A COMPARISON OF METABOLISM OF RAPIDLY AND SLOWLY GAINING BEEF CATTLE

by

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A COMPARISON OF METABOLISM OF RAPIDLY AND SLOWLY GAINING BEEF CATTLE

CHAPTER I

INTRODUCTION

Through centuries of trial and error methods, farm animals now tend to resemble more closely the breeders' ideal in appearance than did their ancestors. Successful breeders of the past usually used individual merit as a basis of selection, although there was always much talk of pedigree and the selections were undoubtedly influenced by the merits of ancestors and collateral relatives. Even after the rediscovery of Mendelism showed that identical pedigrees need not mean identical heredity, animal breeding literature (at least until the 1920's) was glutted with efforts to force unjustified meaning into extended pedigrees. Among animal geneticists today there are still some who do not appreciate that the presence of unduplicatable environmental variations makes it axiomatic that outstanding individuals will not usually have as good progeny as they are themselves and, conversely, that poor individuals will usually have progeny of greater merit than themselves. Mendel's Law of Segregation explained this phenomenon. Therefore, other means are required to supplement pedigree analysis and enhance the efficacy of the selection of parents for continuous improvement in subsequent generations.

It was demonstrated many years ago that the progeny test is an effective means of increasing the accuracy of identification of genotypes and this precept has been preached, propagandized, and practiced by progressive breeders of livestock. While the progeny test does what is claimed, it is not an economically efficient means of identifying genetic potential in such traits as growth rate and meat production efficiency in beef cattle. Nor is the problem resolved by selections based on showring standards. What is needed are selection criteria for growth as expressed by rate and efficiency of gain which combine the accuracy of a progeny test with what approaches the economy of a showring classification.

If one accepts the theory that the vast majority of traits of economic importance are under the control of a large number of genes of minor effect and that the polygenic complexes influencing early growth also influence growth at later stages of development, some of the time lag in progeny testing may be eliminated by developing a test applicable at an earlier age. Such a concept demands investigation through new approaches, new techniques, and new experimental methods which force us to give up the familiar for the sake of the unknown.

The limits of space, time, and money ordinarily prevent any single investigator or group of investigators in

large animal biology from gathering data, the conclusions from which fall within narrow confidence intervals. The problem then, in the words of Dr. I. Michael Lerner, is

> "To steer carefully between the Scylla of generalization from insufficient evidence and the Charybdis of excessive caution. The temptation to take refuge in lack of information is as great as the temptation to elevate dogma based on subjective hypotheses to the status of fact."

By weighing the evidence carefully, one should be able to reach a reasonably objective decision as to whether the data obtained by the methods employed are worthy of further study and whether the new approach does indeed open more accurate or more efficient avenues of approach. The writer is committed to the belief that variations in rate and efficiency of gain are the end results of variations in metabolism, and that, therefore, there must be a period or stage of development at which measurements may be taken from which accurate estimates of the genetic potential of rate and efficiency of gain may be derived and applied in practice. However, the economics of livestock production as well as other factors tend to make the animal breeder a conservative, scientifically if not politically, and more than a priori demonstrations of the value of an alternative selection criterion must be presented before he may be induced to adopt a radical change in methods of beef cattle evaluation.

Variations in metabolism are reflected in the composition of the urine and it is a reasonable possibility that

they are also reflected in the composition of the blood. Thus, they should furnish a readily accessible source of information that may be descriptive of, or correlated with, the different rates or different types of metabolism that lead to differences in rate and efficiency of gain. If this hypothesis be true, a difference in metabolism between rapidly and slowly gaining beef cattle should produce a change, either quantitative or qualitative, in the constituents of the urine and perhaps the blood.

Therefore, this study embraces an investigation of the normal constituents of the urine and blood of beef cattle tested for rate and efficiency of gain at Oregon State College in the hope that correlations between blood and urine chemistry with rate and efficiency of gain may be established. A certain by-product would be basic data on the blood and urine chemistry of beef cattle.

CHAPTER II

REVIEW OF LITERATURE

> "The hypotheses of science are continually changing. Old hypotheses break down and new ones take their place. But the classification of known phenomena which a hypothesis has suggested, and the new discoveries of phenomena to which it has led, remain as positive and permanent additions to natural knowledge when the hypothesis itself has vanished from thought."
>
> J. H. Poynting.

