plans for Experiment 178-B are shown in Tables 19 through 24 and Figures 13 through 22.

A summary of the feedlot performance during the growing phase is shown in Table 19. No significant differences were observed in performance during early life between barrows and gilts fed a similar 16 percent protein ration (Table 20).

Average daily gain was significantly greater for barrows than for gilts during the finishing phase (Figure 13). There was a significant interaction of sex with DES + MT which influenced feed intake. Barrows fed DES + MT ate significantly less feed during the finishing phase than did barrows consuming the basal ration. Hormone supplementation did not affect feed intake in gilts (Figure 14). In addition, Figure 14 shows that barrows fed the basal ration ate significantly more feed than gilts fed either the basal or the hormone diet. Feed efficiency was significantly improved by DES + MT in this trial (Figure 15).

None of the main effects had a significant influence on dressing percentage in this experiment, but there was a significant protein x sex interaction effect (Figure 16). Increased protein resulted in increased dressing percentage in barrows; this response was significant in gilts.

There was a favorable effect of DES + MT on percent yield of lean primal cuts. There was a significant interaction of sex x hormone which is shown in Figure 17. This interaction manifested itself in a differential response to hormone supplementation by sex. Gilts showed only a slight increase in percent lean primal cuts, while barrows showed a significant increase.

There were no significant differences observed in percent ham in this trial.

There was a significant interaction of hormone x sex affecting percent loin. Loin yield in gilts was not materially affected by DES + MT, but barrows showed a significant increase in this cut due to hormone supplementation (Figure 18).

Picnic shoulder and Boston butt percentage yield were unaffected in this trial by any treatment.

Backfat thickness was significantly reduced in barrows by DES + MT in this experiment. There were 2 significant interactions influencing backfat thickness. The effects of both protein x hormone and hormone x sex interactions are presented in Figure 19. The protein x hormone interaction shows that average backfat thickness was not materially affected by DES + MT on the high protein diet, but was significantly reduced on the low protein diet. The hormone x sex interaction shows that backfat thickness was not reduced in gilts fed DES + MT, but was decreased to a significant extent in barrows.

Hormone x sex interaction significantly influenced loin eye area in this experiment, but none of the treatment means differed significantly.

Carcass length was significantly increased by DES + MT in gilts fed 12 percent protein in this trial. There was a significant 3 factor interaction which influenced carcass length (Figure 20). Gilts fed the basal ration showed an increase in carcass length as protein was increased from 12 to 14 percent, but gilts fed the ration containing DES + MT showed decreased length with increased protein. The reverse effect was true for barrows. DES + MT increased length of barrows with increasing protein; barrows fed the basal ration showed a decreased

length as protein was increased. None of these effects were significant, with the exception of the difference between gilts on the basal and hormone rations at the 12 percent protein level.

Loin eye marbling score was not affected by any treatment in this trial.

Loin eye color score was not significantly different between any of the treatment groups in this trial.

Loin eye firmness score was significantly affected by sex. Gilts had significantly firmer muscle (10th rib l. dorsi) than barrows (Figure 21).

Loin roast aroma and flavor scores for incidence of boar odor and flavor were significantly increased by DES + MT in this experiment (Figure 22).

## Experiment 178-C

### Experimental

The third trial in the series was designated as Experiment 178-C. This trial was designed to examine the effects of DES + MT alone, without protein or sex considerations. The experiment was a completely random design (Table 25) utilizing 24 barrows individually fed in concrete confinement from self feeders. The ration used (Table 1) was a 14 percent protein corn-soybean meal diet fed with and without 2.2 mg of DES + MT per kg of feed. Pigs for this experiment were randomly assigned to treatment from a uniform group. The trial commenced on January 23, 1969. Pigs averaged 45 kg initially and were

slaughtered on an individual basis for carcass study as weight reached 100 kg. There were 2 pigs in the trial, one assigned to each treatment, with identical ear notch numbers; the identity of these two animals was lost at slaughter. Therefore, the carcass data are all based on the remaining 11 pigs in each treatment group.

Longissimus dorsi samples from the 10th to 13th rib area were analyzed for moisture, fat, and protein content in this trial.

## Results

The treatment means for Experiment 178-C are summarized in Table 26. Analysis of variance tables for this experiment are given in Tables 27 through 31.

Out of 22 responses measured in this trial, only 3 showed any significant differences.

Feedlot performance did not differ significantly between treatments, but there was a trend toward decreased feed intake and improved efficiency due to DES + MT.

None of the carcass objective measurements differed significantly in this experiment, although there was a trend toward increased leanness due to DES + MT. This was evidenced by slight increases in carcass length and yield of lean cuts, and slight decreases in dressing percent, backfat thickness and loin eye marbling score. Of all the carcass leanness parameters, backfat thickness was most affected by hormone supplementation, but even so, the difference was not significant.

In this trial the only carcass subjective measurement which was significantly affected by DES + MT was pork chop aroma score. There

was a significantly higher incidence of boar odor in chops from pigs treated with DES + MT. None of the other carcass subjective measurements, including chop flavor score, roast aroma score, and roast flavor score, were significantly different.

Analysis of longissimus dorsi samples revealed a significantly lower percentage of dry matter (higher % moisture) in pigs fed DES + MT.

The percent protein in longissimus dorsi was significantly greater for pigs fed DES + MT. Protein was expressed on a dry matter basis.

There was no significant difference in percent fat in longissimus dorsi, although there was a trend toward decreased fat due to DES + MT.

## Experiment 178-D

### Experimental

Experiment 178-D was the last in a series of 4 feeding trials. In this trial, the design was a 2 x 2 factorial (Table 32) involving sex and hormone supplementation. The protein level was fixed at 14 percent of the diet (Table 1). The crossbred pigs used in this experiment were selected from outcome groups based on sex, weight, and littermate, and were randomly assigned to treatments. The pigs were fed in individual concrete confinement pens from self-feeders. The average initial weight was 54.5 kg. Pigs were slaughtered on an individual basis for carcass study as they reached 100 kg. The trial commenced on May 19, 1969. On this trial, one barrow died midway

through the experiment. Death was attributed to generalized edema due to heat prostration. One pig carcass was condemned for a condition of granuloma in the muscle, apparently unrelated to treatment. Because the orthogonality of the factorial design was destroyed by loss of these data, computer analysis using a complete and a reduced model was necessary in order to partition the sums of squares. Therefore, only abbreviated analysis of variance tables are shown, and sums of squares generated from these tables are not additive.

## Results

The summary of treatment means is shown in Table 33, and abbreviated analysis of variance tables are presented in Tables 34 through 37 and Figures 23 through 38 illustrate significant effects.

The interaction of hormone and sex influenced daily gain significantly. This interaction is graphed in Figure 23, which shows that daily gain in gilts was not materially affected by DES + MT, but was significantly reduced in barrows by the hormone. Barrows fed the basal diet gained significantly more than did gilts fed the basal diet.

Average daily feed intake was significantly greater in barrows than in gilts (Figure 24). Hormone supplementation also influenced daily feed intake significantly. Pigs fed DES + MT consumed significantly less feed than those fed the basal diet (Figure 25).

Feed conversion efficiency was favorably affected by DES + MT. Pigs consuming the hormone supplemented feed had a significantly lower feed conversion ratio than pigs fed the basal diet. This difference is shown in Figure 26.

Dressing percentage was not affected by any treatment in this experiment.

Hormone supplementation markedly increased the percent yield of lean primal cuts in this experiment (Figure 27).

There were no significant main effects seen in percent ham yield, but the hormone x sex interaction was significant. This interaction is illustrated in Figure 28. The graph shows that DES + MT decreased yield of ham slightly in gilts, but increased it significantly in barrows. Gilts fed the basal ration had significantly larger hams than barrows fed the basal ration.

Percent yield of loin was not significantly affected by any treatment.

Percent yield of picnic shoulder was increased by DES + MT. This effect was significant (Figure 29).

There was also a positive significant response to DES + MT manifested in percent yield of Boston butt (Figure 30).

Backfat thickness was significantly reduced by supplementation with DES + MT (Figure 31).

Loin eye area was not affected by any treatment in this trial, nor was carcass length. Liver weight was also measured in this trial, but no significant differences due to any treatment were observed. Loin eye marbling score, loin eye color score, and loin eye firmness score were all unaffected by any treatment.

Loin tenderness score was significantly different between sexes (Figure 32). The meat from barrows required less shear force to part the fibers than did that from gilts.

In this trial, the boar odor and flavor incidence scores for pork chop aroma and flavor and loin roast aroma and flavor were significantly increased by DES + MT (Figures 33 and 34).

Moisture, fat, and protein were determined on longissimus dorsi samples taken from the 10th to 13th rib area. The percent dry matter in the meat was not significantly different between treatments.

Percent protein in longissimus dorsi (expressed on a dry matter basis) was significantly lower in barrows than in gilts, and was significantly decreased by hormone supplementation (Figures 35 and 36).

Percent fat in longissimus dorsi (expressed on a dry matter basis) was significantly affected by sex and DES + MT. In this trial, gilts showed significantly less fat in the lean tissue than barrows (Figure 37). Supplementation with DES + MT significantly increased the percent fat in longissimus dorsi over that found in pigs fed the basal ration (Figure 38).

This trial concluded the series of feedlot performance and carcass study experiments. Table 44 presents a summary of all the significant performance and carcass responses observed in the 4 trials.

## Experiments 178-E and F

### Experimental

Experiments 178-E and F were the last two experiments performed in the 178 series. Both of these trials were metabolism studies. Barrows were housed in metabolism crates constructed so as to permit total collection of all excreta separately. The crates were equipped

with automatic water fountains, and with fans for cooling. The floors were of expanded steel mesh. Barrows were full-hand-fed twice daily and a record of daily feed intake was made. Barrows were weighed, placed in the crates, and fed the experimental diets for a period of acclimatization to the regime. The pretrial period was 9 days in the first metabolism trial and 11 days in the second one. Collection of total feces and urine excreted was made as previously described for a period of 6 days in both trials. Barrows were weighed again at the termination of the feeding period.

The design of the experiments is shown in Table 38. In the first metabolism trial (conducted from May 29 to June 12, 1969), crossbred barrows averaging 58 kg initially were used; terminal average weight was 65.7 kg. In the second metabolism trial (conducted from July 28 to August 14, 1969), similar barrows were used. Average initial weight was 57.1 kg, and average terminal weight was 67.8 kg. Each trial consisted of 8 barrows; the blocks used in the design were littermate pairs, and four barrows were assigned to each treatment. The basal (14% protein) diet was fed with and without 2.2 mg of DES + MT per kg of feed, as shown in Table 1.

Criteria examined in both trials were daily feed intake, total gain, daily nitrogen retention (g N/kg feed consumed), apparent digestibility of dry matter and nitrogen, and excretion of 17-keto-steroids in urine.

## Results

The treatment means for both trials are shown in Table 39, and analysis of variance plans are presented in Tables 40 and 41 for

for Experiment 178-E and Tables 42 and 43 for Experiment 178-F.

No significant difference due to DES + MT was observed in daily feed intake, although a slight decrease in feed intake in the first metabolism trial and a more marked decrease in the second occurred in pigs fed the hormone supplement.

Total gain was very slightly decreased in pigs fed DES + MT in Experiment 178-E, but was moderately increased in hormone supplemented pigs in Experiment 178-F. Neither difference was significant, however.

Daily nitrogen retention, expressed as g of nitrogen retained per kg of feed consumed, did not differ significantly due to treatment in either trial. Pigs fed DES + MT showed a moderate decrease in nitrogen retention in the first metabolism trial, but showed only a slight decrease in the second trial; neither difference was great enough to be significant.

Apparent digestibility of dry matter and nitrogen was similar for both treatment groups in both trials. Digestibility did not appear to vary between trials, either.

In the first metabolism trial, excretion of 17-ketosteroids in urine was significantly different due to treatment. Pigs fed DES + MT had a higher daily excretion of 17-ketosteroids in urine than pigs fed the basal ration. In the second trial opposite results were observed. Pigs fed the hormone supplement in this experiment showed a lower daily excretion of 17-ketosteroids in urine than did pigs fed the basal diet, but this difference was not significant.

## GENERAL DISCUSSION

### The Effects of Hormone, Protein, and Sex on the Feedlot Performance of Growing-Finishing Swine

Several recent studies have been reported which indicate that DES + MT affects the performance of swine in the feedlot.

Wallace et al. (1967) reported a significant decrease in both average daily gain and average daily feed intake due to feeding DES + MT at 2.2 mg each per kg of diet.

Baker et al. (1967) reported that DES + MT decreased average daily gain in barrows, but not in gilts. They observed also that feed efficiency response to DES + MT was obtained only at higher levels of protein.

Doornenbal and Frankenham (1969) reported a non-significant increase in average daily gain for gilts and barrows fed a practical high protein ration containing 2.2 mg each of DES + MT per kg of feed, but they reported that feed efficiency was not altered by treatment.

#### Average Daily Gain

In this series of experiments, rate of gain was affected significantly by hormone in only 1 out of 4 trials (Table 44). Hormone treatment decreased rate of gain only in barrows in this particular case, since there was a significant interaction of hormone x sex.

Sex affected rate of gain in two trials (Table 44). Barrows gained significantly faster than gilts. No effect on rate of gain due to protein level was observed in any trial.

Barrows responded significantly more to DES + MT than gilts. This difference was manifested in a marked decrease in rate of gain for hormone supplemented barrows, but essentially no change was observed in gilts fed the hormone. This interaction of DES + MT with other factors (especially sex and protein level) may be one reason that some of the responses to DES + MT in some trials have been so variable. This observation on gain response to DES + MT is in general agreement with other work reported in papers mentioned in the literature review. Gain response to this combination of hormones has been erratic at best, and it may be that the response varies with experimental conditions.

Average Daily Feed Intake

Feed intake is one of the most variable parameters in animal research. Daily feed consumption can be affected by a variety of factors, including hormone supplementation, sex, and protein level. In this experiment there was a significant reduction in feed intake attributed to DES + MT in the second and fourth feeding trials (Table 44). In the other trials there was a marked trend toward reduced feed intake due to hormone, but the effect was not significant. There was a significant hormone x sex interaction in Experiment 178-B. This pattern has been noted by other workers (Wallace et al., 1967; Beacom, 1963) who reported that feed intake in gilts was unaffected by

hormone supplementation, but was markedly decreased in barrows when DES + MT was added to the ration. In this experiment sex also influenced daily feed intake significantly in the last feeding trial (Table 44). Barrows consumed significantly more than gilts in this trial.

The observed trend toward decreased feed intake was rather consistent in this study, and has also been reported by numerous other workers. Either DES or MT fed alone is capable of eliciting the response (Dinusson et al., 1951). The feed intake reduction is most probably one of the factors contributing to reduced rate of growth and increased feed efficiency reported in many of the trials involving hormone supplementation.

Feed Conversion Efficiency

The feed conversion efficiency ratio (feed/gain) was significantly improved by DES + MT in the same 2 trials which showed a significant decrease in feed intake caused by the hormone. Neither sex nor protein significantly influenced feed efficiency in any trial conducted in this experiment.

It is probable that the decreased feed intake due to hormone was responsible for this increased efficiency observed in the same experiments. Dinusson et al. (1951) and Heitman and Clegg (1957) reported improved efficiency due to supplementation with DES.

Wallace et al. (1967) reported that increased feed conversion efficiency due to DES + MT was manifested most at higher protein levels. This is in agreement with the work of Baker et al. (1967), who reported similar findings.

Opposite results were observed in this study. There were 2 trials in which protein level varied (Experiments 178-A and B). No significant differences in feed efficiency were observed in Experiment 178-A, but in Experiment 178-B there was a more marked improvement in efficiency due to DES + MT in pigs fed the low protein diet than in those fed the high protein diet.

In Experiment 178-D, efficiency was improved more by DES + MT in gilts than in barrows.

## The Effects of Hormone, Protein, and Sex on the Carcass Characteristics of Swine

### Dressing Percentage

Dressing percentage was affected by hormone in only the first trial of this series. Beacom (1963) reported no change in dressing percentage due to DES or a combination of estradiol and testosterone. Other workers have obtained similar results.

There was a significant 3 factor interaction (protein x hormone x sex) observed in the first trial, which influenced dressing percent. When this interaction was graphed (Figure 1) it was evident that barrows and gilts responded in an opposite manner to hormone supplementation and protein level. Differences in carcass leanness in barrows and gilts fed different protein levels are well documented. It may have been this effect which was responsible for the 3 factor interaction. Due to this 3 factor interaction, it was impossible to make inferences concerning any of the main effects on dressing percent.

Percent Lean Primal Cuts

Percent lean primal cuts are a good index of overall carcass leanness. Lean primal cuts were increased significantly due to DES + MT in 3 out of 4 trials (Table 44) in this study. Increased protein level was also responsible for an increase in percent lean cuts in the first trial. This increase in percent lean cuts due to DES + MT was probably an additive effect accumulated in increments in each of the 4 lean cuts. Percent ham was not changed by DES + MT in any trial, but was significantly greater in gilts than in barrows in Experiment 178-A. In addition, there was a significant hormone x sex interaction which affected percent ham in Experiment 178-D. Gilts did not respond to DES + MT, while barrows showed a significant increase in percent ham due to the hormone. There was a significant hormone x sex interaction influencing percent loin in the first two trials (Figures 4 and 18). In both cases, gilts showed a very slight negative response in percent loin to the hormone supplement, while barrows responded with a marked and significant increase in loin yield. Percent picnic shoulder was significantly increased by DES + MT in 2 trials, as was percent Boston Butt.

When the cumulative effects of these increases are summed together into percent lean primal cuts, the result is a consistent increase of lean cuts in the range of about 2 percent. There were 2 significant hormone x sex interactions which showed a differential response in percent lean cuts due to DES + MT in barrows and gilts (Figures 2 and 17). Barrows responded more markedly than gilts to hormone supplementation influence on percent lean cuts.

In general, this response in lean cuts is a good indication that there is a significant improvement in carcass leanness due to DES + MT. This observation is in agreement with the results reported by Wallace et al. (1967), Baker et al. (1967), Beacom (1963), and Doornenbal and Frankenham (1969). Hale and Johnson (1970) also reported an increase in lean cuts due to hormone supplementation.

Backfat Thickness

Workers cited in the preceding section and in the literature review have reported that, accompanying the increased yield of primal cuts usually stimulated by DES + MT, there is nearly always a simultaneous decrease in backfat thickness. Results obtained in this investigation corroborate these findings. Backfat thickness was significantly reduced by DES + MT in 3 out of 4 trials. Protein level also tended to affect backfat in the first trial. Increased protein level decreased backfat significantiy. In the second trial, both protein and sex interactions with hormone affected backfat thickness response (Figure 19). From the graphs of these interactions it is apparent that DES + MT reduced backfat in barrows and in pigs fed the low level of protein.

These results are logical, since gilts are usually leaner than barrows to start with, and pigs fed high levels of protein are leaner than those fed low levels of protein; therefore, the gilts and high protein fed pigs would respond less in backfat thickness reduction when DES + MT was fed.

Loin Eye Area

Loin eye area was not affected by DES + MT in any of the trials. This is in agreement with the work of Wallace et al. (1967). Baker et al. (1967) reported an increase in loin eye area due to DES + MT only at superadequate levels of protein.

