SOME HORMONAL INFLUENCES ON GROWTH, COMPOSITION AND MEAT QUALITY

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INTRODUCTION

Most information available concerning the influence of hormones on the rate and efficiency of growth of meat producing animals and on their subsequent carcass composition and meat quality has been obtained from experiments in which hormones were administered to animals. In the present paper, however, discussion will center on experiments where measurements of endogenous hormones have been made and where these measurements have been related to productive characteristics. Unfortunately, there are only a limited number of reports of experiments in this category, mainly because of the difficulty in acquiring meaningful measurements of endogenous hormones. Consequently, considerable reference will be made to indirect evidence from experiments that have involved animals not used for meat production and from experiments involving the administration of hormones to animals.

RATIONALE FOR USING HORMONE LEVELS

The value of measures of endogenous hormones to meat scientists is two-fold. First, basic physiological information is provided which may help explain why similarly treated animals frequently produce meat with widely differing characteristics. Secondly, such measurements may aid in predicting the actual or the potential productivity of an animal. Hormone characteristics probably differ from most measurements which have been used as predictors of productivity, in that they contribute to the determination of a productive characteristic, rather than being determined by that characteristic. Thus, in the hypothetical example in Fig. 1 growth hormone (GH) contributes to the determination of percent carcass fat, while carcass density is determined, at least partly, by percent carcass fat. The usefulness of either of these relationships will depend on how close they are and this, in turn, will be determined by the "other factors" in each case. It should be emphasized that in the case of the hypothetical GH - percent fat relationship the only "other factors" that will affect it are those that do not affect percent fat through an effect on GH. For example, if growth hormone releasing factor concentration is related to percent fat it will probably be through its effect on GH synthesis or release and consequently it will not constitute an "other factor".

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The problem of which hormone measurement(s) to make and of the conditions under which to make them has generally been resolved on the basis of simplicity and economy rather than on the basis of known usefulness. Fig. 2 shows diagrammatically some measurements which may be made. Thus, in the endocrine gland the concentration and the rate of synthesis may be measured. Other measurements and the sites of sampling are listed. Certain assumptions must hold in order for any of these measurements to give a useful indication of hormone effectiveness at the tissue level.

With this brief introduction to some of the attributes and problems of relating hormone measurements to productive characteristics of meat animals as a background, results of specific studies can be considered.

RELATIONSHIP OF THYROID TO MEAT COMPOSITION AND QUALITY

The thyroid gland will be considered first, mainly because a number of measures of thyroid status have been related to characteristics of meat producing animals. The relatively great activity in this field (Kossila, 1967; Falconer and Draper, 1968) is probably at least partially attributable to the presence of iodine in thyroxine, since iodine acts as a built in marker for studies on the thyroid gland (Gimlette, 1967).

Tata (1964) has reviewed the basic biochemical actions of thyroxine. This information, together with the results of studies such as that of Scow (1959), indicates that thyroxine and GH act synergistically on growth of rats, and would suggest that endogenous thyroxine status may provide a useful indication of growth potential. However, such a suggestion is not supported by the results of experiments in which meat animals have been treated with thyroid hormones or with thyroid depressant substances. In reviewing such studies, Blaxter et al. (1949) and Casida et al. (1959) have pointed out that the results are characterized by their inconsistencies. Recent work by Draper et al. (1969) offered a possible explanation for these inconsistencies. They demonstrated a highly significant curvilinear relationship between the growth rates of lambs and the rate of release of ^{131}I from their thyroids. Thus, thyroid activities either above or below optimum were detrimental to growth of the lambs. It follows that administration of thyroxine to an animal with sub-optimal thyroid activity should increase growth rates, but if the animal's thyroid activity is already optimal, then exogenous thyroxine administration may decrease growth rates.

Relationships between thyroid activity and carcass composition or meat quality have not been widely investigated although the symptoms of hypo- and hyperthyroidism would suggest that sub-optimal thyroid activity would be associated with increased fatness. Here again, however, the results of thyroxine administration have not been very promising. For example, Kirton and Barton (1958) implanted six-year-old Romney ewes with three levels of thyroxine in the hope that this treatment would specifically decrease the fat content of the carcasses. Although considerable weight losses were recorded over a 28 day period no significant effects on percent fat were obtained.