The number and variety of experiments involving studies of metabolism and growth in beef cattle have been considerable. It is true that many of them have not been primarily designed to discover basic metabolic reasons for the mode of inheritance of the differences between animals, but have been used for this purpose ex post facto. The results that have contributed to our understanding of the metabolic phenomena involved have come from straight selection experiments and analyses of physiological, biochemical and nutritional data collected for other purposes. It is entirely impossible to include a review of all publications which have appeared on the subject and exceedingly difficult to select from the welter of papers dealing with similar data under a great variety of unspecified conditions those of particular note or significance in terms of priority. Review articles may serve as rather complete reference lists of publications to date, while Biological Abstracts

and Animal Breeding Abstracts provide good entries for more recent publications. In this thesis only citations of immediate pertinence are made as judged, not by considerations of priority, but by utility in illustrating or enlightening the results and discussion.

A. Growth Measurements

1. Feedlot Studies in Relation to Rate and Efficiency of Gain.

The need for a measure of performance in beef cattle was recognized at an early date. Robert Bakewell and other early beef cattle breeders obtained a rather accurate measure of efficiency of their production, but little controlled work of this nature was done until recent years. Sheets (187,pp.41-47) reported one of the earliest studies of measured performance in beef cattle in which carcass quality and efficiency, measured by pounds of cold carcass produced per 100 pounds of Total Digestible Nutrients (TDN) consumed, were considered.

Black and Knapp (23,pp.72-77) concluded that the test period used in measuring beef cattle performance should be limited to a weight constant period of 500-900 pounds live weight; also that the final evaluation be based on efficiency of gain during this period and on carcass grade. They found a high correlation between rate and efficiency of gain. In 1941, Knapp et al.(128) reported that daily gain and efficiency of gain were not highly correlated in

a time-constant population. They found that daily gain may be used with a high degree of accuracy to predict efficiency of gain of animals fed through a comparable weight period, but that much of the accuracy might be lost when wide variations exist between individuals in initial and final weights. According to Knapp and co-workers (129,pp.285-292) approximately 80 percent of the differences in carcass grade can be accounted for by differences in initial weight and total gain while on feed.

That a feedlot test for rate and efficiency of gain is expensive in both time and money, especially in areas where supplementary concentrate feeding is not practiced, is immediately apparent. For this reason research workers sought some rapidly obtainable phenotypic measurement either anatomical, physiological, or metabolical which is highly correlated with rate and efficiency of gain so that it may be employed in predicting these factors with accuracy. Obvious skeletal differences provided a plausible measure of such growth since investigators agreed that general factors do exist which affect all parts of the body.

2. Skeletal Measurement Studies in Relation to Rate and Efficiency and Gain.

Castle (48,pp.51-55) from several correlation studies gave evidence that factors which control growth in the rabbit are general in their action and affect all parts of the body in the same general direction and to a

proportional degree. Moreover, Castle (49) found that the lengths of the different bones within an individual are highly correlated, and that all the bone lengths he studied were correlated to a high degree with body weight. In addition to this, he found for the rabbit that the length of ears was highly correlated with body weight. These studies seemed to show that muscular development is definitely correlated with skeletal development in some manner, and that both are controlled, apparently, by the same system of general growth factors. Wright (213,pp.75-106) analysed Castle's data and came to the conclusion that, for the most part, the factors which control bone length are general. However, he also concluded that in the development of certain bones and groups of bones there was a slight amount of variation which was controlled by specific growth factors and was consequently independent of general growth factors.

The researches of Sumner (197,pp.391-397) and Green (93,pp.406-416) seem to indicate that in the mouse both general and specific factors affect size. In mice, rabbits, and domestic fowls (Dunn, 61) it has been clearly demonstrated that size is a quantitative character. Since environmental agencies complicate the problem, most if not all, studies in size inheritance in mammals have been somewhat disappointing, especially since no clean-cut polygenic systems have been demonstrated with satisfaction. In a

study of growing dairy heifers Eckles and Swett (62,pp.3-29) found that almost any unknown important skeletal measurement can be calculated with a high degree of accuracy from one known skeletal measurement. They found that height at withers alone was a satisfactory criterion of skeletal development. The paper of Swett, Graves and Miller (198) which gave an intensive comparison of the differences in conformation between a highly specialized dairy cow and a highly specialized beef cow deserves mention. These investigators came to the conclusion that the skeletal difference in conformation between the two was caused by the development or lack of development of fleshing. Unfortunately, they neither defined "fleshing" nor gave a physiological basis for the differential growth in such a direction. Gregory (97,pp.230-249) found from a study of muscle-skeletal relationships that the genetic agencies which affect the development of muscle diameter have a certain degree of independence from those which affect linear skeletal development.