Carcass Length

Carcass length was affected by hormone in only one trial. Gilts fed DES + MT at the 12 percent protein level had significantly longer carcasses than those fed the 12 percent protein basal ration. No other inferences concerning main effects on carcass length are meaningful due to the significant 3 factor interaction observed. There was a non-significant trend toward increased length due to DES + MT in the other trials. Baker et al. (1967) also reported an increased length of carcass due to DES + MT.

Carcass Subjective Measurements

None of the trials showed any significant response to DES + MT in loin eye marbling score, loin eye color score, loin eye firmness score, or loin tenderness score. These responses were similar in all 4 trials. Loin meat aroma and flavor scores for incidence of boar odor were significantly increased in all 4 trials. There appeared to be a definite increase in the incidence of boar odor and flavor in the meat of pigs fed DES + MT. This boar odor increase was strongly manifested in the first 2 trials, and was seen to a lesser extent in the last 2 trials. In the first 2 trials, a number of carcasses were

condemned for boar odor incidence, but in the last 2 trials, eating quality of the meat of most pigs was judged acceptable even though a slight boar odor in meat of treated pigs was detectable by a trained taste panel.

These results are in agreement with those reported in numerous papers cited in the literature review. Wallace et al. (1967) found a very strong boar odor in meat of pigs fed DES + MT. The odor problem seems to be complex, and is affected by other factors than hormone supplementation (Martin, 1968). There seems to be no doubt, however, that methyltestosterone is the hormone responsible for stimulation of the production of this odor and flavor.

Chemical Composition of Loin

In the last 2 trials, the chemical composition of samples of lean longissimus dorsi was determined. Percent dry matter in the loin was significantly less for pigs fed DES + MT in Experiment 178-C. Percent protein in loin was also significantly increased by DES + MT in this experiment. Fat content was also reduced non-significantly in hormone fed pigs in this trial. Results differed markedly in the next trial. There was no significant difference observed between treatment groups in percent dry matter. Percent protein in the loin was significantly decreased by DES + MT, and percent fat was significantly increased by hormone. This same trend was apparent in differences between barrows and gilts, the loins of barrows being significantly fatter and having less protein than those from gilts. The difference in these responses between the two trials is difficult to reconcile.

In Experiment 178-C, loin percent dry matter and protein and pork chop aroma score were the only responses observed to be significantly different due to treatment. None of the carcass leanness parameters were significantly different, yet loins of treated pigs were significantly leaner as evidenced by chemical analysis. On the other hand, in Experiment 178-D, the major carcass leanness indices (percent lean primal cuts and backfat thickness) were significantly improved by hormone supplementation, yet loin meat from treated pigs contained significantly more fat and less protein than meat from control pigs. These results are in conflict with those reported by Doornenbal and Frankenham (1969), although the results of Experiment 178-C agree with their findings. Plimpton (1966) reported that 70 kg boars implanted with 96 mg of DES had (at slaughter weight) a greater percentage of moisture and a lower percentage of fat in the longissimus dorsi than did control boars. The pigs in Experiment 178-D which received DES + MT had every indication of being leaner, meatier animals than the control group. Loin eye marbling score was increased non-significantly by DES + MT in this trial, and this increase in marbling is probably the cause of the increased fat content and decreased protein content observed in longissimus dorsi samples of treated pigs. DES + MT may decrease depot fat to a greater extent than intramuscular fat.

## The Effects of DES + MT on the Nitrogen Retention of Growing-Finishing Swine

There is some evidence (D. H. Baker, unpublished data) that DES + MT stimulates increased nitrogen retention in swine. Baker studied the nitrogen retention patterns of 6 barrows in a cross-over design and found that in every case feeding DES + MT resulted in an increased nitrogen retention in these barrows. An increase in protein anabolism due to DES alone and MT alone is well documented in other species, especially in ruminants in the case of DES. Certainly one might expect to find an increase in nitrogen retention due to therapy with known potent anabolic drugs.

Results of the two metabolism trials performed in this investigation conflict with this. There was a slight but non-significant decrease in nitrogen retention of barrows fed DES + MT in two trials. Other parameters were also not significantly different. These results are opposite those of Baker's unpublished data. Several explanations of this difference come to mind. The pigs in this trial were full-hand-fed a 14 percent protein diet twice daily, while Baker used 16 percent protein, and restricted daily feed intake to 1.8 kg per day. In Experiment 178-E the pigs consumed less feed than did Baker's pigs, but the feed intake of pigs in Experiment 178-F was greater than that of Baker's pigs. The depression in feed intake in Experiment 178-E was attributed to high ambient temperature. It has been demonstrated (Wallace et al., 1967; Baker et al., 1967) that pigs fed DES + MT respond to the hormone more markedly at higher protein levels. It may have been that the pigs in Experiments 178-E and F did not consume

sufficient protein to allow normal nitrogen retention.

This overall depression in feed intake observed in all pigs in the metabolism trials may have affected the response to DES + MT, since 65 kg pigs under normal conditions would consume about twice as much feed as did these pigs, which were confined in metabolism crates. In addition to this overall decrease in feed intake attributed to stressful experimental conditions, the pigs fed DES + MT showed the typical depression in feed intake characteristic of hormone fed pigs. This difference in feed intake between control and treated pigs may have caused the slight reduction in nitrogen retention in pigs fed DES + MT, although the feed factor was accounted for in calculations. Heat and confinement stress may have been directly responsible for the lack of significant responses to DES + MT.

On the other hand, all pigs in these trials exhibited a positive mean nitrogen balance which would indicate that some anabolism was taking place. In fact, all pigs on both treatments did show a weight gain from the initial to the final weighing. Growth (protein synthesis) may have been occurring at the maximum possible rate under the experimental conditions. If this was the case, the body protein stores of the pigs may have been filled; therefore, no further anabolism under prevailing conditions might be expected to occur in response to DES + MT.

Other workers (Leathem, 1956; Applezweig, 1962) report that when the body protein stores are filled, little or no anabolic response to hormone therapy occurs. Robinson and Singleton (1966) were able to demonstrate an anabolic response in pigs fed a low protein diet, but not in pigs fed a high protein diet, when an anabolic steroid hormone was administered.

Variation in feed intake between individual pigs and variation from day to day in the same pig were both considerable. This was reflected in a marked variation in nitrogen retention between pigs and within pigs between days.

A test of the variation between pigs is available. Dividing sampling error mean square into experimental error mean square (Tables 40 and 42) gives an F with 3 and 40 degrees of freedom. In both of the metabolism trials conducted in this study, there was a significant variation in nitrogen retention between experimental units (pigs), regardless of block or treatment.

Certainly there are factors which are often beyond experimental control which can influence the results of a trial. The nitrogen balance experiments conducted in this study do not give evidence for a protein anabolism due to DES + MT, despite the fact that a response favoring increased nitrogen retention might be expected from the use of such compounds.

## The Effects of DES + MT on the Excretion of Urinary 17-ketosteroids in Swine

Since one of the hormones fed in these experiments, methyltestosterone, is excreted in a conjugated ketone derivative form in urine, a determination was made in the two metabolism trials to detect 17-ketosteroids in urine. These substances are metabolic end products of steroid hormones of all types.

A significantly greater amount of 17-ketosteroids was excreted by pigs fed DES + MT in the first metabolism trial. No significant

difference due to treatment was observed in the second trial, although there was a trend toward a lower excretion of 17-ketosteroids in the treated pigs. Pigs in Experiment 178-E did not excrete as much total urine per day as did those in Experiment 178-F. It was noted that the 17-ketosteroids were more difficult to detect in dilute urine than in concentrated urine. There also appeared to be great individual variation among pigs with regard to urinary output and 17-ketosteroid excretion.

Adrenal hormone output influences output of 17-ketosteroids, and it may be that the individual metabolisms of the pigs accounted for more variation than did the hormone present in the diet. Pigs were consuming only 3.5 to 5.5 mg of hormone per day.

The feed intake of barrows differed between the two metabolism trials, and this factor may have influenced the results obtained. Dorfman and Shipley (1956) state that in humans the normal daily excretion of urinary 17-ketosteroids varies with age, sex, stress factors, and endogenous hormone therapy. In this study, DES + MT did not appear to consistently affect the excretion of 17-ketosteroids in urine of swine.

## General Comments

Work reported by researchers studying DES and MT indicates that, fed alone or in combination, these humoral substances affect the performance and carcasses of pigs. The exact mechanism of action remains unclear at this time. There is reason to believe that some

of the response in carcass leanness attributed to DES + MT may be due to the reduced feed intake commonly observed when this combination of hormones is fed to pigs. The improved lean to fat ratio resulting when pigs are fed on an energy restricted diet is well documented.

Baker et al. (1967) reported that loin eye area response to DES + MT is generally improved at higher levels of protein; they postulated that this points to a protein-anabolic action. This alone, though, cannot explain all the common responses to DES + MT. The reduction in backfat thickness commonly seen has been attributed to a possible antilipogenic action of DES + MT. Decreased backfat thickness may also be a factor in the increased yield of lean primal cuts observed in 3 trials in this investigation and by other workers. A change in rate of deposition of either protein or fat would be reflected in the leanness criteria used in these experiments.

In regard to the stimulation of increased boar odor incidence, the value of feeding DES + MT is questionable. Some treated pigs in the first 2 trials exhibited very undesirable odor and flavor in the meat; however, in the second 2 trials the meat odor and flavor was acceptable for most pigs even though some incidence of boar odor in treated pigs was evident to the trained taste panel. The boar odor present in the carcasses of some pigs in Experiments 178-A and B was strong enough to cause condemnation of some carcasses; however, no carcasses were condemned for odor or flavor in Experiments 178-C and D.

A possible explanation of this might lie in the formulation of the hormone premix. Researchers at Eli Lilly and Company discovered that

there was a cis-trans isomerism in diethylstilbestrol hitherto unknown (Herb Brown, personal communication). This isomerism resulted in a racemic mixture of cis DES (60%) and trans DES (40%) after a period of time, even though the manufacturing process produced all trans-DES. Cis-DES was found to be biologically inert in estrogenic activity, while the trans isomer was very active. Both forms, however, showed up in full amount upon chemical analysis. A new stabilized form of DES was developed which contained 95 percent of the trans isomer and which would not racemize to the cis form. The first 2 trials were performed using the old type hormone supplement, while the remainder used the newer stabilized form. It was postulated that the estrogenic activity of the DES was not sufficient to balance the androgenic effects of the methyltestosterone in the old type hormone mixture. This may have caused the strong boar odor and flavor observed in some pigs in the early trials. Incidence of boar odor was much lower in the later trials using the high-trans stilbestrol mixture.

Numerous hormone x sex interactions were observed in all 4 trials. In general, these interactions were manifested in a different degree or direction of response in barrows and gilts. This sex difference in response to hormone supplementation is probably due to the fact that barrows have no endogenous source of sex hormones other than the small amounts produced in the adrenal cortex, whereas gilts have an ovarian source of natural steroid sex hormones. Doornenbal and Frankenham (1969) also observed hormone x sex interactions and concluded that different proportions of sex steroid hormone supplementation for

barrows and gilts would be necessary to achieve equal responses in both sexes.

In these experiments, the hormone combination affected performance and carcass quality more in barrows than in gilts.

## SUMMARY AND CONCLUSIONS

Four feeding and carcass trials and 2 metabolism trials were conducted to determine the effects of DES + MT on growth, carcass quality, and nitrogen retention in growing-finishing pigs.

Average daily gain was reduced by hormone supplementation, as was feed intake. Feed efficiency was generally improved by hormone.

There was a marked and significant trend toward increased carcass leanness, manifested in a decreased backfat thickness, increased length, and increased percent of lean cuts, both individually and as the 4 lean primal cuts. Loin eye marbling, color, firmness, or tenderness score were not affected by DES + MT. Chemical composition of longissimus dorsi was significantly but not consistently affected by hormone supplementation.

Hormone supplementation produced a significant increase in the incidence of boar odor in meat of pigs. This odor was judged undesirable and in many cases in early trials, unacceptable.

In later trials, however, the incidence of sex odor was detectable and was present to a degree such that the eating quality of the meat was reduced in some, but not all, cases.

Two metabolism trials failed to show any significant differences in nitrogen retention, feed intake, weight gain, or digestibility of dry matter and nitrogen between hormone treated and control pigs.

Excretion of 17-ketosteroids in urine was not consistently affected by hormone.

A possible protein anabolic effect or antilipogenic effect was postulated to explain the mode of action of DES + MT in increasing carcass leanness. It was also noted that the reduced feed intake common to administration of this combination of drugs was possibly involved in the carcass leanness response.

As part of the study, the effects of protein level and sex were also investigated. In general, increasing protein level resulted in improved performance and carcass quality. Gilts had superior carcasses to barrows, and were more efficient but gained more slowly than barrows. Sex and protein level were found to interact with each other and with DES + MT in influencing many performance and carcass traits.

It was concluded that the mode of action of DES + MT in improving carcass leanness was unclear. Furthermore, all the effects of DES + MT on performance and carcass quality in swine are not manifested consistently.

The value of DES + MT in improving carcass leanness is fairly evident, but the problem of boar odor which may appear in the meat of pigs fed this hormone combination remains unresolved.

This investigation has attempted to define the effects of diethylstilbestrol and methyltestosterone (and their interactions with other factors) on the performance and carcass quality of finishing pigs.

It is the feeling of the author that the effects are fairly well defined in this study, and by other work cited in the literature

review. Future research work on this problem ought to be concentrated on defining the mode of action of DES + MT in the body of the pig. Another area of research which needs to be investigated is the boar odor problem; some means of reducing the incidence of boar odor in pigs fed DES + MT may be available. Perhaps another practical approach to the problem would be the feeding of boars to market weight, using only a DES supplement to delay or prevent the development of the natural boar odor.

At this time, however, DES + MT does not appear to be a consistently practical approach to improving performance and carcass quality in pigs, due mainly to the possibility of producing undesirable odor and flavor in meat.

# APPENDIX I

Tables

Table 1. Experiment 178. Composition of diets

| Ingredient | Protein levels, % 12 | 14 | 16 |
|---|---|---|---|
| Ground yellow corn (8.9% C.P.) | 89.05 | 84.05 | 79.05 |
| Solvent soybean meal (50% C.P.) | 8.00 | 13.00 | 18.00 |
| Defluorinated phosphate (32% Ca; 18% P) | 1.80 | 1.80 | 1.80 |
| Calcium carbonate (38% Ca) | 0.50 | 0.50 | 0.50 |
| Iodized salt | 0.50 | 0.50 | 0.50 |
| Trace mineral premix 35C-73[a] | 0.05 | 0.05 | 0.05 |
| Vitamin premix (U.F.)[b] | 0.05 | 0.05 | 0.05 |
| Chemotherapeutic premix[c,d] | 0.05 | 0.05 | 0.05 |
| Totals | 100.00 | 100.00 | 100.00 |

[a] The composition is shown in Table 3.
[b] The vitamin fortification is shown in Table 4.
[c] Basal diets contained tylosin phosphate, 11.0 mg/kg.
[d] Hormone diets contained 2.2 mg/kg each of diethylstilbestrol and methyltestosterone and 11.0 mg/kg of tylosin phosphate.

Table 2. Experiment 178. Calculated analysis of diets

| Calculated analysis | Protein levels, % 12 | 14 | 16 |
|---|---|---|---|
| Protein, % | 11.93 | 13.99 | 16.04 |
| Energy, met. cal./kg | 3208 | 3166 | 3123 |
| Calcium, % | 0.80 | 0.80 | 0.80 |
| Phosphorus, % | 0.62 | 0.62 | 0.62 |
| Vitamin A, I.U./kg | 5700 | 5723 | 5557 |
| Vitamin $D_3$, I.U./kg | 441 | 441 | 441 |
| Riboflavin, mg/kg | 12.5 | 12.5 | 12.5 |
| Niacin, mg/kg | 215.4 | 215.4 | 215.4 |
| Choline, mg/kg | 800.0 | 800.0 | 800.0 |
| Vitamin $B_{12}$, µg/kg | 11.0 | 11.0 | 11.0 |
| Pantothenic acid, mg/kg | 20.0 | 20.0 | 20.0 |

Table 3. Experiment 178. Composition and contribution of trace mineral premix 350-73

| Element[a] | % in premix | Level in feed when added at 0.05% mg/kg |
|---|---|---|
| Manganese | 10.0 | 50.0 |
| Zinc | 10.0 | 50.0 |
| Iron | 10.0 | 50.0 |
| Copper | 1.0 | 5.0 |
| Cobalt | 0.1 | 0.5 |
| Iodine | 0.3 | 1.5 |

[a] Supplied as manganese sulfate, ferrous sulfate, ferrous carbonate, iron oxide, copper oxide, cobalt carbonate, potassium iodide, and zinc sulfate.

Table 4. Experiment 178. Contribution of vitamin premix

| Vitamin | Contribution per kg diet |
|---|---|
| Riboflavin | 6.6 mg |
| Niacin | 22.1 mg |
| Pantothenic acid | 13.2 mg |
| Choline chloride | 88.2 mg |
| Vitamin $B_{12}$ | 11.0 µg |
| Vitamin A | 2756 I.U. |
| Vitamin $D_3$ | 441 I.U. |

Table 5. Experiment 178. Dry matter and protein analysis, % of diets

| Analysis | Protein levels, % 12 | 14 | 16 |
|---|---|---|---|
| Dry matter, % | 85.84 | 86.93 | 85.53 |
| Crude protein, % (d.m. basis) | 12.71 | 14.58 | 16.44 |

Table 6. Experiment 178. Code for marbling score of longissimus dorsi at 10th rib

| Amount of marbling | Code | | |
|---|---|---|---|
| | - | | + |
| Devoid | | 0 | |
| Practically devoid | 1 | 2 | 3 |
| Traces | 4 | 5 | 6 |
| Slight | 7 | 8 | 9 |
| Small | 10 | 11 | 12 |
| Modest | 13 | 14 | 15 |
| Moderate | 16 | 17 | 18 |
| Slightly abundant | 19 | 20 | 21 |
| Moderately abundant | 22 | 23 | 24 |
| Abundant | 25 | 26 | 27 |
| Very abundant | 28 | 29 | 30 |
| Extremely abundant | 31 | 32 | 33 |

Table 7. Experiment 178. Code for color of longissimus dorsi at 10th rib

| Color of lean | Code |
|---|---|
| Very dark | 1 |
| Dark | 2 |
| Greyish pink (ideal) | 3 |
| Lightly light in color | 4 |
| Chicken meated - very light | 5 |

Table 8. Experiment 178. Code for firmness of longissimus dorsi at 10th rib

| Firmness of lean | Code |
|---|---|
| Hard | 1 |
| Medium hard | 2 |
| Medium soft | 3 |
| Soft | 4 |
| Oily | 5 |

Table 9. Experiment 178. Code for boar odor and flavor score

| Degree of boar odor or flavor | Code |
|---|---|
| None | 1 |
| Slight | 2 |
| Moderate | 3 |
| Strong | 4 |

Table 10. Experiment 178-A. Experimental design and distribution of animals

| Treatment factor | Lot 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| DES + MT | - | + | - | + |
| Protein level, % | 16 | 16 | 12 | 12 |
| Number of pigs[a] | 18 | 18 | 18 | 18 |

[a] Each lot consisted of 9 barrows and 9 gilts.