RELATIONSHIP OF GROWTH HORMONE

Growth hormone (GH) or somatotropin has been shown in in vitro studies to stimulate the release of free fatty acids from adipose tissue (Goodman, 1968) and to accelerate the incorporation of amino acids into protein (Korner, 1967). On the basis of these effects together with its effect when administered to rats, endogenous GH production would be expected to be a major determinant of growth rate. Knobil (1961) discussed some of the studies in which GH administration markedly increased growth rates, while simultaneously decreasing the proportion of fat and increasing the proportion of protein and water. Most of these studies involved laboratory animals.

Growth hormone administration to domestic animals, however, has not been widely practiced, even on an experimental basis, mainly because the costs of administering it commercially are probably prohibitive (Casida et al., 1959). Generally, the results have not been particularly impressive, although they have frequently been in the expected direction. Turman and Andrews (1955) reported a decreased fat content in the carcasses of pigs treated with GH. Brumby (1959) showed an increased growth rate in Jersey heifers, Struempler and Burroughs (1959) demonstrated an increased nitrogen balance in GH treated lambs, and Manns and Boda (1967) reported increased circulating nonesterified fatty acids and decreased circulating amino nitrogen in sheep. Other workers, however, have not obtained changes after administration of GH to sheep (Wheatley et al., 1966) or pigs (Lind et al., 1969). With regard to humans, Kaplan et al. (1968) reported that GH administration has been shown to be effective in overcoming dwarfism in children when a GH deficiency could be demonstrated.

Early work concerning the relationship between endogenous GH status and productive characteristics involved pituitary rather than circulating GH levels due to the sensitivity of the available assays. Nalbandov (1963) used the results of Baird et al. (1951), Baker et al. (1955), Armstrong and Hansel (1956) and others to develop his dilution theory, whereby it was postulated that body growth is determined by the GH available per unit body weight. He pointed out that in the experiments discussed, pituitary GH concentration changed only a little, relative to the ratio of pituitary weight to body weight. Several reports have appeared since 1963, however, which do not give unqualified support for Nalbandov's "dilution theory". For example, Birge et al. (1967) and Garcia and Gerschwind (1968) with rats and Purchas et al. (1969) with bulls, indicated that changes in pituitary GH content with age arose primarily from changes in pituitary GH concentration rather than pituitary weight. Also, Gerrits (1968) reported no significant differences in pituitary GH per unit body weight in lines of pigs selected for increased and decreased backfat thickness. In none of these studies was there any measure made of carcass composition or meat quality. Siers (1968) measured circulating GH levels in pigs at three different ages and found that correlations with indices of carcass quality were low and generally negative. Frohman and Bernardis (1968), on the other hand, showed with rats that decreased plasma and pituitary levels of GH resulting from lesions of the ventro-medial hypothalamus were paralleled by a decrease in linear growth and an increase in body fat content.

In an experiment involving 100 Holstein heifers which were slaughtered either at first estrus or breeding size, and which were raised on one of two planes of nutrition, Purchas (1970) measured radioimmunoassable GH in anterior pituitary extracts and in blood plasma at slaughter. The usefulness of hormone levels, such as those in plasma prepared from blood collected at slaughter, can be questioned, as various stress conditions are known to affect circulating GH levels. However, they could be useful values, as it has been suggested that provocative levels of hormones may be better indicators of hormone status than resting levels (Daughaday, 1968). Growth rates and estimates of carcass composition, from the physical separation of a flank or a round, were also obtained for the heifers. Tenderness was measured objectively on a club steak and GH was assayed in plasma samples collected by syringe from the jugular veins of 40 of the animals from 4 to 10 months of age. Finally, in thirty animals cortisol and corticosterone concentrations were estimated fluorimetrically in slaughter plasma and in adrenal homogenates. Some of the results from this study are shown in the next few slides.

Table 1 summarizes some statistical evidence suggesting that high levels of circulating GH tended to be associated with lower growth rates. The statistics in this slide were calculated using the mean of the seven jugular GH levels available for each animal. The least squares model included corrections for endocrine measurements, carcass weight and other discrete variables. Analysis of individual jugular GH values using a split plot design together with orthogonal contrasts indicated that a high plane of nutrition, which significantly increased growth rate, was associated with a significantly lower GH level. There was no way to determine whether the higher growth rates were a cause or an effect of the lower GH levels. It is conceivable that low circulating levels may in some cases reflect greater utilization at the peripheral level. Siers (1968) and Trenkle (1970) have also noted that circulating GH levels are generally negatively related to growth rates.