In spite of the fact that the data reported above were not presented in relation to time, the principles were applied to beef cattle. Experimental attempts to correlate anatomical measurements with rate and efficiency of gain in beef cattle may be said to have started with Hultz (118,pp.71-94). In 1927 he found that very rangy calves made more rapid gains than very low-set calves and that

cattle on a fattening ration changed type. Lush (145) reported that steers of many shapes will gain well and steers which gain the same may be of many different shapes. This was also true of dressing percentage and meat values. Lush, Knox and Koger (24,pp.331-337) and Stanley and McCall (194,pp.35-53) reported a positive correlation between rate of feedlot gain and skeletal size. Woodward, Clark and Cummins (212) observed that large type calves were heavier at weaning time than small type calves and made larger and more economical feed lot gains. In their study, little difference existed between types in dressing percentage and carcass grade.

In a study with 50 head of steers of beef, dual purpose and dairy breeding, Black, Knapp, and Cook (24,pp.465-472) discovered, contrarily, that steers considered low-set from a standpoint of weight had a significant advantage over tall steers in amount and efficiency of gain, dressing percentage and carcass grade. In a similar study, Kohli, Cook, and Dawson (134,pp.352-364) compared the relationship of height at withers, height to floor of chest, heart girth, width at shoulders, and length of body with rate of gain, efficiency of feed utilization, and age at slaughter in milking Shorthorns. They found that steers tended to vary independently of the body dimensions measured. It may be concluded on the basis of the above studies that correlations between rate of gain and anatomical measurements

are not of a high enough order to adopt effectively in predicting rate and efficiency of gain.

3. Other Studies.

In an effort to discover a development period of shorter duration and lower cost in which to test rate and efficiency of gain, Knapp and Clark (130,pp.174-181) studied the genetic and environmental correlations between growth rates of beef cattle at different ages using 422 steers from 43 sires in a 252 day feeding trial of three 84-day periods. Their analysis indicated that there was little environmental correlation between the three periods and that since the genetic influence became greater as the feeding period progressed only the third period would be required for analysis. The authors concluded that progeny testing of calves for gaining ability seems unnecessary and selections for this ability can be made through feeding tests of the prospective sires. Koger and Knox reported (133,pp.760-767) that the growth rate of steers on the range was positively correlated with their gains in the feedlot. They concluded that, when environment is constant for different animals, there is a positive relationship between gains made at different periods. In a later study, Knapp and Clark (131,pp.365-370) found a gross correlation of 0.0001 between score at weaning and gain in the subsequent feedlot test.

The cause of variation in the live weight increase of animals on experiment has been further investigated by Dunlop (59 and 60,pp.151-159). He found that varying food intakes and initial weights, inherent drawbacks of the group feeding method, accounted for much of this variation. When these two factors are rigidly controlled, small differences in live weight metabolism and the digestive capacity of animals, for all purposes, are the same and cannot account for any great part of the residual variation. Confirmation of the small differences in digestive capacity was presented by Baker, Colby, and Lyman (16,pp.726-732). Further evidence showed that differences in the proportion of fat to protein laid down affect the magnitude of the weight gains of animals (60,pp.151-159). Growth rate and efficiency, measured by weight increase, is influenced by feed intake (quantitatively and qualitatively) and by the nature of the resulting metabolic syntheses. Both represent genetic-environmental interrelationships.

B. Endocrine Control of Metabolism and Growth.

1. Anterior Pituitary Growth Extracts.

The anterior pituitary hormones, both directly and indirectly through the secretions of the organs which they influence, exert a profound effect on growth through the utilization and metabolism of carbohydrates, proteins, and fats. This subject has been extensively reviewed by Li and

Evans (138,pp.197-225), Barker (17,pp.45-82) and others. Evans, Simpson and Li (66,p.71) injected the hormone into normal adult female rats for 435 days. The dosage was increased gradually from 0.4 to 2.0 mg. per day so that growth continued for the entire period. The greatest weight attained was 662 gm. and the range of final weights did not overlap; the smallest rat in the treatment group weighed 410 gm., whereas the largest control rat weighed 353 gm.