Table 11. Experiment 178-A. Summary of feedlot performance

| Criteria | Treatments 16% C.P. Basal | 16% C.P. DES + MT | 12% C.P. Basal | 12% C.P. DES + MT |
|---|---|---|---|---|
| Average daily feed, kg | 2.62 | 2.53 | 2.86 | 2.74 |
| Average daily gain, kg (66 days) | 0.75 | 0.75 | 0.81 | 0.75 |
| Feed/gain | 3.50 | 3.36 | 3.54 | 3.64 |

Table 12. Experiment 178-A. Protein and hormone treatment means and standard deviations of feedlot performance measurements[a,b,c]

| Criteria | Standard deviation of the difference between means ($\overline{Sd}$) | | Treatment means | | | |
|---|---|---|---|---|---|---|
| | | | Protein levels, % | | Hormone | |
| | Protein | Hormone | 16 | 12 | Basal | DES+MT |
| Average daily feed, kg | 0.0750 | 0.1557 | 2.58 | 2.80 | 2.74 | 2.63 |
| Average daily gain, kg | 0.0300 | 0.0300 | 0.75 | 0.78 | 0.78 | 0.75 |
| Feed/gain | 0.0860 | 0.1414 | 3.43 | 3.59 | 3.52 | 3.50 |

[a] Tabular $t_{n=2}^{\alpha=0.05} = 6.314$.

[b] Test statistic t(calculated) = $\dfrac{\overline{X}_1 - \overline{X}_2}{\overline{Sd}}$ .

[c] Animals were group fed; therefore, only 2 degrees of freedom are available for the t test of differences between protein or hormone means.

Table 13. Experiment 178-A. Summary of responses to treatments

| Response | TREATMENTS: Gilts 16% P basal | Gilts 16% P DES+MT | Gilts 12% P basal | Gilts 12% P DES+MT | Barrows 16% P basal | Barrows 16% P DES+MT | Barrows 12% P basal | Barrows 12% P DES+MT | Significant effect[a] |
|---|---|---|---|---|---|---|---|---|---|
| Gain, kg | 46.61 | 49.39 | 52.31 | 51.56 | 51.56 | 50.14 | 54.38 | 47.72 | |
| Dressing % | 72.75 | 70.39 | 71.37 | 70.97 | 72.67 | 71.17 | 72.87 | 69.74 | 3x* ($\omega$=1.93) |
| % lean cuts | 50.16 | 50.69 | 48.84 | 48.69 | 47.72 | 50.37 | 46.95 | 49.46 | 3x* ($\omega$=3.10) |
| % ham | 18.69 | 18.68 | 18.30 | 18.26 | 17.83 | 18.52 | 17.30 | 18.09 | S* |
| % loin | 15.60 | 15.75 | 15.29 | 14.89 | 14.43 | 15.70 | 14.64 | 15.30 | HxS* ($\omega$=0.84) |
| % picnic | 9.28 | 9.33 | 8.80 | 9.09 | 9.13 | 9.55 | 8.61 | 9.27 | P**, H** |
| % butt | 6.60 | 6.91 | 6.42 | 6.43 | 6.29 | 6.71 | 6.41 | 6.81 | PxS* ($\omega$=0.35) |
| Backfat, cm | 3.30 | 3.30 | 3.86 | 3.56 | 3.81 | 3.35 | 4.06 | 3.40 | P**, H** |
| LEA, $cm^2$ | 26.58 | 25.94 | 26.00 | 25.23 | 25.03 | 26.13 | 24.90 | 22.97 | |
| Length, cm | 77.39 | 78.38 | 77.83 | 78.59 | 77.60 | 78.94 | 78.23 | 78.16 | |
| Marbling score | 11.55 | 10.17 | 14.55 | 14.72 | 11.83 | 14.39 | 14.39 | 16.44 | P* |
| Color score | 3.22 | 3.22 | 3.33 | 3.33 | 3.22 | 3.28 | 3.50 | 3.22 | |
| Firmness score | 2.56 | 2.67 | 2.44 | 2.67 | 2.33 | 2.44 | 2.56 | 2.33 | |
| Aroma score | 1.13 | 1.37 | 1.20 | 1.20 | 1.11 | 1.41 | 1.15 | 1.36 | H** |
| Flavor score | 1.04 | 1.18 | 1.08 | 1.07 | 1.00 | 1.27 | 1.04 | 1.20 | H** |

[a] 3x indicates 3 factor interaction ($\omega_{p=8;n_2=56}^{\alpha=0}$); HxS and PxS indicate 2 factor interaction ($\omega_{p=4;n_2=56}^{\alpha=0}$).
* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).
P = protein; H = hormone; S = sex.

Table 14. Experiment 178-A. Analysis of variance of pig gain, dressing %, % lean cuts, % ham, and % loin

| Source of variation | Degrees of freedom | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Pig gain | Dressing % | % lean cuts | % ham | % loin |
| Treatment | 7 | 57.5476 | 12.2710* | 15.60** | 1.98 | 2.22* |
| Protein | 1 | 76.9843 | 4.7336 | 28.00* | 3.51 | 2.10 |
| Hormone | 1 | 41.2026 | 61.3839** | 34.58 | 2.31 | 3.17 |
| Sex | 1 | 17.4168 | 1.0760 | 16.72 | 5.39* | 2.38 |
| P x H | 1 | 86.6924 | 0.1243 | 0.78 | 0.00 | 1.53 |
| P x S | 1 | 62.7005 | 0.1959 | 3.00 | 0.01 | 1.10 |
| H x S | 1 | 114.5180 | 3.9289 | 27.30* | 2.60 | 5.28* |
| P x H x S | 1 | 3.3184 | 14.4544* | 26.14* | 0.05 | 0.01 |
| Replications | 8 | 6.2461 | 2.7903 | 3.70 | 0.89 | 0.53 |
| Error | 56 | 38.1003 | 2.0574 | 5.31 | 0.97 | 1.16 |
| Total | 71 | 36.4291 | 3.2878 | 6.15 | 1.06 | 1.19 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 15. Experiment 178-A. Analysis of variance of % picnic shoulder, % Boston butt, backfat thickness, loin eye area, and carcass length

| Source of variation | Degrees of freedom | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | % picnic shoulder | % Boston butt | Backfat thickness | Loin eye area | Carcass length |
| Treatment | 7 | 0.826** | 0.44* | 0.7723** | 11.5171 | 2.39 |
| Protein | 1 | 2.645** | 0.21 | 1.4348** | 23.4588 | 0.26 |
| Hormone | 1 | 2.276** | 1.47** | 2.2412** | 6.0312 | 10.39 |
| Sex | 1 | 0.005 | 0.02 | 0.4348 | 24.4994 | 0.71 |
| P x H | 1 | 0.245 | 0.12 | 0.2929 | 12.0707 | 2.97 |
| P x S | 1 | 0.009 | 0.87* | 0.2890 | 4.8241 | 0.64 |
| H x S | 1 | 0.605 | 0.29 | 0.7013 | 0.4162 | 0.19 |
| P x H x S | 1 | 0.000 | 0.08 | 0.0123 | 9.3028 | 1.68 |
| Replications | 8 | 0.294 | 0.21 | 0.4123 | 20.4744 | 6.00 |
| Error | 56 | 0.290 | 0.20 | 0.1955 | 6.6347 | 4.32 |
| Total | 71 | 0.343 | 0.22 | 0.2755 | 8.6784 | 4.32 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 16. Experiment 178-A. Analysis of variance of loin eye marbling score, loin eye color score, loin eye firmness score, loin roast aroma score, and loin roast flavor score

| Source of variation | Degrees of freedom | Mean squares: Loin eye marbling | Loin eye color | Loin eye firmness | Loin roast aroma | Loin roast flavor |
|---|---|---|---|---|---|---|
| Treatment | 7 | 39.25 | 0.597 | 0.16 | 0.13 | 0.077 |
| Protein | 1 | 166.53* | 0.222 | 0.00 | 0.02 | 0.010 |
| Hormone | 1 | 12.92 | 0.056 | 0.06 | 0.61** | 0.330** |
| Sex | 1 | 41.25 | 0.014 | 0.50 | 0.02 | 0.020 |
| P x H | 1 | 1.32 | 0.125 | 0.05 | 0.12 | 0.080 |
| P x S | 1 | 9.76 | 0.000 | 0.06 | 0.01 | 0.010 |
| H x S | 1 | 38.29 | 0.055 | 0.23 | 0.08 | 0.110 |
| P x H x S | 1 | 4.68 | 0.125 | 0.21 | 0.02 | 0.000 |
| Replications | 8 | 67.63 | 0.422 | 0.53 | 0.04 | 0.030 |
| Error | 56 | 31.35 | 0.230 | 0.51 | 0.08 | 0.033 |
| Total | 71 | 36.21 | 0.238 | 0.48 | 0.08 | 0.037 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 17. Experiment 178-B. Experimental design and distribution of animals during the growing phase

| Sex | Number of pigs | Lot |
|---|---|---|
| Gilts | 30 | 1 |
| Barrows | 30 | 2 |

Table 18. Experiment 178-B. Experimental design and distribution of animals during the finishing phase

| Treatment factors | Lot 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| Sex | G | G | G | G | B | B | B | B |
| Protein level, % | 12 | 12 | 14 | 14 | 12 | 12 | 14 | 14 |
| DES + MT | + | - | + | - | + | - | + | - |
| Number of pigs | 6 | 6 | 6 | 6 | 6 | 6 | 6 | 6 |

Table 19. Experiment 178-B. Summary of feedlot performance during the growing phase

| Criteria | Sex | |
|---|---|---|
| | Gilts | Barrows |
| Average daily gain, kg | 0.64 | 0.67 |
| Average daily feed, kg | 1.74 | 1.84 |
| Feed/gain | 2.72 | 2.75 |

Table 20. Experiment 178-B. Analysis of variance of average daily gain during the growing phase

| Source of variation | Degrees of freedom | Mean square |
|---|---|---|
| Sex | 1 | .0086 |
| Error | 58 | .0028 |
| Total | 59 | .0029 |

Table 21. Experiment 178-B. Summary of responses to treatments

| Response | TREATMENTS: Gilts 14% P basal | Gilts 14% P DES+MT | Gilts 12% P basal | Gilts 12% P DES+MT | Barrows 14% P basal | Barrows 14% P DES+MT | Barrows 12% P basal | Barrows 12% P DES+MT | Significant effect[a] |
|---|---|---|---|---|---|---|---|---|---|
| ADG, kg | 0.78 | 0.82 | 0.79 | 0.78 | 0.86 | 0.82 | 0.86 | 0.82 | S* |
| ADF, kg | 2.89 | 2.97 | 3.16 | 3.01 | 3.24 | 2.93 | 3.49 | 2.80 | HxS** (ω=0.27) |
| F/G | 3.72 | 3.62 | 4.01 | 3.62 | 3.76 | 3.59 | 4.07 | 3.69 | H** |
| Dressing % | 71.44 | 69.79 | 69.37 | 69.05 | 69.91 | 71.03 | 71.35 | 70.66 | PxS* (ω=1.36) |
| % lean cuts | 49.93 | 49.33 | 48.22 | 49.20 | 47.73 | 50.17 | 47.22 | 49.98 | HxS* (ω=2.15) |
| % ham | 19.65 | 19.18 | 19.18 | 19.48 | 18.93 | 19.35 | 18.45 | 19.48 | |
| % loin | 15.27 | 15.08 | 14.33 | 14.45 | 13.77 | 15.50 | 14.37 | 14.93 | HxS* (ω=0.91) |
| % picnic | 9.18 | 8.95 | 8.75 | 9.22 | 8.87 | 9.13 | 8.58 | 8.97 | |
| % butt | 5.87 | 6.08 | 5.95 | 6.07 | 6.18 | 6.20 | 5.80 | 6.57 | |
| Backfat, cm | 3.68 | 4.19 | 4.15 | 3.72 | 4.10 | 3.56 | 4.40 | 3.68 | PxH*, HxS** (ω=0.42) |
| LEA, $cm^2$ | 28.64 | 27.67 | 26.79 | 23.99 | 25.38 | 27.32 | 24.58 | 27.69 | HxS* (ω=2.92) |
| Length, cm | 82.55 | 82.23 | 80.75 | 84.67 | 81.28 | 84.03 | 82.13 | 83.50 | 3x* (ω=3.43) |
| Marbling score | 10.25 | 12.67 | 16.08 | 14.00 | 13.08 | 14.08 | 14.17 | 16.33 | |
| Color score | 3.33 | 3.33 | 3.33 | 3.50 | 3.67 | 3.50 | 3.33 | 3.67 | |
| Firmness score | 2.33 | 2.33 | 2.33 | 2.67 | 3.00 | 2.67 | 2.83 | 3.00 | S* |
| Aroma score | 1.15 | 1.42 | 1.12 | 1.78 | 1.00 | 1.45 | 1.00 | 1.65 | H** |
| Flavor score | 1.03 | 1.42 | 1.00 | 1.60 | 1.03 | 1.17 | 1.00 | 1.20 | H** |

[a] 3x indicates 3 factor interaction ($\omega_{p=8;n_2=35}^{\alpha=0.10}$); HxS, PxS, and PxH indicate 2 factor interaction ($\omega_{p=4;n_2=35}^{\alpha=0.10}$).

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

P = protein; H = hormone; S = sex.

Table 22. Experiment 178-B. Analysis of variance of average daily gain, average daily feed, feed/gain, dressing %, and % lean cuts

| Source of variation | Degrees of freedom | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | ADG | ADF | F/G | Dressing % | % lean cuts |
| Treatment | 7 | 0.0064 | 0.2989** | 0.1969 | 5.057* | 7.49 |
| Protein | 1 | 0.0017 | 0.1360 | 0.3623 | 2.279 | 4.88 |
| Hormone | 1 | 0.0021 | 0.8698** | 0.7931** | 1.779 | 23.39* |
| Sex | 1 | 0.0262* | 0.1381 | 0.0130 | 8.234* | 1.88 |
| P x H | 1 | 0.0016 | 0.2721 | 0.1887 | 0.178 | 2.74 |
| P x S | 1 | 0.0008 | 0.0268 | 0.0130 | 11.213* | 0.99 |
| H x S | 1 | 0.0101 | 0.6348** | 0.0026 | 4.307 | 17.39* |
| P x H x S | 1 | 0.0021 | 0.0144 | 0.0059 | 7.411 | 1.19 |
| Replications | 5 | 0.0012 | 0.1583 | 0.1014 | 1.998 | 6.25 |
| Error | 35 | 0.0065 | 0.0755 | 0.0976 | 1.959 | 4.89 |
| Total | 47 | 0.2789 | 0.1175 | 0.1128 | 2.425 | 5.43 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 23. Experiment 178-B. Analysis of variance of % ham, % loin, % picnic shoulder, % Boston butt, backfat thickness, and loin eye area

| Source of variation | Degrees of freedom | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | % ham | % loin | % picnic shoulder | % Boston butt | Backfat thickness | Loin eye area |
| Treatment | 7 | .0.8726 | 2.0061* | 0.2919 | 0.3447 | 0.5806** | 16.6492 |
| Protein | 1 | 0.2002 | 1.7633 | 0.2852 | 0.0018 | 0.1290 | 26.6388 |
| Hormone | 1 | 1.2352 | 3.7408* | 0.5852 | 0.9352 | 1.0322* | 1.2487 |
| Sex | 1 | 1.2352 | 0.2408 | 0.2267 | 0.4602 | 0.0000 | 3.3299 |
| P x H | 1 | 1.4352 | 0.5634 | 0.5002 | 0.3169 | 0.9677* | 0.0000 |
| P x S | 1 | 0.0252 | 1.9201 | 0.0604 | 0.0053 | 0.1290 | 19.5628 |
| H x S | 1 | 1.9602 | 4.2009* | 0.1304 | 0.1519 | 1.4193** | 58.6886* |
| P x H x S | 1 | 0.0169 | 1.6132 | 0.2550 | 0.5418 | 0.3871 | 6.6597 |
| Replications | 5 | 1.8462 | 0.8550 | 0.1433 | 0.3602 | 0.1677 | 3.7760 |
| Error | 35 | 1.0497 | 0.8673 | 0.2188 | 0.2380 | 0.1871 | 9.0156 |
| Total | 47 | 1.1081 | 1.0356 | 0.2217 | 0.2669 | 0.2452 | 9.5733 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 24. Experiment 178-B. Analysis of variance of carcass length, loin eye marbling score, loin eye color score, loin eye firmness score, loin roast aroma score, and loin roast flavor score

| Source of variation | Degrees of freedom | Mean squares: Carcass length | Loin eye marbling | Loin eye color | Loin eye firmness | Loin roast aroma | Loin roast flavor |
|---|---|---|---|---|---|---|---|
| Treatment | 7 | 10.8387 | 22.52 | 0.1310 | 0.4970 | 0.54* | 0.290** |
| Protein | 1 | 0.6452 | 82.69 | 0.0000 | 0.1875 | 0.21 | 0.010 |
| Hormone | 1 | 44.7741** | 9.19 | 0.0834 | 0.0209 | 3.10** | 1.300** |
| Sex | 1 | 0.3871 | 16.33 | 0.3334 | 2.5209* | 0.10 | 0.310 |
| P x H | 1 | 6.1935 | 8.33 | 0.3333 | 0.5208 | 0.27 | 0.060 |
| P x S | 1 | 0.1290 | 11.02 | 0.0833 | 0.0208 | 0.02 | 0.030 |
| H x S | 1 | 0.2581 | 6.03 | 0.0000 | 0.0874 | 0.02 | 0.320 |
| P x H x S | 1 | 23.4838* | 24.08 | 0.0833 | 0.0209 | 0.03 | 0.010 |
| Replications | 5 | 4.8903 | 8.12 | 0.1333 | 0.5208 | 0.11 | 0.016 |
| Error | 35 | 4.1380 | 20.81 | 0.2952 | 0.5553 | 0.19 | 0.088 |
| Total | 47 | 5.2258 | 19.72 | 0.2535 | 0.5315 | 0.23 | 0.110 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 25. Experiment 178-C. Experimental design

| Lot | Number of barrows[a] | Treatment |
|---|---|---|
| 1 | 12 | 14% C.P. basal |
| 2 | 12 | 14% C.P. + DES + MT |

[a] Each lot contained one pig with identical ear notches. The identity of both these pigs was lost at slaughter; therefore, carcass data are based on the remaining 11 pigs in each lot.