That variation in hormone measurements can result from particular physiological states, rather than being determinants of these states, has recently been demonstrated in the case of human obesity by Londono et al. (1969). They showed that the characteristically small response of circulating GH levels to insulin in obese subjects could be increased by inducing the subjects to lose weight. Although only six individuals were included in the study, the increases in response were closely correlated ($r = 0.97$) with the size of the weight losses. In a similar way, it is possible that high growth rates in cattle may in some way give rise to lower levels of circulating GH. This is opposed to the discussion based on Fig. 1 where it was suggested that hormones were probably determinants of productive characteristics.

Table 2 lists some coefficients of correlation between pituitary GH concentration and other characteristics of 50 heifers, which were slaughtered when they attained a withers height of 120 cm. The negative relationship between pituitary GH levels and carcass weight implies that animals with high pituitary GH concentrations had lower carcass weights per unit withers height. The next four correlations in this table also suggest that high pituitary concentrations of GH were associated with leaner less mature cattle. Such relationships, it seems, could result from either a specific stimulation of bone and muscle growth or a specific inhibition of

fat deposition. Both of these actions had been attributed to GH but the significant and negative relationship between pituitary GH concentration and growth rate would suggest that the inhibition of fat deposition was dominant in this particular situation.

PLASMA CORTISOL AND CORTICOSTEROIDS

Table 3 outlines relationships between plasma cortisol concentration and growth rates or tenderness. Similar correlations were shown for plasma corticosterone. Corticosteroids were highest in the group on a low plane of nutrition and were lowest in the group fed MGA(R), presumably due to a feedback effect of the MGA. This suggests that these steroids may only be detrimental to growth rate and tenderness at high levels; in which case a curvilinear relationship may be expected. This was the case with tenderness where the inclusion of a quadratic component increased the percent variation accounted for from 15.3 to 32.3%, but it was not the case with growth rate. Comparable results were also obtained with adrenal levels of cortisol and corticosterone, in that highly significant negative correlations were shown with growth rate. However, relationships between adrenal corticosteroid concentrations and tenderness were not statistically significant. Although there have been very few studies relating endogenous corticosteroid levels to carcass quality, there have been some experiments involving the administration of corticosteroids to animals. For example, Spurlock and Clegg (1962) reported that administration of cortisone to lambs increased growth rate, feed consumption and percent fat. They suggested that such a treatment may be useful in finishing lambs provided they had completed 75% or more of their muscle development.

Whether any relationship between corticosteroid levels and growth rates or meat quality is direct or indirect is uncertain. Indirect relationships may result from a third factor affecting the two measurements similarly or from a third factor being affected by one measurement and affecting the other. Thus, corticosteroids may affect growth by influencing GH production, since there is some indication in human work that response of GH to hypoglycemia is impaired when corticosteroids are administered (e.g., James et al. 1968). On the other hand, Bassett (1968) has suggested that the lower levels of ketone bodies and free fatty acids in the blood of fasted sheep treated with cortisol were not due directly to the cortisol but rather to an increased insulin output. Support for this suggestion is provided by the fact that cortisol administration apparently impairs the action of insulin on glucose uptake in the sheep (Bassett and Wallace, 1967).

SUMMARY

Although only a relatively small number of specific hormones and their possible relationships to carcass and meat quality have been discussed

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(R)MGA is a registered trademark for Melengestrol acetate, Upjohn Co., Kalamazoo, Michigan.

in the present paper, this is in no way meant to imply that these are the most important ones. Rather, they were chosen because the authors have had some direct experience with them.

It seems appropriate to conclude by stressing what is probably one of the major limitations of studies investigating relationships between endogenous hormone production and productive characteristics. That is, that hormones, like enzymes, may act quite differently in in vitro assaying systems than in the animal from which they were taken. Dr. Hales of the University of Cambridge (Hales, 1967) has recently discussed this aspect with regard to the regulation of glucose metabolism by hormones and he stressed particularly that the levels of other hormones may be important determinants of the activity of any particular hormone in a particular situation.