Since true growth is generally regarded as the accumulation of proteins, it is reasonable to expect from the foregoing that an important function of the growth hormone is to retain nitrogen which, in turn, increases the body protein content. Teel and Watkins (199,pp.662-685), working with dogs, reported a drop of 20 to 30 percent in the blood non protein nitrogen (NPN) following injections of growth extracts from the anterior pituitary and showed that about 70 percent of the decrease in NPN was accounted for by decreases in amino acids and urea. Gaebler (86,p.46), also with dogs, confirmed these findings and in addition found a decrease in urinary nitrogen chiefly at the expense of the urea. Farr and Alpert (67,pp.772-775) noted a transient fall in plasma amino acids in dogs following intraperitoneal injections of a growth promoting pituitary extract.

Experiments with rats have given similar results. Harrison and Long (105,pp.971-978) reported that injections

of anterior pituitary into fasted rats caused a decrease of NPN. Later experiments by Marx et al. (151,pp.544-550) and Fraenkel-Conrat, Fraenkel-Conrat and Evans (81,pp.200-212) with partially purified growth hormone confirmed these conclusions.

Changes in the body composition of animals after treatment with pituitary extracts which caused accelerated growth have been studied by several workers. Bierring and Nielsen (22,pp.1015-1021) in studying the composition of tissues of rats that had been treated with alkaline anterior pituitary extracts found that the resultant weight increase is not exclusively due to water retention. Lee and Schaffer (137,pp.337-363) found that treated rats maintained almost exactly the initial composition and heat values while the control group showed significant decreases in the proportion of water, nitrogen, fat-free dry tissue, and ash and increases of fat and heat value of the tissue. The energy expended was 1.7 times the energy gained per gram weight increase for the treated group and 2.4 times the energy gained per gram weight increase for the control animals. Studies with pure growth hormone by Gordan et al. (91,pp.153-160) and Li and Evans (138,p.211) have shown that the hormone reduces the urinary nitrogen in various conditions. In some cases the decrease of urinary nitrogen corresponded almost quantitatively to the gain in body weight.

In addition to the effects noted above the anterior pituitary also affects the utilization and metabolism of a number of specific dietary factors. If an immature animal is placed on a diet of insufficient food intake, growth, as represented by skeletal elongation and gain in body weight, is reduced. Administration of somatotrophin (anterior pituitary growth hormone) to such an animal results in more rapid growth associated with reduced nitrogen excretion (137,pp.337-363 and 139,pp.91-95). These findings suggest that the growth retardation during conditions of reduced caloric intake may be due in part to a decreased secretion of somatotrophin.

Considerable data are available indicating that somatotrophin will not promote a weight increment in animals that are nutritionally deficient. Thus "growth hormone" failed to promote a gain in body weight in rats deficient in vitamins A and B_1 (63 and 64), pantothenic acid (143,pp.85-87), and the essential fatty acids (63,p.126). Similarly, "growth hormone" failed to promote an increment in body weight in rats fed a low protein (6% casein) diet (90,pp.317-319 and 91,pp.153-160). Supplementing the diet with dl-methionine or increasing the casein content to a minimum of 12 percent of the ration, however, resulted in a significant weight increment following "growth hormone" treatment. Chow and Greep (50,pp.191-192) reported that the quality as well as the quantity of

dietary protein is also of importance in conditioning the response to hormone administration. These workers found that the gain in weight of immature hypophysectomized rats treated with a growth promoting fraction of the anterior pituitary was appreciably less when the source of dietary protein was soya protein than when it was casein or lactalbumin.

In other experiments it was found that growth hormone extracts were equally active in adrenalectomized animals (189,pp.234-240) and in those which were completely thyroidectomized (186,pp.227-236) and that gonads were not required for the action of the growth hormone (206,pp.468-471) and (65,pp.511-546).

2. Adrenocorticotrophic Extracts.

The fact that growth hormone reduces the blood amino acids seems justifiably to be brought into relationship with its effect on protein anabolism. Together with such findings that, as the growth hormone causes a marked retention of nitrogen and an increase in the protein content of the carcass of treated animals, the hormone may be regarded as a protein anabolic agent (112,p.222). If this is true, the contrasting results obtained with adrenocorticotrophic hormones are not surprising. Gordan et al. (90), Marx et al. (152,pp.102-105), and Li and Evans (138,p.222) found that adrenocorticotrophic hormone causes an increase in urinary

nitrogen excretion with a proportionate loss of body weight in the rat and that this effect is manifest on the second day of hormone injection and persists for 24 hours after injection is stopped. Fraenkel-Conrat and co-workers (81, pp.200-212) and Simpson et al. (188,pp.135-137) showed that liver arginase is increased by the administration of adrenocorticotrophic hormone as well as by certain other adrenal cortical substances thus having the opposite effect to that of the growth hormone. Since this hormone counteracts the action of growth hormone (152,pp.102-105), it would be expected that adrenocorticotrophic hormone elevates the concentration of free amino acids in the blood plasma. This may be due either to direct protein catabolic action of the hormone or an inhibition of the synthesis of tissue protein.