Table 26. Experiment 178-C. Summary of mean responses to treatments

| Response | Treatments: 14% protein basal | 14% protein DES+MT |
|---|---|---|
| Average daily gain, kg | 0.80 | 0.80 |
| Average daily feed, kg | 2.92 | 2.76 |
| Feed/gain | 3.67 | 3.50 |
| Dressing % | 72.97 | 71.88 |
| % lean primal cuts | 52.24 | 52.39 |
| % ham | 19.75 | 20.15 |
| % loin | 16.52 | 16.47 |
| % picnic shoulder | 9.24 | 9.21 |
| % Boston butt | 6.67 | 6.55 |
| Average backfat, cm | 3.18 | 3.07 |
| Loin eye area, $cm^2$ | 31.28 | 29.86 |
| Carcass length, cm | 77.14 | 77.57 |
| Loin eye marbling score | 12.64 | 10.09 |
| Loin eye color score | 3.09 | 3.18 |
| Loin eye firmness score | 2.18 | 2.45 |
| Pork chop aroma score | 1.04 | 1.07** |
| Pork chop flavor score | 1.04 | 1.03 |
| Loin roast aroma score | 1.03 | 1.08 |
| Loin roast flavor score | 1.00 | 1.02 |
| % dry matter in l. dorsi | 27.75 | 26.21* |
| % protein in l. dorsi (d.m. basis) | 74.77 | 78.82* |
| % fat in l. dorsi (d.m. basis) | 23.21 | 21.57 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 27. Experiment 178-C. Analysis of variance of average daily gain, average daily feed, and feed/gain

| Source of variation | Degrees of freedom | Mean squares | | |
|---|---|---|---|---|
| | | ADG | ADF | F/G |
| Treatment | 1 | 0.0002 | 0.1381 | 0.1768 |
| Error | 22 | 0.0051 | 0.0538 | 0.0547 |
| Total | 23 | 0.0049 | 0.0575 | 0.0600 |

Table 28. Experiment 178-C. Analysis of variance of dressing %, % lean cuts, % ham, % loin, and % picnic shoulder

| Source of variation | Degrees of freedom | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | Dressing % | % lean cuts | % ham | % loin | % picnic shoulder |
| Treatment | 1 | 6.5455 | 0.1315 | 0.8405 | 0.0113 | 0.0041 |
| Error | 20 | 4.3429 | 120.1973 | 2.0987 | 2.2369 | 0.4427 |
| Total | 21 | 4.4478 | 11.4536 | 2.0388 | 2.1309 | 0.4429 |

Table 29. Experiment 178-C. Analysis of variance of % Boston butt, backfat thickness, loin eye area, carcass length, and loin eye marbling score

| Source of variation | Degrees of freedom | Mean squares | | | | |
|---|---|---|---|---|---|---|
| | | % Boston butt | Backfat thickness | Loin eye area | Carcass length | Loin eye marbling |
| Treatment | 1 | 0.0891 | 0.0729 | 11.4463 | 0.9497 | 35.6364 |
| Error | 20 | 0.4125 | 0.2826 | 18.3926 | 2.3381 | 14.9477 |
| Total | 21 | 0.4169 | 0.2729 | 18.0644 | 2.2716 | 15.9329 |

Table 30. Experiment 178-C. Analysis of variance of loin eye color score, loin eye firmness score, pork chop aroma score, pork chop flavor score, loin roast aroma score, and loin roast flavor score

| Source of variation | Degrees of freedom | Mean squares | | | | | |
|---|---|---|---|---|---|---|---|
| | | Loin eye color | Loin eye firmness | Pork chop aroma | Pork chop flavor | Loin roast aroma | Loin roast flavor |
| Treatment | 1 | 0.0454 | 0.4091 | 0.4259** | 0.0018 | 0.0164 | 0.0018 |
| Error | 20 | 0.1273 | 0.2182 | 0.0185 | 0.0035 | 0.0089 | 0.0018 |
| Total | 21 | 0.1234 | 0.2272 | 0.0379 | 0.0034 | 0.0093 | 0.0018 |

** Significant (P = 0.01 or less).

Table 31. Experiment 178-C. Analysis of variance of % dry matter, % protein, and % fat in L. dorsi

| Source of variation | Degrees of freedom | Mean squares: L. dorsi dry matter | L. dorsi protein | L. dorsi fat |
|---|---|---|---|---|
| Treatment | 1 | 12.9977* | 90.1733* | 14.3157 |
| Error | 20 | 2.1170 | 20.6030 | 22.0444 |
| Total | 21 | 2.6352 | 23.9158 | 21.6764 |

* Significant (P = 0.05 or less).

Table 32. Experiment 178-D. Experimental design and distribution of animals

| Sex | Treatments: 14% protein basal | 14% protein DES+NT |
|---|---|---|
| No. of gilts | 12 | 12[a] |
| No. of barrows | 12[b] | 12 |

[a] The carcass of one pig was condemned for a condition of granuloma in the muscle tissue. Flavor and tenderness of meat from this carcass was not determined.

[b] One pig died during the experiment. Apparent cause of death was generalized edema and congestive heart failure due to heat prostration. Due to loss of these data, orthogonality of the design was destroyed. Computer analysis using a complete and a reduced model was necessary in order to partition the sums of squares. For this reason, sums of squares generated from mean squares in the analysis of variance tables for Experiment 178-D are not additive.

Table 33. Experiment 178-D. Summary of responses to treatments

| Response | TREATMENTS: Gilts 14% P basal | Gilts 14% P DES+MT | Barrows 14% P basal | Barrows 14% P DES+MT | Significant effect[a] |
|---|---|---|---|---|---|
| Average daily gain, kg | 0.77 | 0.76 | 0.93 | 0.81 | HxS* (ω=0.08) |
| Average daily feed, kg | 2.96 | 2.56 | 3.28 | 2.73 | S*, H** |
| Feed/gain | 3.84 | 3.38 | 3.53 | 3.34 | H** |
| Dressing % | 73.05 | 72.89 | 72.58 | 73.00 | |
| % lean primal cuts | 52.67 | 53.40 | 51.16 | 53.03 | H* |
| % ham | 20.67 | 20.51 | 19.69 | 20.66 | HxS* (ω=0.84) |
| % loin | 16.76 | 16.72 | 16.23 | 16.56 | |
| % picnic shoulder | 9.02 | 9.46 | 8.89 | 9.32 | H** |
| % Boston butt | 6.20 | 6.72 | 6.36 | 6.48 | H* |
| Average backfat, cm | 3.37 | 3.05 | 3.49 | 2.98 | H** |
| Loin eye area, $cm^2$ | 31.26 | 29.66 | 28.81 | 29.20 | |
| Carcass length, cm | 78.84 | 79.55 | 77.88 | 79.63 | |
| Liver weight, kg | 1.44 | 1.48 | 1.56 | 1.48 | |
| Loin eye marbling score | 11.58 | 14.08 | 15.86 | 16.83 | |
| Loin eye color score | 3.17 | 3.29 | 3.27 | 3.17 | |
| Loin eye firmness score | 2.42 | 2.33 | 2.36 | 2.33 | |
| Average loin tenderness score | 8.06 | 8.12 | 7.13 | 7.64 | S* |
| Pork chop aroma score | 1.04 | 1.16 | 1.03 | 1.28 | H* |
| Pork chop flavor score | 1.02 | 1.15 | 1.03 | 1.31 | H** |
| Loin roast aroma score | 1.07 | 1.20 | 1.05 | 1.28 | H* |
| Loin roast flavor score | 1.10 | 1.14 | 1.05 | 1.33 | H* |
| % dry matter in l. dorsi | 25.95 | 26.79 | 27.33 | 27.30 | |
| % protein in l. dorsi[b] | 78.85 | 72.78 | 72.56 | 68.85 | S*, H* |
| % fat in l. dorsi[b] | 19.77 | 25.91 | 26.76 | 29.07 | S**, H* |

[a] HxS indicates 2 factor interaction ($\omega_{p=4}^{\alpha=0}; n_2^{10}=43$); H = hormone, S = sex.
[b] Dry matter basis.
* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 34. Experiment 178-D. Analysis of variance of average daily gain, average daily feed, feed/gain, dressing %, % lean cuts, % ham, and % loin

| Source of variation | Degrees of freedom | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | ADG | ADF | F/G | Dressing % | % lean cuts | % ham | % loin |
| Sex | 1 | 0.1282** | 0.6741* | 0.3527 | 0.3798 | 10.3459 | 2.0002 | 1.4280 |
| Hormone | 1 | 0.0487* | 2.6602** | 1.2454** | 0.1981 | 19.7485* | 1.9202 | 0.2600 |
| H x S | 1 | 0.0298* | 0.0675 | 0.2328 | 0.9749 | 3.8436 | 3.7175* | 0.3895 |
| Error | 43 | 0.0072 | 0.1283 | 0.0904 | 2.5854 | 3.4231 | 0.7571 | 0.7479 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 35. Experiment 178-D. Analysis of variance of % picnic shoulder, % Boston butt, backfat thickness, loin eye area, carcass length, liver weight, and loin eye marbling score

| Source of variation | Degrees of freedom | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | % picnic shoulder | % Boston butt | Backfat thickness | loin eye area | carcass length | liver weight | loin eye marbling |
| Sex | 1 | 0.2231 | 0.0142 | 0.9775 | 24.7574 | 2.2484 | 0.0341 | 144.9805 |
| Hormone | 1 | 2.1649** | 1.1879* | 1.9710** | 4.3163 | 17.4903 | 0.0054 | 35.3138 |
| H x S | 1 | 0.0002 | 0.4622 | 0.1000 | 11.5046 | 3.2026 | 0.0449 | 6.8694 |
| Error | 43 | 0.2995 | 0.2023 | 0.1270 | 11.2715 | 4.5884 | 0.0330 | 46.1289 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 36. Experiment 178-D. Analysis of variance of loin eye color score, loin eye firmness score, pork chop aroma score, loin roast aroma score, and % dry matter, protein, and fat in *L. dorsi*

| Source of variation | Degrees of freedom | Mean squares | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | Loin eye color | Loin eye firmness | Pork chop aroma | Loin roast aroma | *L. dorsi* dry matter | *L. dorsi* protein | *L. dorsi* fat |
| Sex | 1 | 0.0011 | 0.0082 | 0.0359 | 0.0149 | 10.4295 | 307.9784* | 302.1272** |
| Hormone | 1 | 0.0011 | 0.0379 | 0.4075* | 0.3846* | 1.9059 | 282.6807* | 209.4248* |
| H x S | 1 | 0.1566 | 0.0082 | 0.0570 | 0.0267 | 2.1810 | 16.9184 | 42.7026 |
| Error | 43 | 0.1801 | 0.3441 | 0.0609 | 0.0668 | 3.6427 | 49.9815 | 39.9594 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 37. Experiment 178-D. Analysis of variance of average loin tenderness score, pork chop flavor score, and loin roast flavor score

| Source of variation | Degrees of freedom | Mean squares: Loin tenderness | Pork chop flavor | Loin roast flavor |
|---|---|---|---|---|
| Sex | 1 | 5.7664* | 0.0698 | 0.0582 |
| Hormone | 1 | 0.9136 | 0.4838** | 0.3017* |
| H x S | 1 | 0.5741 | 0.0659 | 0.1562 |
| Error | 42 | 0.8596 | 0.0486 | 0.0534 |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Table 38. Experiments 178-E and F. Experimental design[a,b] and distribution[c] of barrows over blocks and treatments

| Treatment | Block 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 14% protein basal | $B_{11}$ | $B_{21}$ | $B_{31}$ | $B_{41}$ |
| 14% protein DES + MT | $B_{12}$ | $B_{22}$ | $B_{32}$ | $B_{42}$ |

[a] Total gain and urinary 17-ketosteroids were analyzed statistically with a randomized block design with 1 observation per experimental unit.

[b] Daily feed intake, digestibility of dry matter and nitrogen, and g nitrogen retained/kg feed were analyzed statistically with a randomized block design with subsampling (6 observations per experimental unit.

[c] Subscript numbers indicate block and treatment, respectively; blocks consisted of littermate pairs of barrows.

Table 39. Experiments 178-E and F. Summary of responses to treatments

| Response | TRIAL 178-E treatments 14% P basal | 14% P DES+MT | 178-F treatments 14% P basal | 14% P DES+MT |
|---|---|---|---|---|
| Average daily feed, kg | 1.65 | 1.53 | 2.53 | 2.09 |
| Total gain, kg | 7.38 | 7.15 | 9.53 | 11.92 |
| Daily N retention, g N/kg feed | 10.88 | 7.69 | 10.86 | 9.58 |
| Apparent dig. d.m., % | 84.02 | 86.20 | 87.17 | 87.49 |
| Apparent dig. N, % | 83.46 | 85.30 | 84.89 | 84.61 |
| 17-ketosteroids in urine, mg/day | 4.34 | 12.06* | 11.03 | 6.47 |

* Significant (P = 0.05 or less).

Table 40. Experiment 178-E. Analysis of variance of average daily feed, daily nitrogen retention, and apparent digestibility of dry matter and nitrogen

| Source of variation | Degrees of freedom | Mean squares | | | |
|---|---|---|---|---|---|
| | | ADF | Daily N retention | Dry matter digestibility | Nitrogen digestibility |
| Blocks | 3 | 1.8212 | 33.8991 | 77.7131 | 82.4503 |
| Treatment | 1 | 0.1719 | 121.9219 | 56.7675 | 40.4251 |
| Experimental error | 3 | 0.3453 | 71.7041 | 76.7809 | 119.9883 |
| Sampling error | 40 | 0.0737 | 18.9327 | 84.0818 | 100.0449 |
| Total | 47 | 0.2047 | 25.4476 | 82.6281 | 98.9264 |

Table 41. Experiment 178-E. Analysis of variance of total gain and 17-ketosteroids in urine

| Source of variation | Degrees of freedom | Mean squares | |
|---|---|---|---|
| | | Total gain | 17-ketosteroids in urine |
| Blocks | 3 | 2.6117 | 12.1879 |
| Treatment | 1 | 0.1035 | 119.1967* |
| Error | 3 | 3.9423 | 3.7434 |
| Total | 7 | 2.8236 | 23.8558 |

* Significant (P = 0.05 or less).

Table 42. Experiment 178-F. Analysis of variance of average daily feed, daily nitrogen retention, and apparent digestibility of dry matter and nitrogen

| Source of variation | Degrees of freedom | Mean squares | | | |
|---|---|---|---|---|---|
| | | ADF | Daily N retention | Dry matter digestibility | Nitrogen digestibility |
| Blocks | 3 | 0.5341 | 22.4350 | 3.8385 | 30.3017 |
| Treatment | 1 | 2.3724 | 19.7634 | 1.2577 | 0.9690 |
| Experimental error | 3 | 0.6210 | 13.3350 | 25.6607 | 55.2518 |
| Sampling error | 40 | 0.0361 | 3.6133 | 10.1421 | 18.3034 |
| Total | 47 | 0.1550 | 5.7789 | 10.5413 | 21.0588 |

Table 43. Experiment 178-F. Analysis of variance of total gain and 17-ketosteroids in urine

| Source of variation | Degrees of freedom | Mean squares | |
|---|---|---|---|
| | | Total gain | 17-ketosteroids in urine |
| Blocks | 3 | 8.7409 | 19.1417 |
| Treatment | 1 | 11.4003 | 57.7921 |
| Error | 3 | 3.8064 | 41.7451 |
| Total | 7 | 7.0060 | 34.3503 |

Table 44. Experiment 178-A - D. Significant effects in 4 trials

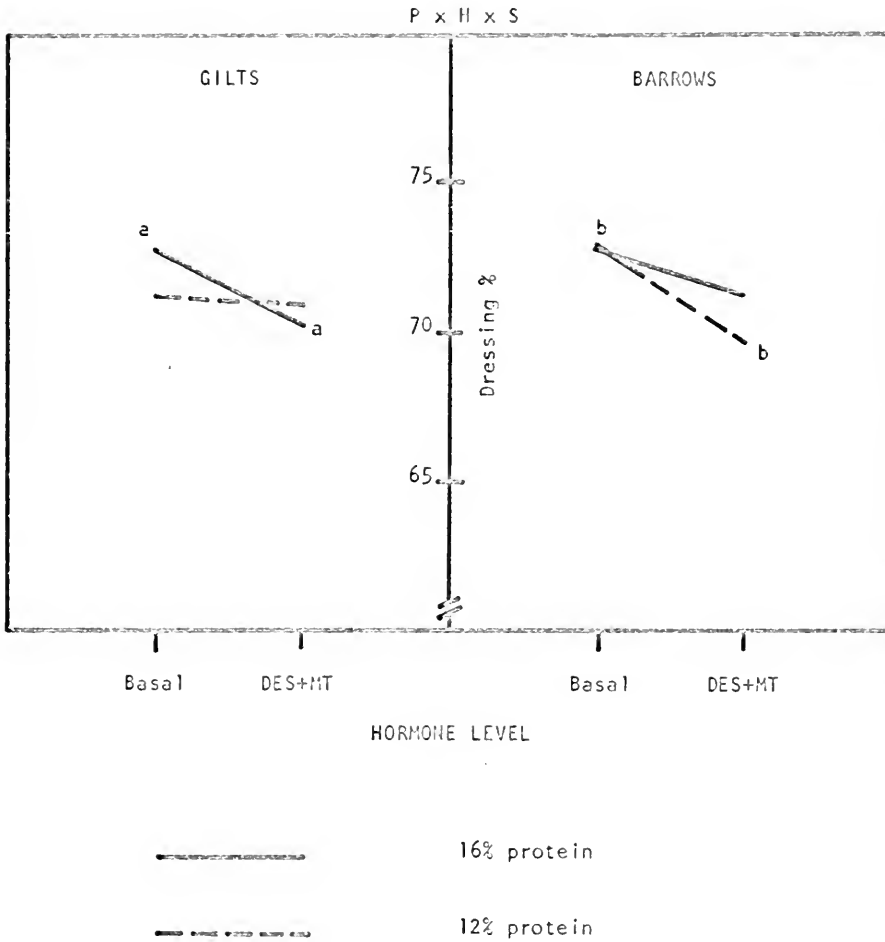
| Response | Trials | | | |
|---|---|---|---|---|
| | 178-A | 178-B | 178-C | 178-D |
| Average daily gain | | S* | | HxS* |
| Average daily feed | | HxS** | | S* H** |
| Feed/gain | | H** | | H** |
| Dressing % | PxHxS* | PxS* | | |
| % lean primal cuts | PxHxS* | HxS* | | H* |
| % ham | S* | | | HxS* |
| % loin | HxS* | HxS* | | |
| % picnic shoulder | P** H** | | | H** |
| % Boston butt | H** PxS* | | | H* |
| Average backfat thickness | P** H** | HxS** PxH* | | H** |
| Loin eye area | | HxS* | | |
| Carcass length | | PxHxS* | | |
| Loin eye marbling score | P* | | | |
| Loin eye firmness score | | S* | | |
| Pork chop aroma score[a] | | | H** | H* |
| Pork chop flavor score[b] | | | | H** |
| Loin roast aroma score | H** | H** | | H* |
| Loin roast flavor score | H** | H** | | H* |
| % dry matter in l. dorsi[c] | | | H* | |
| % protein in l. dorsi (d.m. basis)[d] | | | H* | S* H* |
| % fat in l. dorsi (d.m. basis)[e] | | | | S** H* |

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

[a,b] Chop aroma & flavor tested only in Expt. 178-C & D.
[c,d,e] L. dorsi analyzed only in Expt. 178-C & D.