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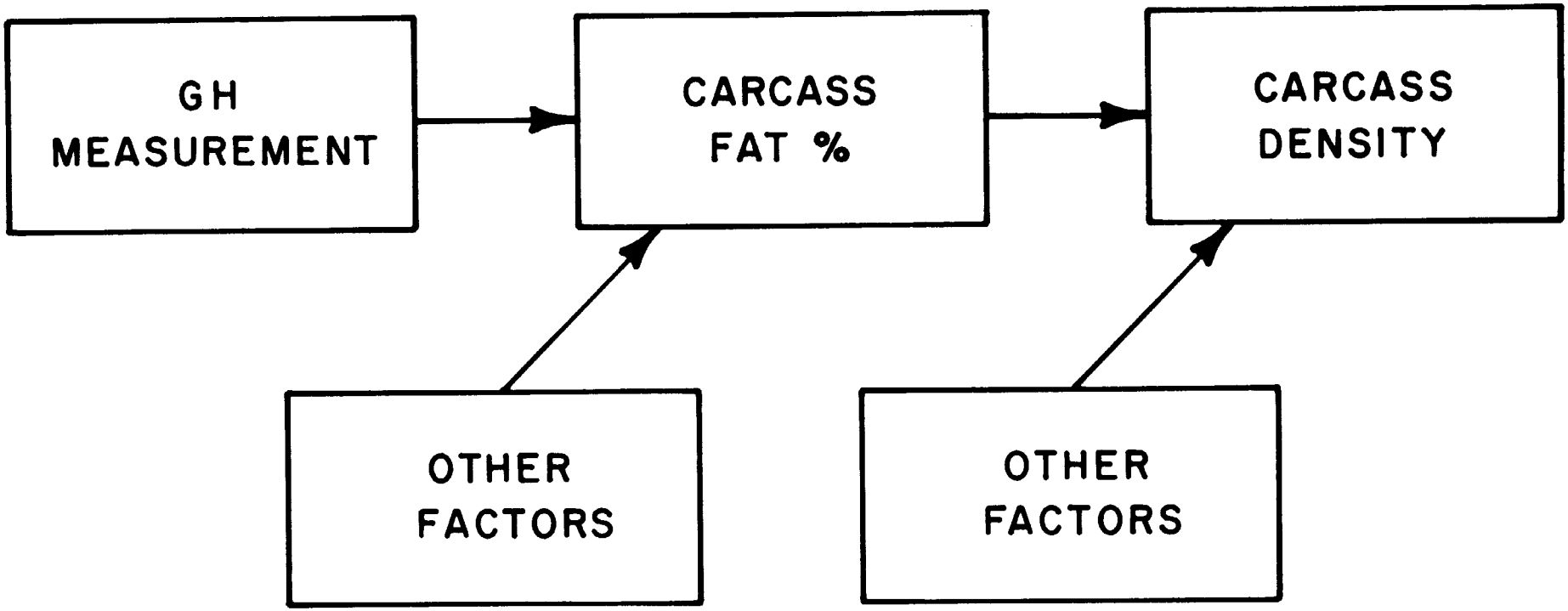

Fig. 1. Hypothetical example of possible direct and indirect influences of various measurements upon carcass fatness.