C. Nitrogenous Metabolites Associated with Growth.

From the foregoing literature it is evident that differential metabolism, growth, and feed intake express themselves through the intermediary metabolic products of the blood and those excreted in the urine of animals. The chemical composition of urine is extremely complex and while small amounts of nitrogenous wastes occur in sweat, saliva and milk, urine is by far the principal medium for their elimination. While urine collection from bulls and steers is a simple matter, satisfactory methods and

practical facilities for the quantitative separation of urine from feces in balance trials with mature cows and heifers are limited. An accurate but expensive method was described by Maynard (154,p.254) whereby an attendant remains behind the animal constantly to collect the excreta as voided. Ritzman and Colovos (178,pp.1-16) described an automatic belt device for collection and separation of solid and liquid excreta. Hobbs, Hanzard, and Barrick (116,pp.565-570) reported an economical and dependable method for holding steers and heifers and described simplified equipment adequate for complete separation of the urine and feces eliminated during short or extended periods of balance study.

The chief urinary nitrogen products in cattle and other mammals are urea, creatinine, creatine, hippuric acid, allantoine, uric acid, ammonia, and amino acids.

1. Urea.

In cattle urine, urea is quantitatively the most important of the nitrogenous wastes and is formed mainly, though not directly, from protein. Under normal conditions, much of the urine urea is of exogenous origin and most of it is formed directly from arginine which is hydrolysed by the enzyme arginase into urea and ornithine. According to Krebs and Henseleit (135,pp.33-66), the formation of ornithine occurs in two steps: (i) the formation of a substance,

citrulline, by the addition of a molecule each of ammonia and carbon dioxide to ornithine and (ii) the addition of a second molecule of ammonia to citrulline with the resultant production of arginine. Urinary urea excretion from cattle has been studied by a number of investigators under various conditions, by various methods, and the results have been reported in various manners. For example, animals used in studies of protein requirements excreted 1.50 to 13.00 gm. of urea per litre of urine (68,pp.399-439) while aged cows excreted 190 to 308 gm. and heifers excreted 164 to 336 gm. per 24 hours on full feed (56,pp.41-46). Hutchinson and Morris (122,p.686) studied endogenous nitrogen excretion of cattle on a low nitrogen diet and in starvation. They found that animals on a low nitrogen diet excreted 3.60 to 6.80 gm. daily while animals in starvation excreted 24.00 to 24.40 gm. daily. In their study, the urea nitrogen represented approximately 30 percent of the total nitrogen excreted on the low nitrogen diet and 60 percent on starvation. Carpenter lists averages ranging from 18.2 to 75.5 percent of total urinary nitrogen for urea excretion in fasting animals. Another worker (68,pp.399-439), in studying cattle, listed daily urinary urea plus ammonia nitrogen excretions ranging from 58.1 to 69.4 percent of the total nitrogen excreted. Hart et al. (106,pp.131-205) gave urinary urea nitrogen 74.07 in studying the percentage distribution of nitrogen in a non-fasting cow. The actual

percentage of urea in the urine of the dairy cow was found by Hayden (58,p.417) to be 1.5 to 3.5 percent.

Blood urea concentrations have been similarly studied. At first beef blood was used as a medium for abstract experimentation on blood and the values for urea obtained were considered of interest only in evaluating a method or technique. Even today, the data on the chemical composition of normal beef blood available for application to a study of physiological processes are meager. Albritton's recent publication (3) exemplifies this situation. Folin and Denis (75,pp.29-42) upon analysing mixed beef blood at the time of slaughter reported urea nitrogen values averaging 14.0 mg. per 100 cc of blood. Hayden and co-workers (109,pp.197-203) (110,pp.102-110) and (111,pp.181-191), working with venous blood samples from dairy cows in three studies, reported urea nitrogen ranges of 5.30 to 27.0 mg. and averages of 12.21, 11.18, and 18.80 mg. per 100 cc of blood. Scheunert and von Pelchrzim (184) reported ranges of 10.0 to 22.0, 10.5 to 23.7 and 13.5 to 22.7 mg. per 100 cc of blood. Fearon (68,pp.399-439) quoted work by Folin and Denis in which the blood urea nitrogen content of the ox was determined. He quoted a range of 13.6 to 15.3 mg. per 100 cc. More recently Colby *et al.* (51,p.652) studied the levels of various beef blood constituents at the termination of a 196-day growing period following weaning. They found an average value of 11.98 mg. per 100 cc.