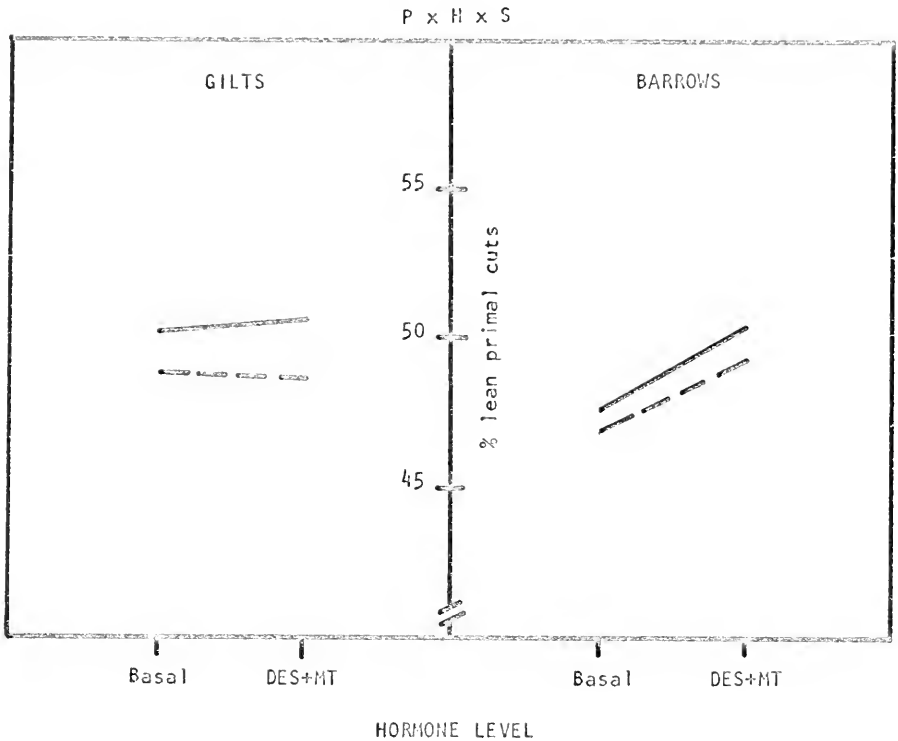
# APPENDIX II

Figures



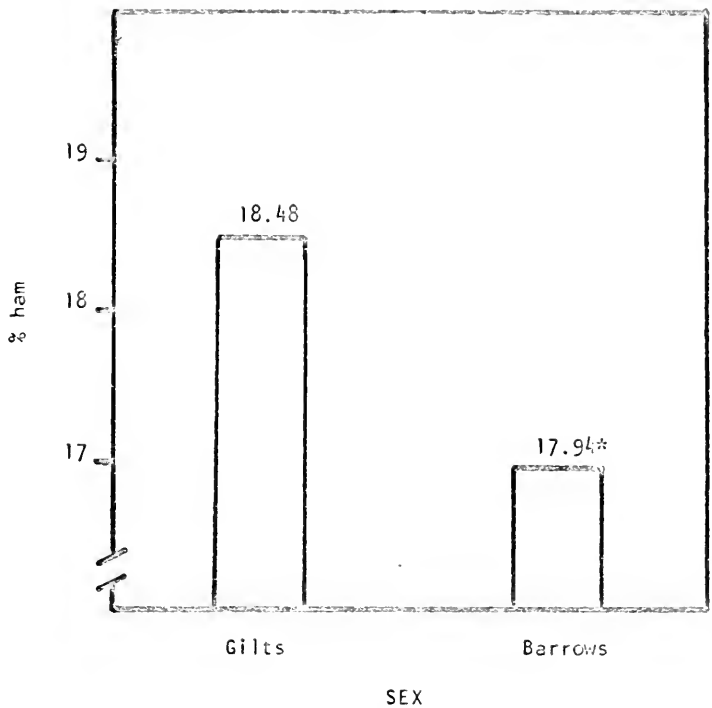

[a,b] Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 1.93$).

Figure 1. Experiment 178-A. The effect of interaction of sex, protein level, and hormone supplementation on dressing %



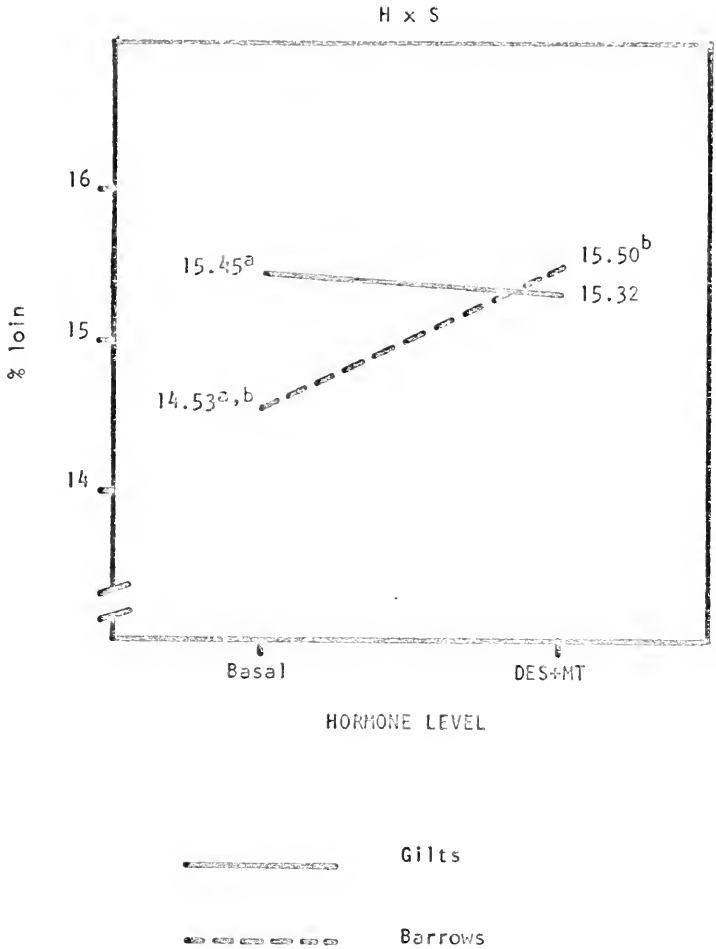

$\omega^{\alpha=0.10} = 3.10.$

Figure 2. Experiment 178-A. The effect of interaction of sex, protein level, and hormone supplementation on % lean primal cuts



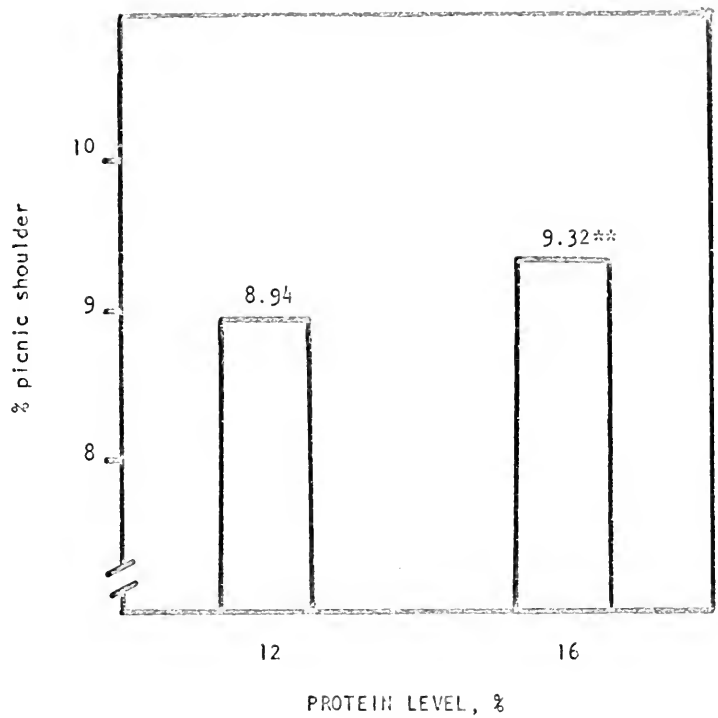

* Significant (P = 0.05 or less).

Figure 3. Experiment 178-A. The effect of sex on % ham



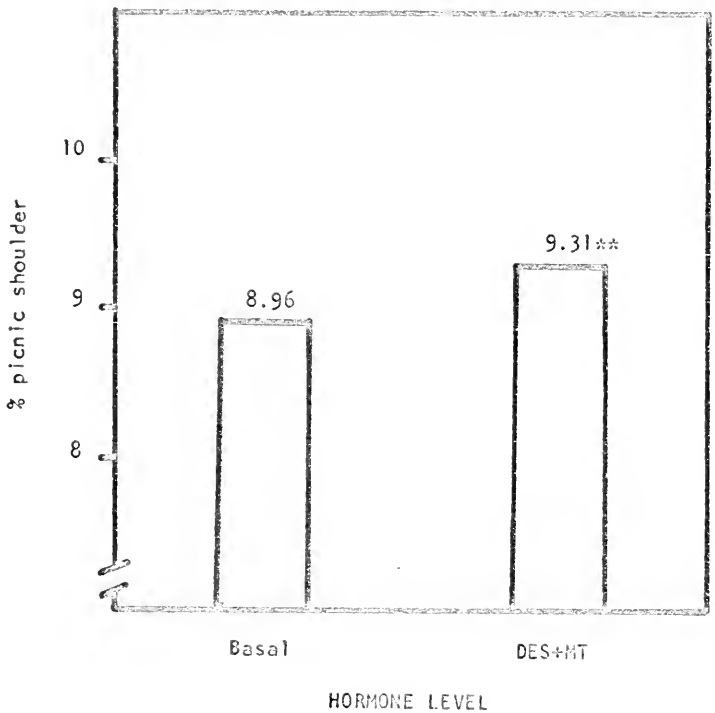

a,b Means with the same superscripts differ significantly ($\omega^{\alpha=0.10} = 0.84$).

Figure 4. Experiment 178-A. The effect of interaction of sex and hormone supplementation on % loin



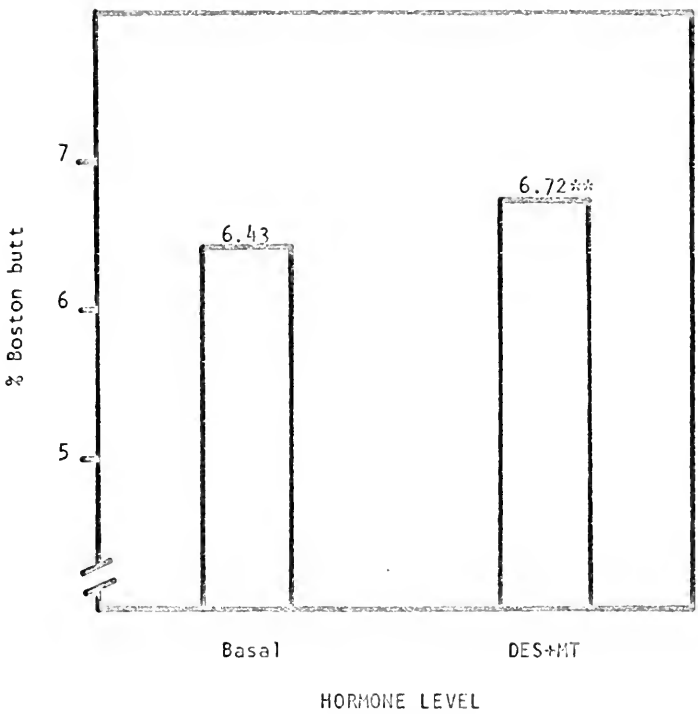

** Significant (P = 0.01 or less).

Figure 5. Experiment 178-A. The effect of protein level on % picnic shoulder



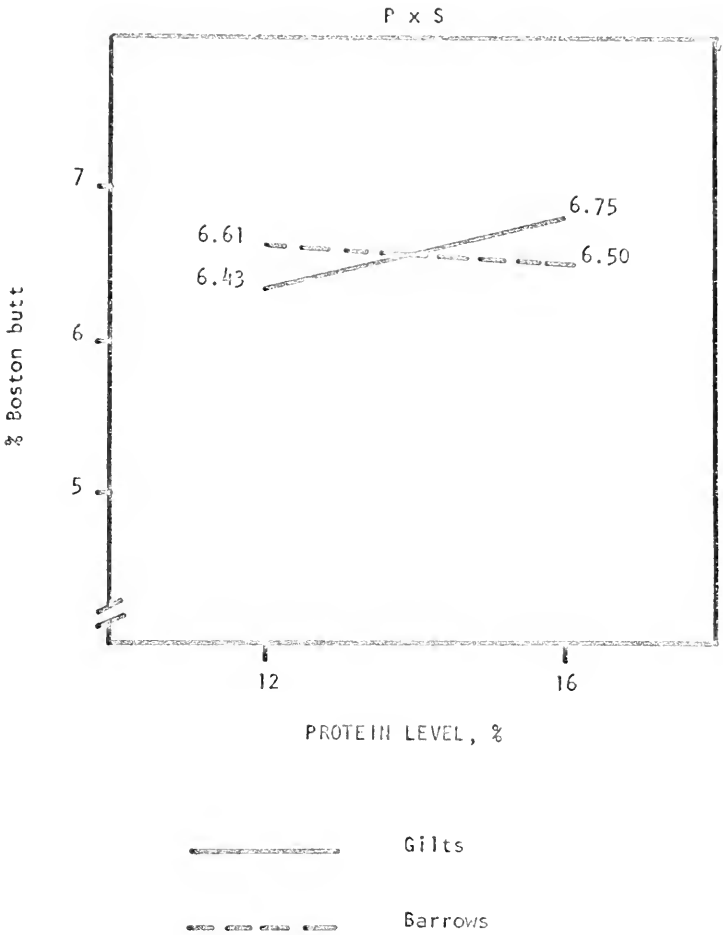

** Significant (P = 0.01 or less).

Figure 6. Experiment 178-A. The effect of hormone supplementation on % picnic shoulder



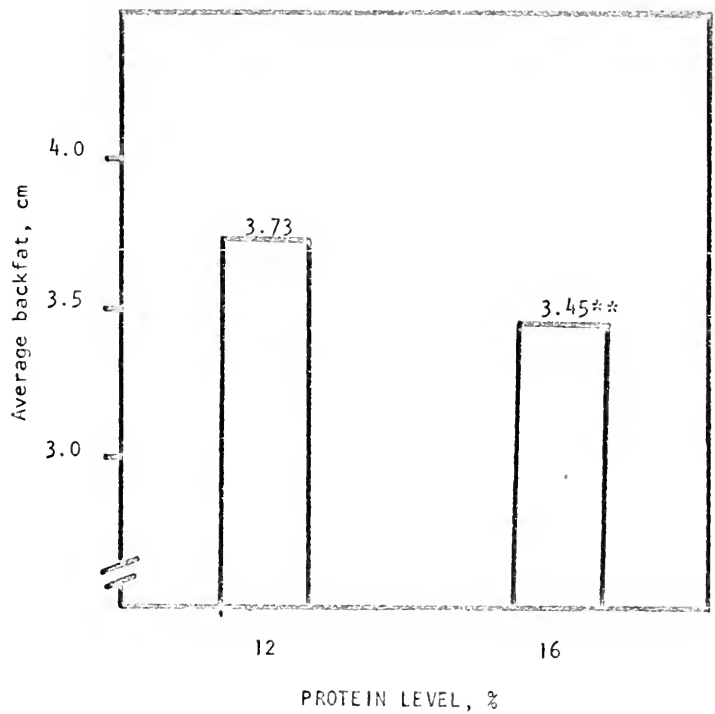

** Significant (P = 0.01 or less).

Figure 7. Experiment 178-A. The effect of hormone supplementation on % Boston butt



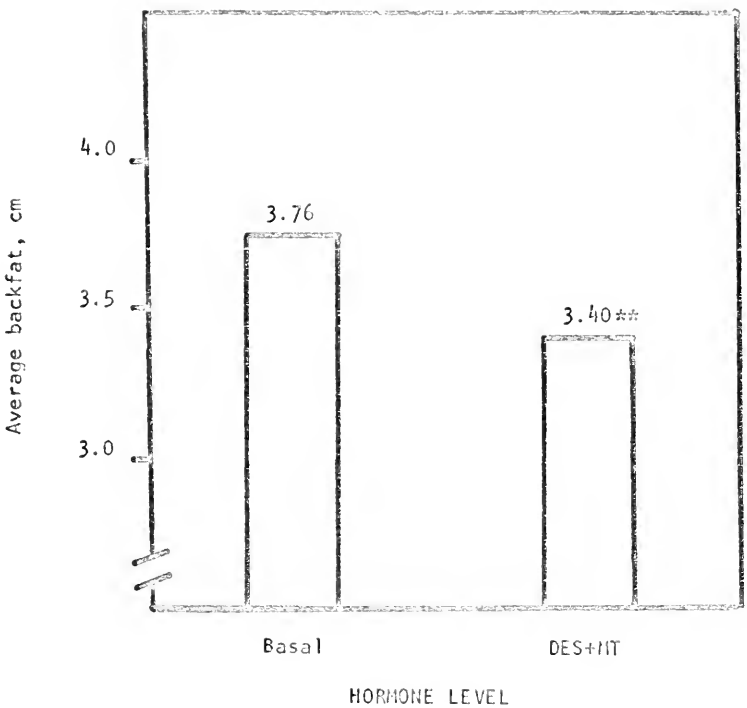

$\omega^{\alpha=0.10} = 0.35.$

Figure 8. Experiment 178-A. The effect of interaction of sex and protein level on % Boston butt



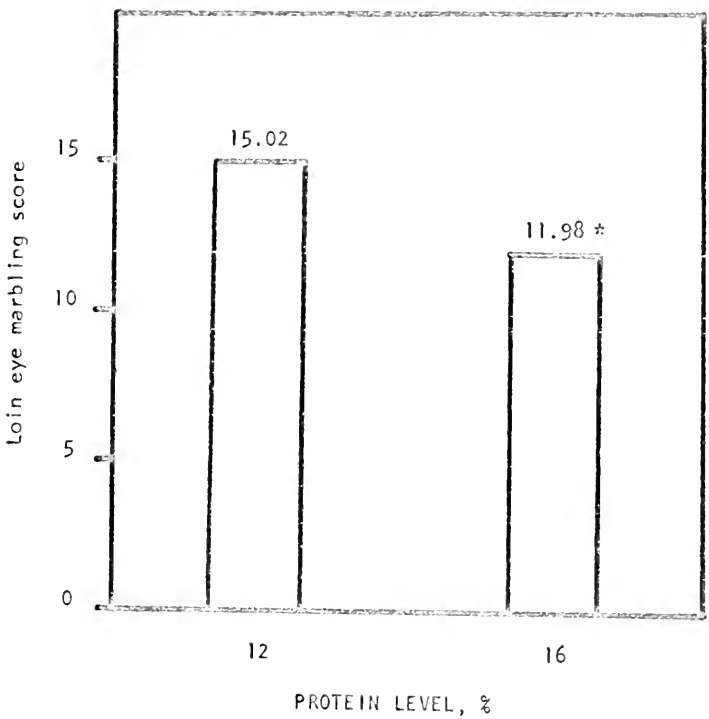

** Significant (P = 0.01 or less).

Figure 9. Experiment 178-A. The effect of protein level on average backfat thickness