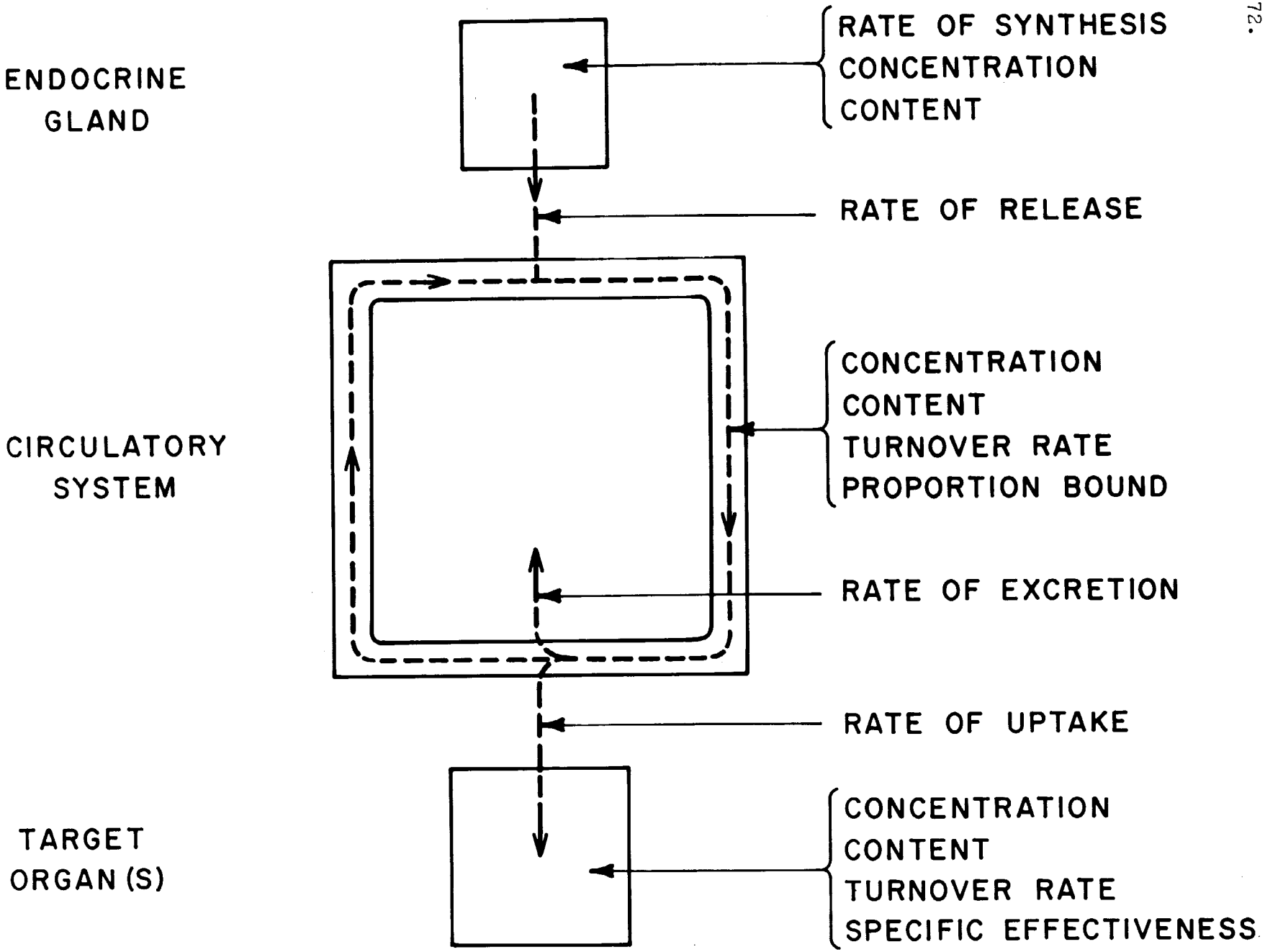

Fig. 2. Possible hormonal measures and some factors influencing their measurement at various sites in the total system.

TABLE 1

Statistical Relationships Between Jugular Growth Hormone Level and Growth Rates

Method	n	statistics	
Correlation coefficient	40	r = -.37	P<0.05
Least squares model (y = log mean jugular GH)	40	b = -.27	P<0.01

TABLE 2

Coefficients of Correlation between Pituitary Growth Hormone Concentration and other Variables

Variable	n	r	Signif.
Carcass wt	50	-.51	P<0.01
Dressing %	50	-.61	P<0.01
Round %	50	0.36	P<0.01
Flank fat %	50	-.44	P<0.01
Cannon Bone %	50	0.41	P<0.01
Growth rate	50	-.49	P<0.01

TABLE 3

Relationships between Plasma Cortisol and Growth Rate or Tenderness

Group	Statistic	Plasma Cortisol	
		Growth Rate	Tenderness
Low plane	r	-.52	0.83**
High plane	r	-.50	0.12
High + MGA	r	-.04	0.005
Total	r^2(%)	40.8	15.3
Total	r^2(%)	42.4	32.3

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L. E. WALTERS: Thank you very much Al for that most interesting paper. I'm sure that most of us at one time or another have heard the question asked as to whether or not the degree with which we may ultimately be able to handle hormones in the animal will make it possible for that animal to better meet our needs. Certainly I think it offers some food for thought. As a reminder, if you have questions that you would like to direct to the speakers or if you have a discussion that you would like to inject that relates to the papers and the topics presented this afternoon, would you please make note of them and at the conclusion of this session we do hope to have ample time for discussion. Following along in the same vein generally and to discuss with us under the title of "The Effects of Sex and Energy Levels on Carcass Composition" we have a man whom many of us know, but a man who has not attended a great many of our Reciprocal Meat Conferences, we are very happy to have him with us and hope he will find it possible to return many times in the future, Professor V. H. Arthaud, University of Nebraska.

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