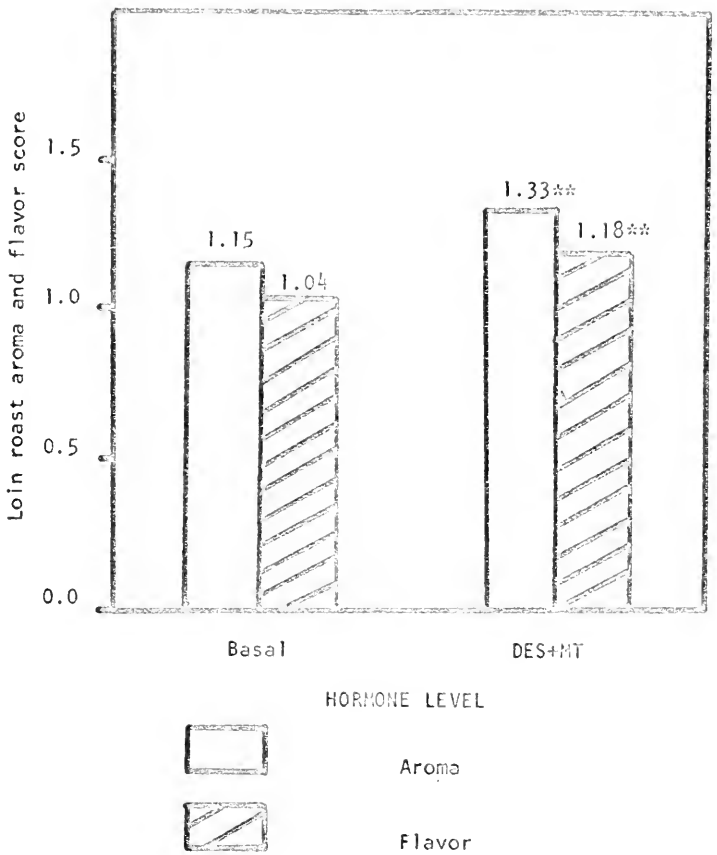

** Significant (P = 0.01 or less).

Figure 10. Experiment 178-A. The effect of hormone supplementation on average backfat thickness



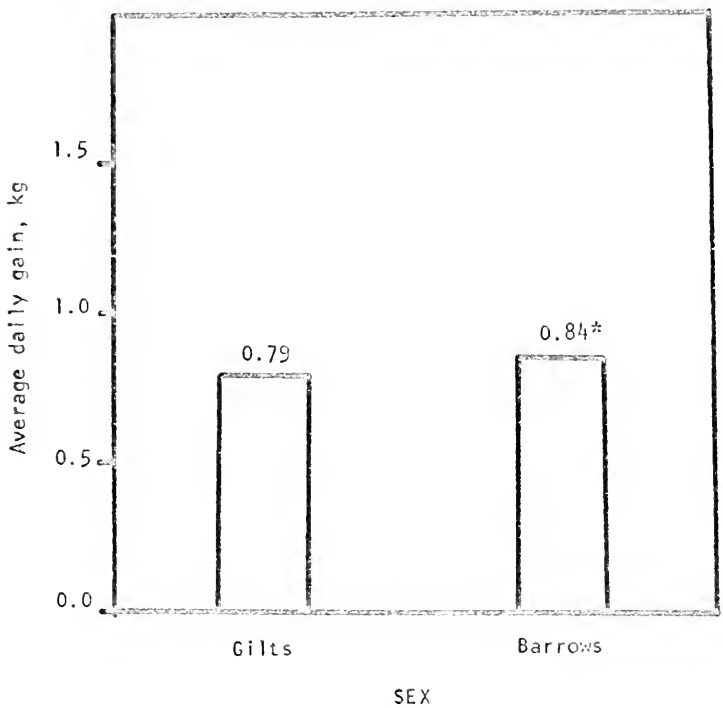

* Significant (P = 0.05 or less).

Figure 11. Experiment 178-A. The effect of protein level on loin eye marbling score



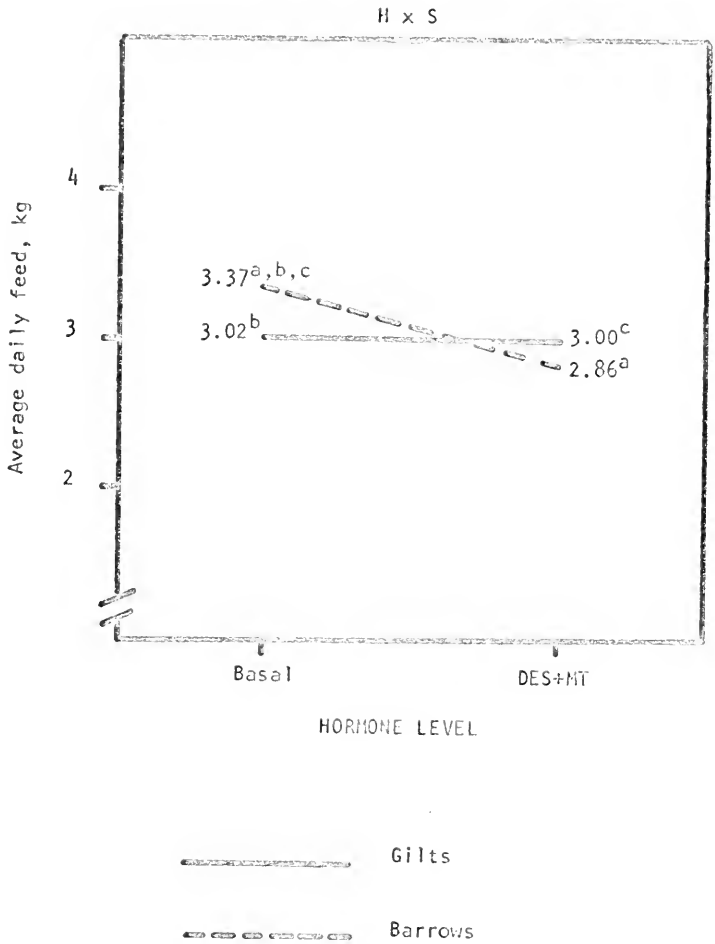

** Significant (P = 0.01 or less).

Figure 12. Experiment 178-A. The effect of hormone supplementation on loin roast aroma and flavor score



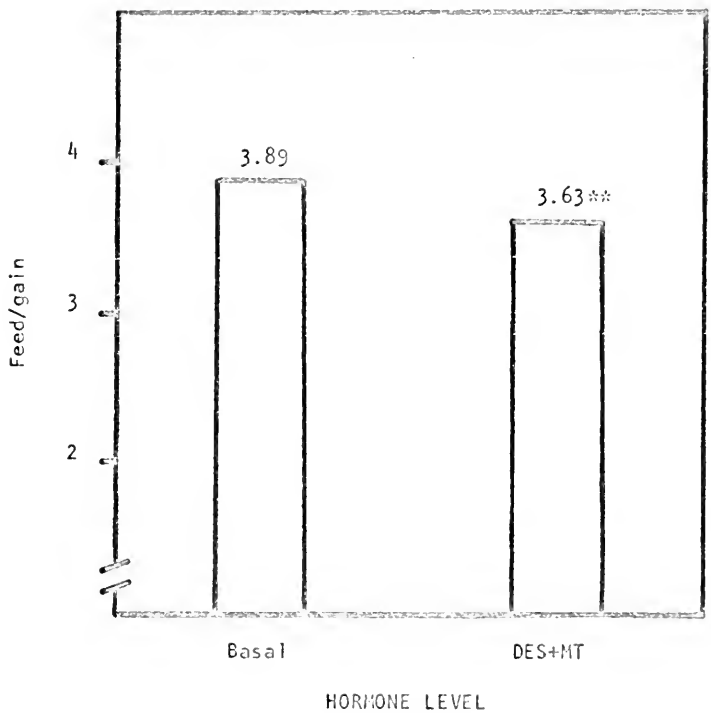

* Significant (P = 0.05 or less).

Figure 13. Experiment 178-B. The effect of sex on average daily gain



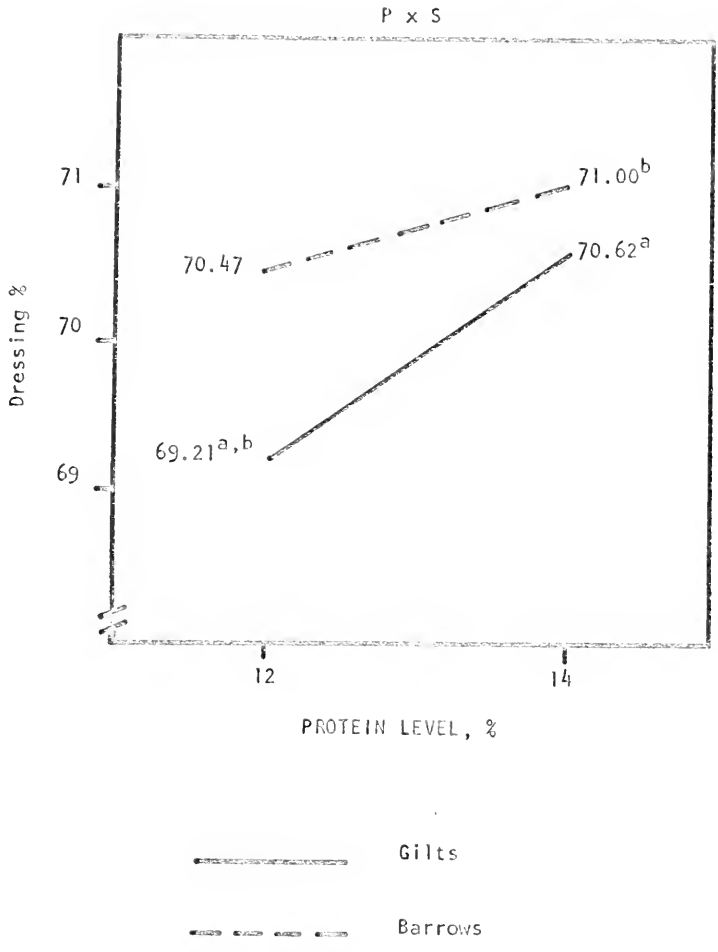

a,b,c Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 0.27$).

Figure 14. Experiment 178-B. The effect of interaction of sex and hormone supplementation on average daily feed intake



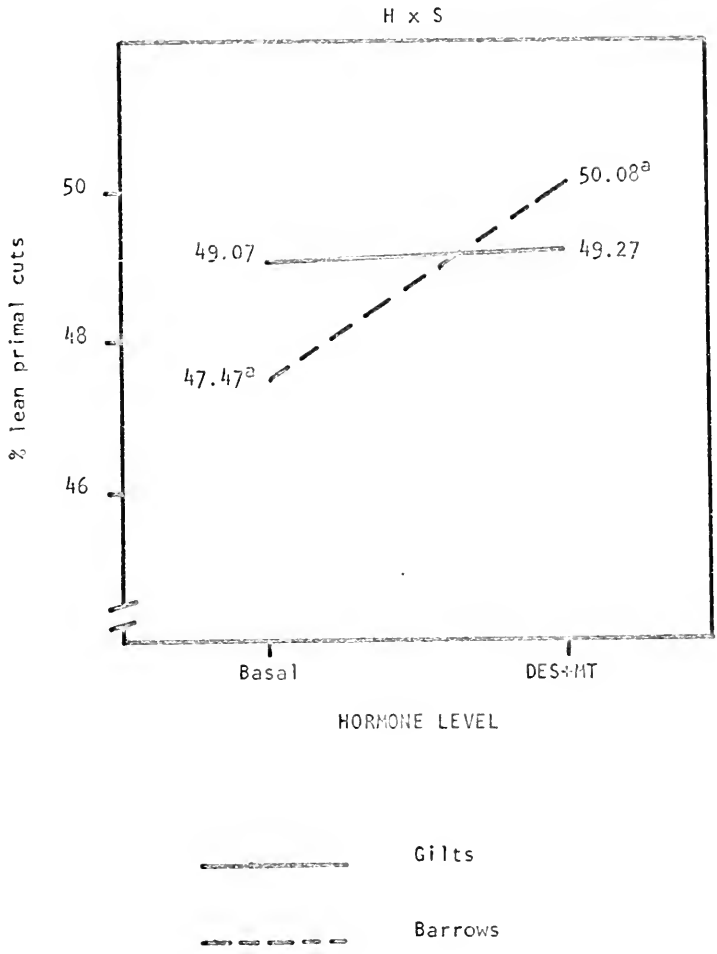

** Significant (P = 0.01 or less).

Figure 15. Experiment 178-B. The effect of hormone supplementation on feed/gain



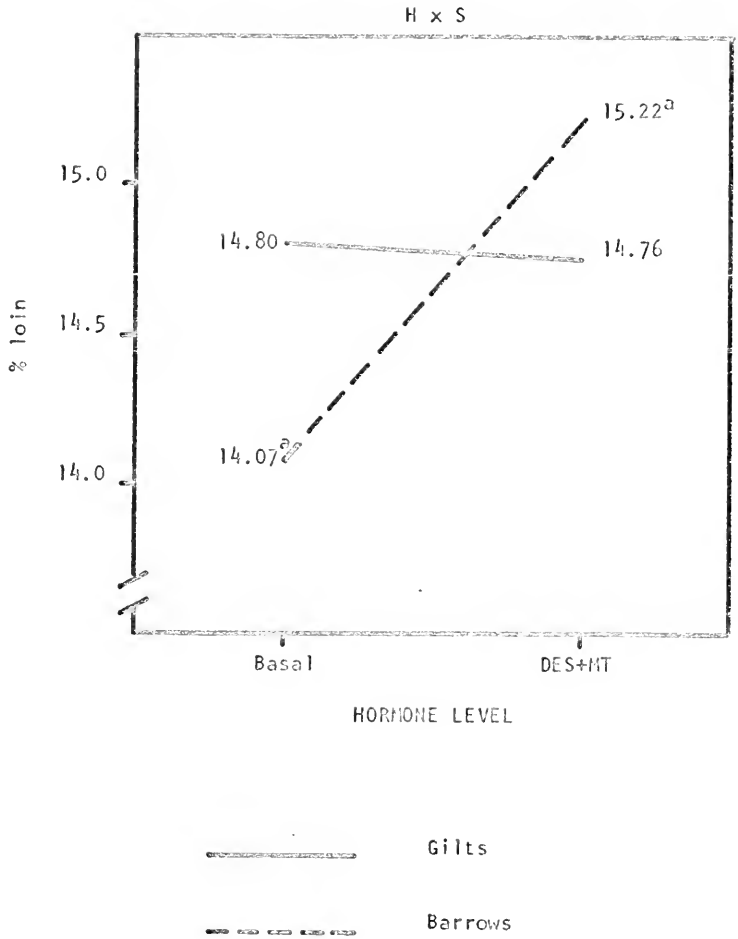

a,b Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 1.36$).

Figure 16. Experiment 178-B. The effect of interaction of sex and protein level on dressing %



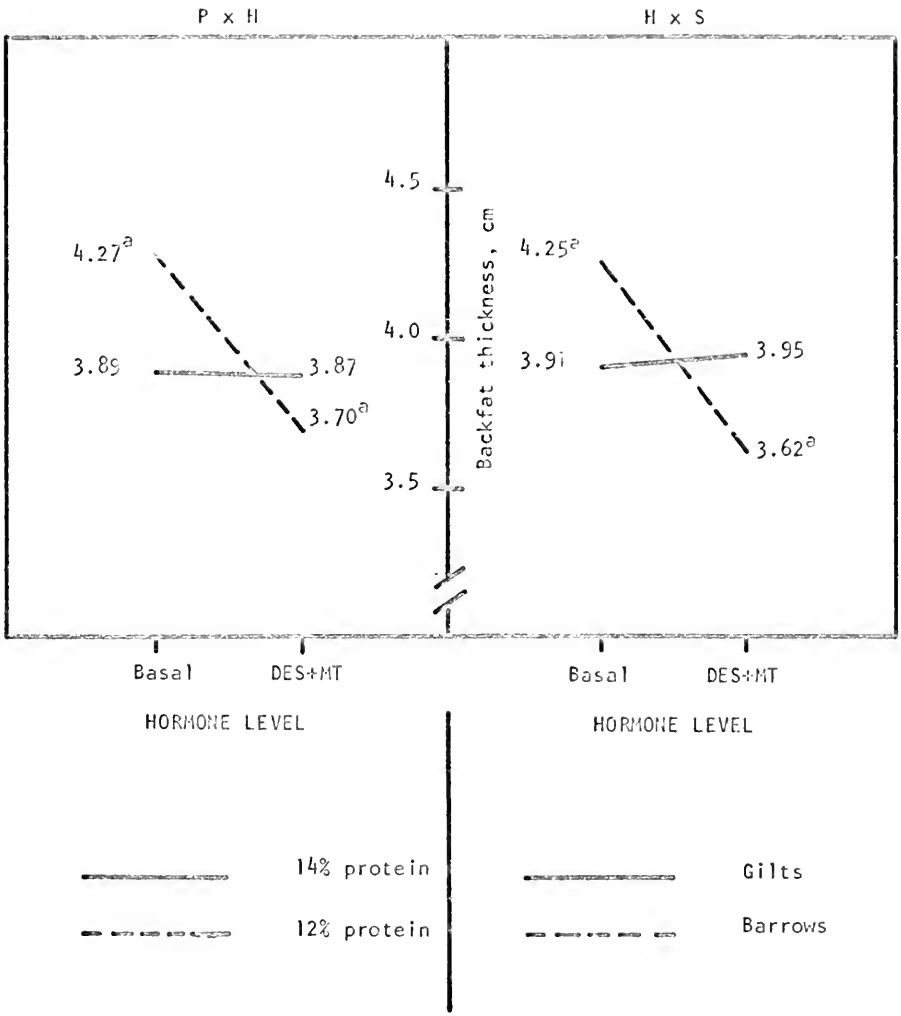

[a] Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 2.15$).

Figure 17. Experiment 178-B. The effect of interaction of sex and hormone supplementation on % lean primal cuts



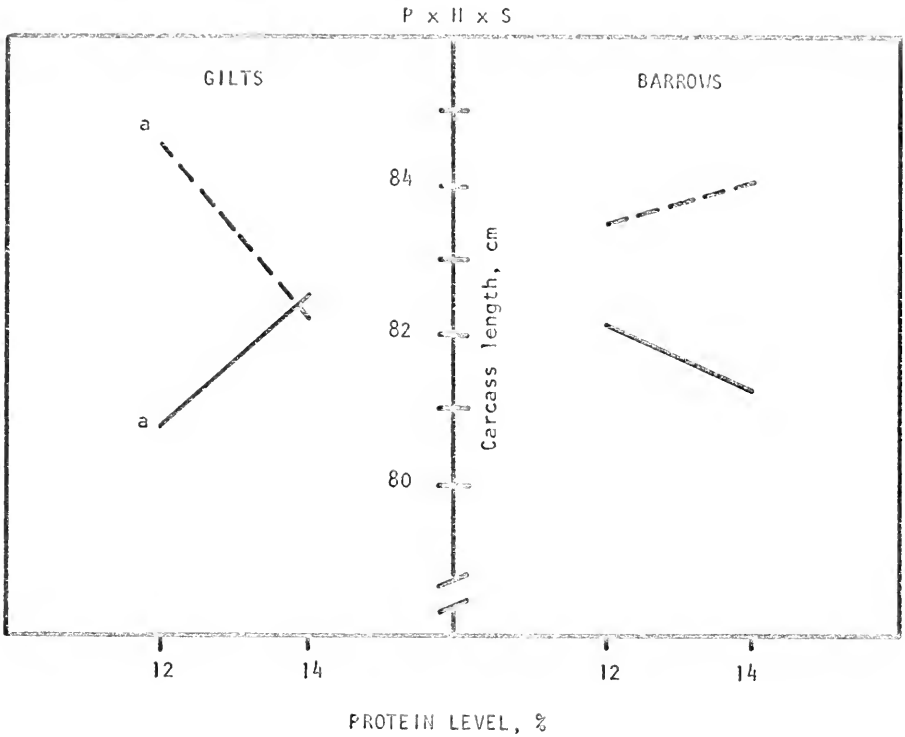

[a] Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 0.91$).

Figure 18. Experiment 178-B. The effect of interaction of sex and hormone supplementation on % loin



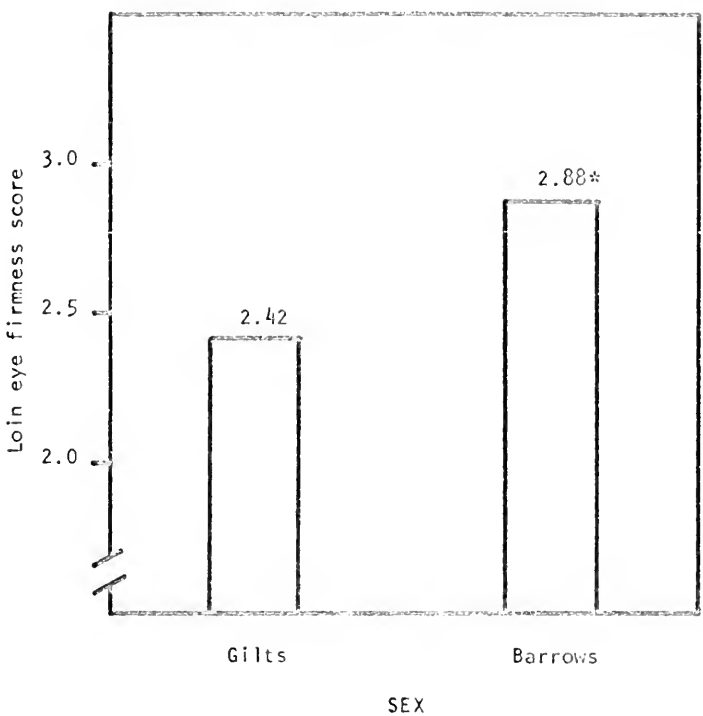

[a] Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 0.42$).

Figure 19. Experiment 178-B. The effect of interaction of hormone supplementation with protein level and with sex on backfat thickness



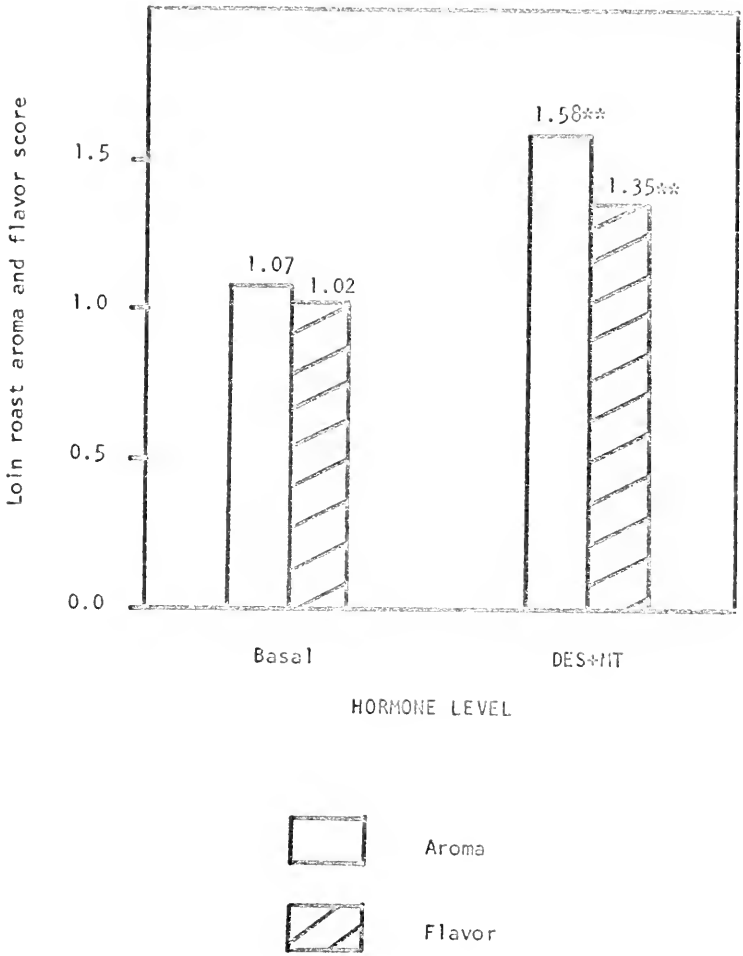

[a] Means with the same superscript differ significantly ($\omega\alpha^{=0.10} = 3.43$).

Figure 20. Experiment 178-B. The effect of interaction of protein level, hormone supplementation, and sex on carcass length



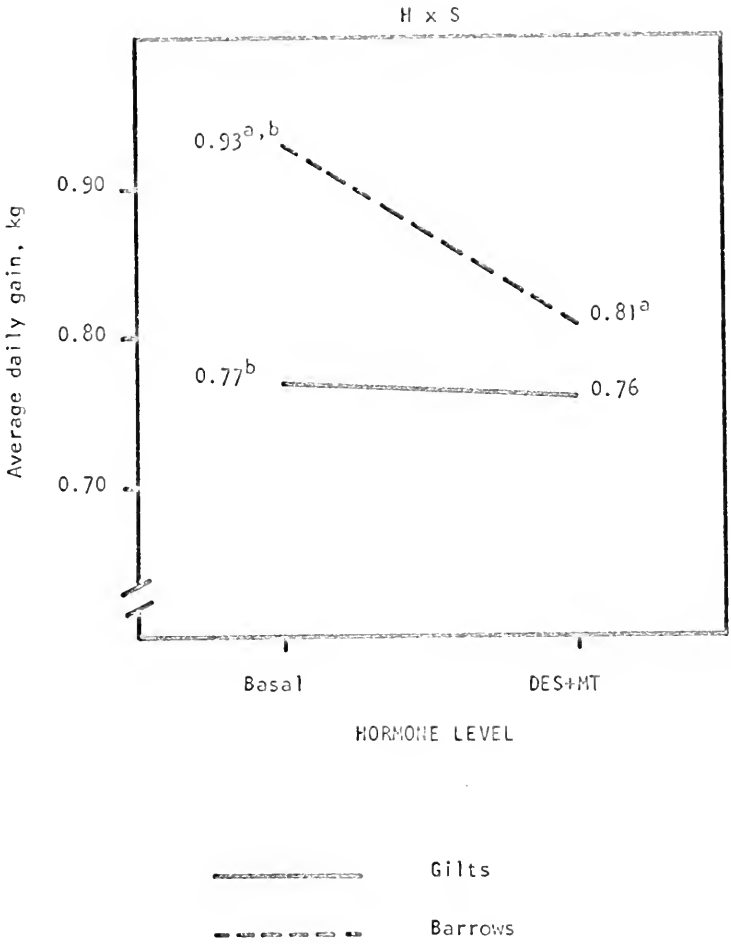

* Significant (P = 0.05 or less).

Figure 21. Experiment 178-B. The effect of sex on loin eye firmness score



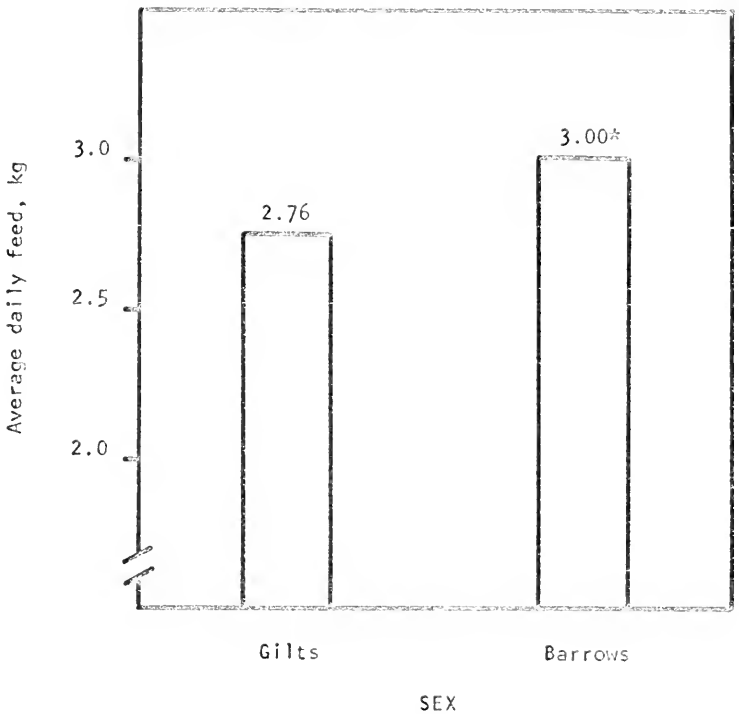

** Significant (P = 0.01 or less).

Figure 22. Experiment 178-B. The effect of hormone supplementation on loin roast aroma and flavor score



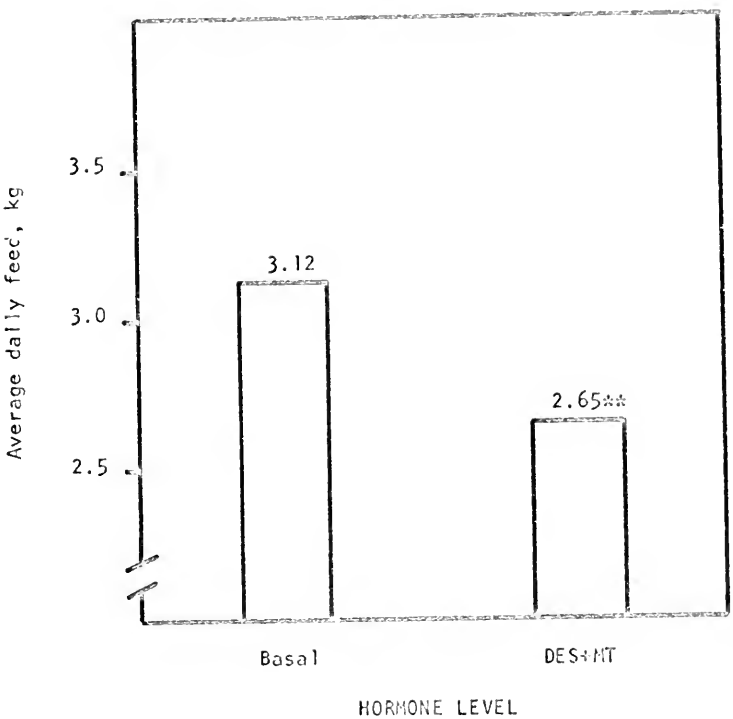

a,b Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 0.08$).

Figure 23. Experiment 178-D. The effect of interaction of sex and hormone supplementation on average daily gain



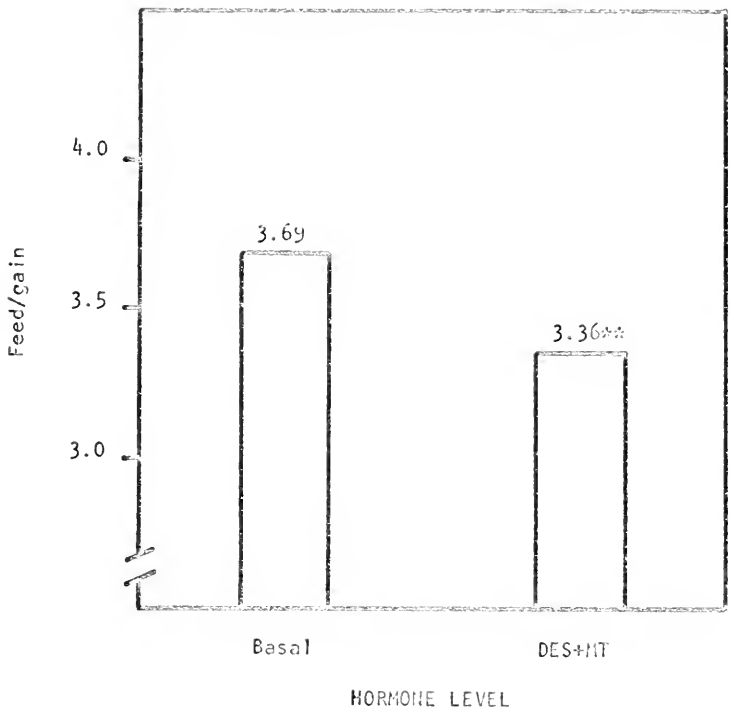

* Significant (P = 0.05 or less).

Figure 24. Experiment 178-D. The effect of sex on average daily feed intake



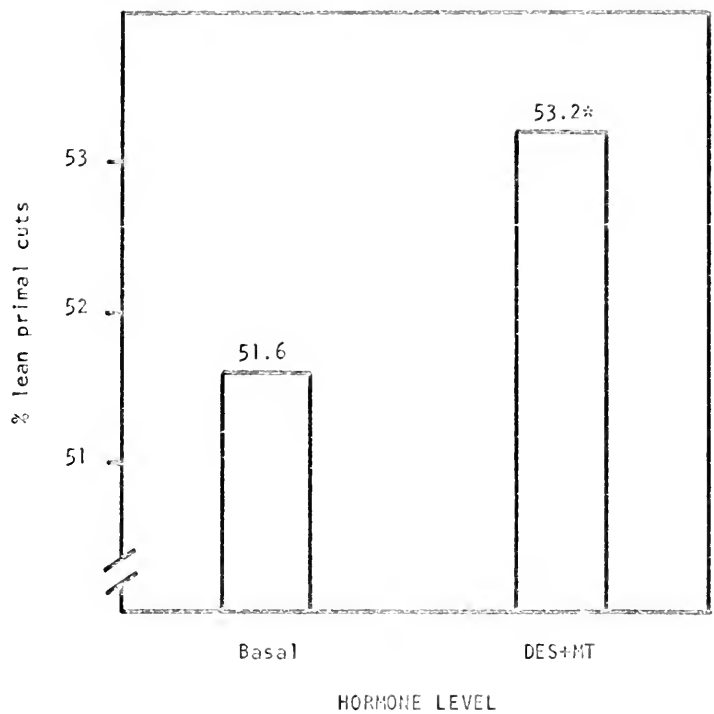

** Significant (P = 0.01 or less).

Figure 25. Experiment 178-D. The effect of hormone supplementation on average daily feed intake



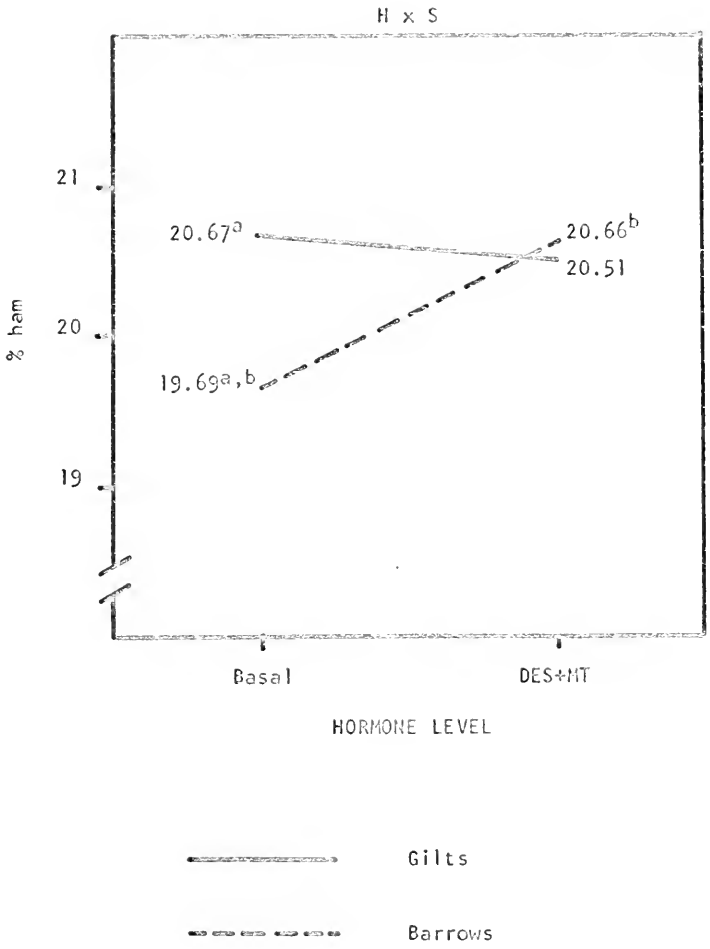

** Significant (P = 0.01 or less).

Figure 26. Experiment 178-D. The effect of hormone supplementation on feed/gain



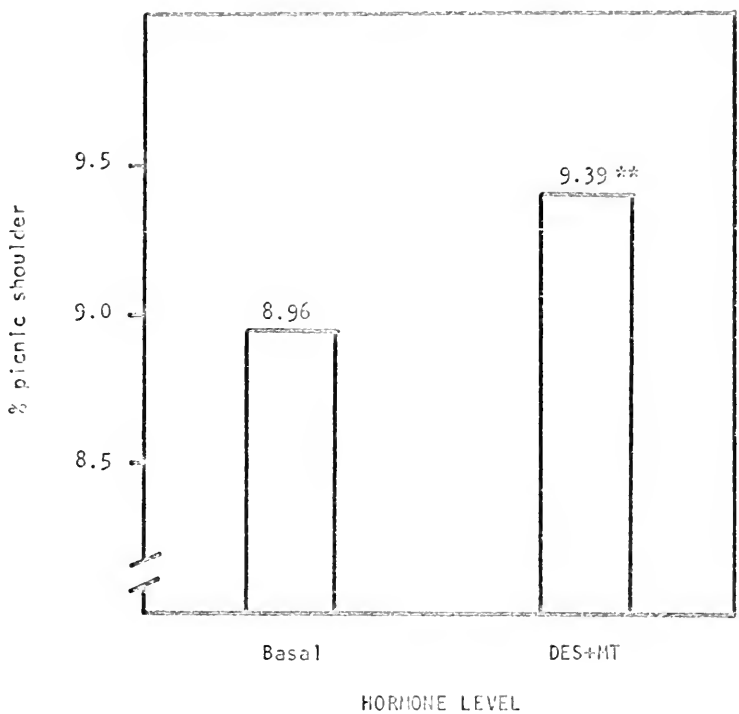

* Significant (P = 0.05 or less).

Figure 27. Experiment 178-D. The effect of hormone supplementation on % lean primal cuts



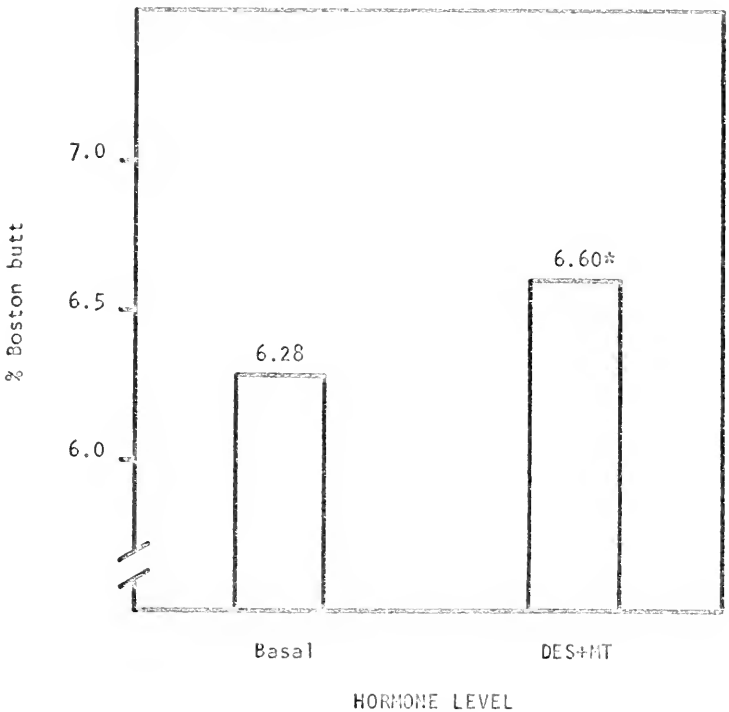

a,b Means with the same superscript differ significantly ($\omega^{\alpha=0.10} = 0.84$).

Figure 28. Experiment 178-D. The effect of interaction of sex and hormone supplementation on % ham



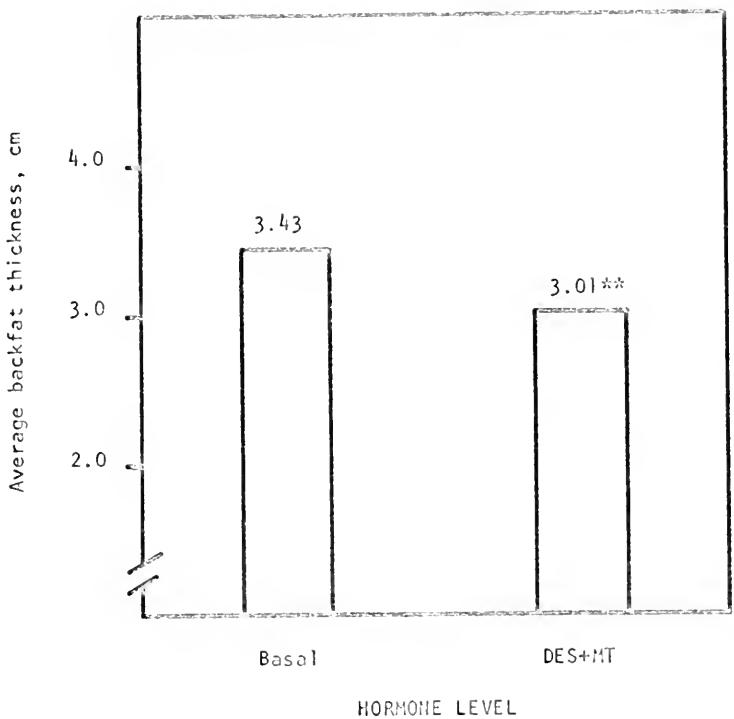

** Significant (P = 0.01 or less).

Figure 29. Experiment 178-D. The effect of hormone supplementation on % picnic shoulder



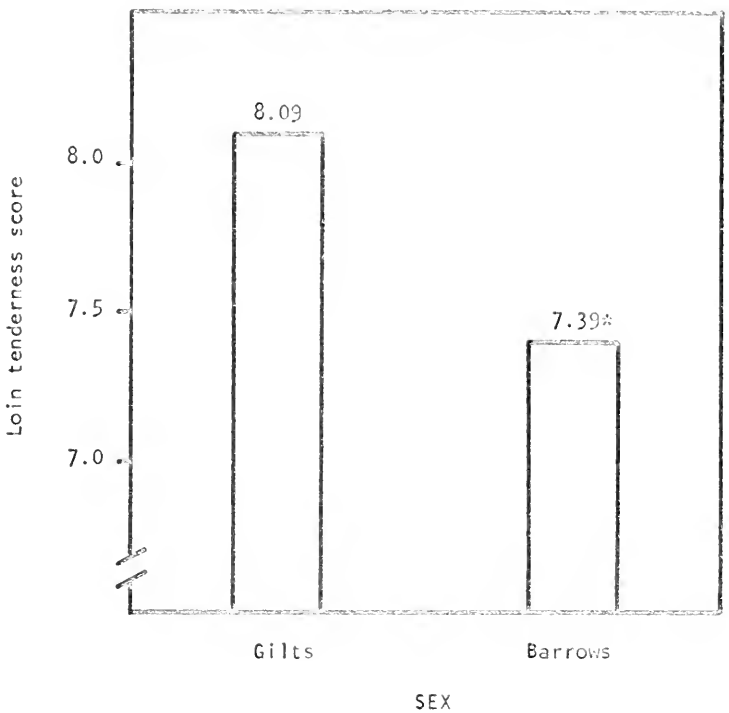

* Significant (P = 0.05 or less).

Figure 30. Experiment 178-D. The effect of hormone supplementation on % Boston butt



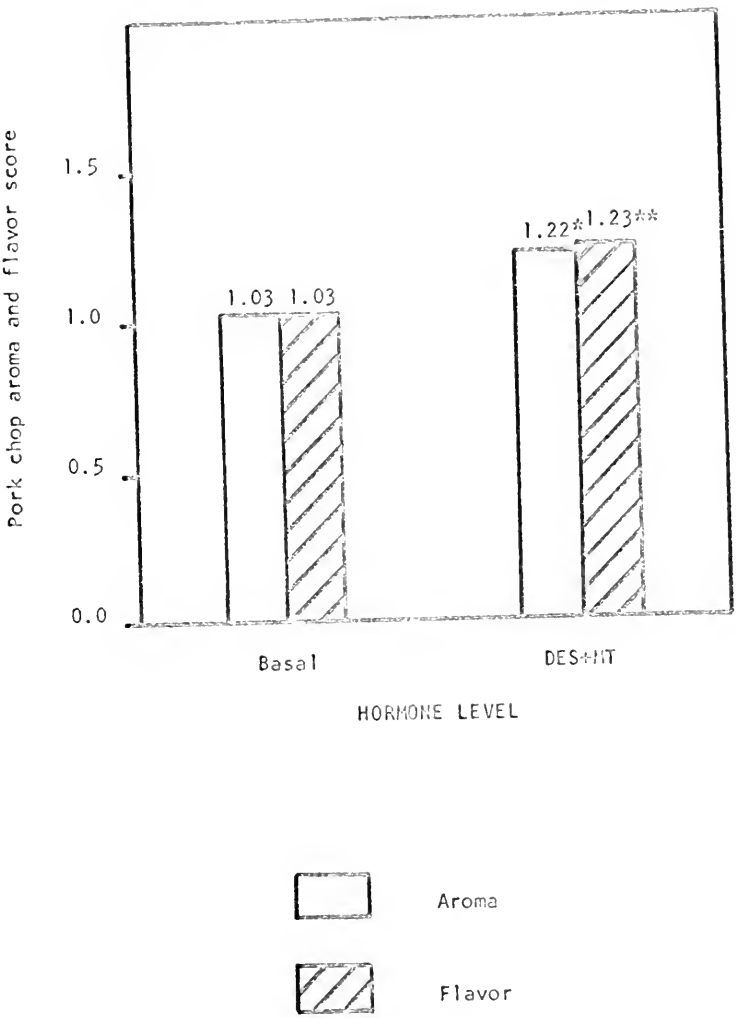

** Significant (P = 0.01 or less).

Figure 31. Experiment 178-D. The effect of hormone supplementation on average backfat thickness



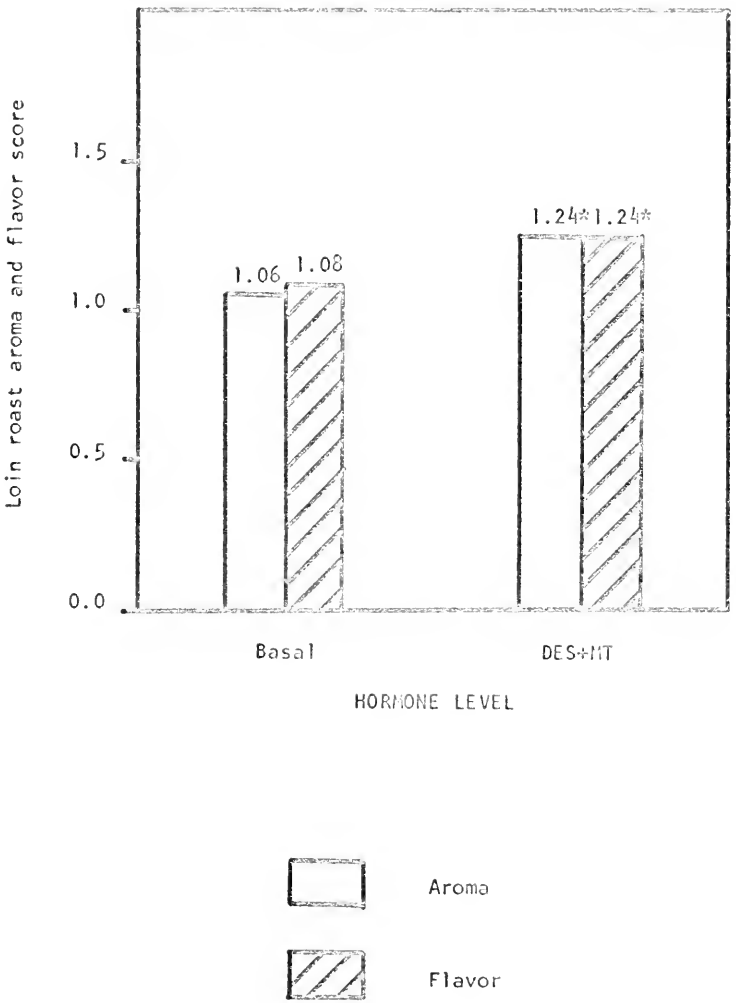

* Significant (P = 0.05 or less).

Figure 32. Experiment 178-D. The effect of sex on loin tenderness



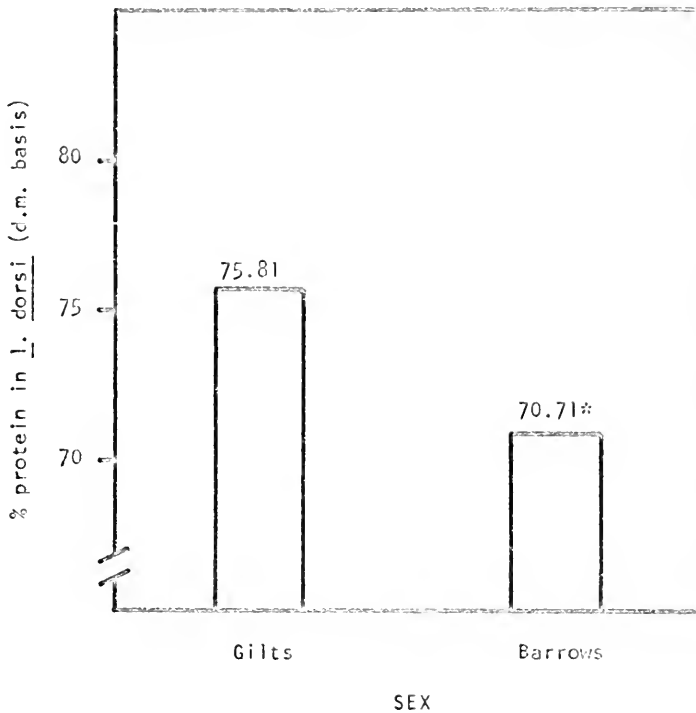

* Significant (P = 0.05 or less).
** Significant (P = 0.01 or less).

Figure 33. Experiment 178-D. The effect of hormone supplementation on pork chop aroma and flavor score



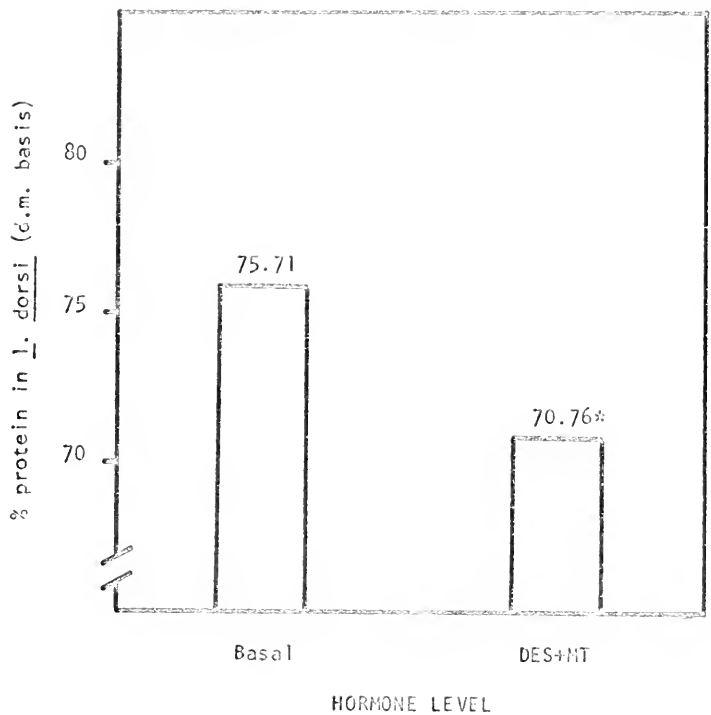

* Significant (P = 0.05 or less).

Figure 34. Experiment 178-D. The effect of hormone supplementation on loin roast aroma and flavor score



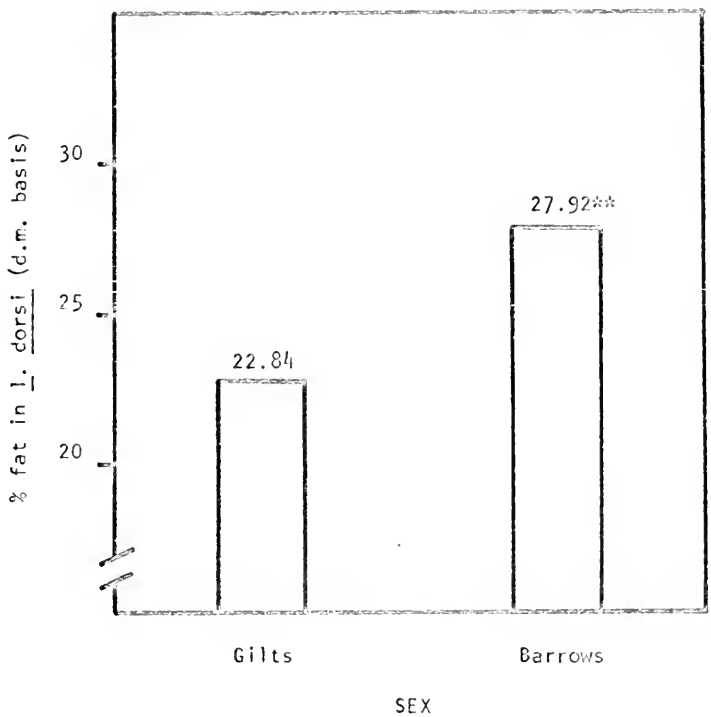

* Significant (P = 0.05 or less).

Figure 35. Experiment 178-D. The effect of sex on % protein in longissimus dorsi (dry matter basis)



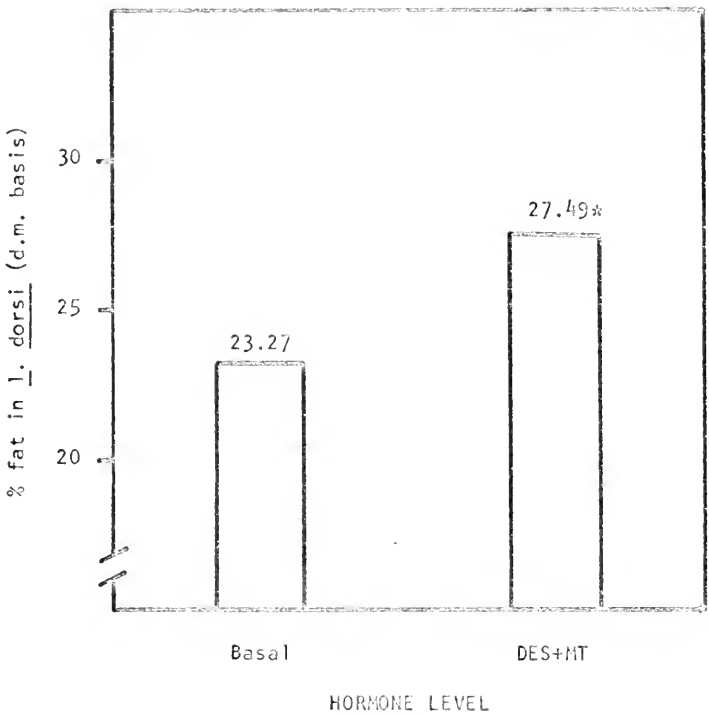

* Significant (P = 0.05 or less).

Figure 36. Experiment 178-D. The effect of hormone supplementation on % protein in longissimus dorsi (dry matter basis)




** Significant (P = 0.05 or less).

Figure 37. Experiment 178-D. The effect of sex on % fat in longissimus dorsi (dry matter basis)




* Significant (P = 0.05 or less).

Figure 38. Experiment 178-D. The effect of hormone supplementation on % fat in longissimus dorsi (dry matter basis)

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## BIOGRAPHICAL SKETCH

Ernest W. Lucas was born February 17, 1942, in Boston, Massachusetts. In 1957 his family moved to California. He graduated from Rio Vista Joint Union High School in 1960. In 1964 he received the Bachelor of Science degree, with a major in Animal Husbandry, from California State Polytechnic College, San Luis Obispo, California. He worked as a graduate research assistant at Iowa State University from 1964 to 1967 and received the Master of Science degree, with a major in Animal Science, from that institution. From 1967 to the present he has worked as a graduate research assistant at the University of Florida while studying toward the degree of Doctor of Philosophy, majoring in Animal Science. He has specialized in swine nutrition in his advanced work. He is a member of the fraternity of Alpha Zeta and of the American Society of Animal Science.

Ernest W. Lucas is married to the former Barbara Damlos, who is from San Francisco, California.

This dissertation was prepared under the direction of the chairman of the candidate's supervisory committee and has been approved by all members of that committee. It was submitted to the Dean of the College of Agriculture and to the Graduate Council, and was approved as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

June, 1970

C. B. Browning
Dean, College of Agriculture

Dean, Graduate School

Supervisory Committee:

H. D. Wallace
Chairman

John E. Moore