In a urea feeding experiment Dinning et al. (56,pp.41-46) reported a steer in which the blood urea level gradually rose to 30.10 mg. percent while the group average rose from 14 to 24 mg. percent.

2. Ammonia.

While in man ammonia stands next to urea in importance as an end product of nitrogen metabolism, it is normally not so important in herbivors. McCollum and Hoagland (148,pp.299-315) found that additional nitrogen eliminated on an acid diet over an alkaline diet is in the form of ammonia. Under grazing conditions the natural diet of herbivors is alkaline (196,pp.1-19). These authors also found that the animal is not able to use the nitrogen of urea to neutralize the acids present in the diet but draws additional nitrogen from the tissues for ammonia production. After Nash and Benedict (164,pp.463-487) demonstrated that urinary ammonia is synthesized by the renal tubules from some precursor in the renal arterial blood, the nature of that precursor excited controversy (124,pp.411-427 and 27,pp.137-158). Van Slyke et al. (204,pp.481-482) demonstrated that much of the urinary ammonia is formed in the kidney by the enzymatic cleavage of the amide nitrogen of glutamine and to a variable extent from amino acid nitrogen.

McDonald (149,pp.574-587) employed sheep to study the ruminant absorption of ammonia. He found that ammonia occurred only in traces, if at all, in the blood of general circulation while the venous blood draining the rumen contained about 1.5 mg. ammonia nitrogen per 100 cc. Since urea, in significant quantities, occurs in the saliva of sheep, McDonald draws attention to the circulation of nitrogen in the normal digestive process of the ruminant viz. urea in saliva is converted in the rumen into ammonia which may be absorbed into the portal blood stream and converted by the liver to urea which again becomes available for secretion in the saliva.

Lindsay (140,pp.79-99) recorded the urine ammonia nitrogen excretion of the cow and ox. She found that the range was similar in both classes of animal, being 0 to 0.025 gm. per 100 ml. for cows and 0 to 0.024 gm. per 100 ml. for oxen. On a percentage basis, the ammonia nitrogen of cows ranged from 0 to 1.7 percent of total nitrogen excreted while in the oxen it ranged from 0 to 3.5 percent. Carpenter (47,p.540) found that the percentage distribution of ammonia nitrogen varied from 2.1 to 38.1 percent of the total urinary nitrogen in fasting steers. In another study, Hutchinson and Morris (122, pp.1682-1694) found the percentage of urinary ammonia nitrogen varied from 2.67 to 4.12 percent for cattle on a low nitrogen diet and from 2.20 to 4.22 percent for fasting cattle.

In a fairly recent study, Dinning et al. (70,pp.41-46) administered urea to cattle and sheep in varying amounts and by several methods. They found from the combined results of all their experiments that toxic levels of urea are reflected in the rapid rise of urea nitrogen of the blood and increases in blood ammonia nitrogen to values over 2.5 mg. percent. Death occurred when blood ammonia values reached approximately 4.0 mg. percent.

3. Amino Acids.

A small amount of the nitrogen present in urine is in the form of amino acids. Their presence is probably due to the inability of the kidney to completely prevent their leaving the blood. Goettsch et al. (89,pp.688-698) studied renal amino acid clearance in the dog. They found that the kidney was able to hold as much as 40 mg. per 100 cc. (64 to 81 percent) of amino acid nitrogen. Hutchinson and Morris (122) found amino acid nitrogen excretion ranges of 0.39 to 0.63 gm. per day in cattle on a low nitrogen diet and 0.20 to 0.28 gm. per day in cattle on a fast. These values represented 2.9 to 3.0 and 0.5 to 0.7 percent of the total urinary nitrogen excretion in the low nitrogen and starvation diets respectively. Based on a review of the composition of cattle blood by Hayden, Dukes (58,p.49) lists 4 to 8.5 mg. per 100 cc. as the range for amino acid nitrogen. The lack of literature on total amino acid nitrogen in cattle blood is surprising (3).

4. Creatinine.

The excretion of creatinine, the anhydride of creatine, in contrast to ammonia and urea, is highly constant and is only slightly influenced by changes of dietary proteins (185,p.51) (57) (18) and (21,p.637). Creatinine is therefore considered to be an index of the magnitude of the metabolism of the tissues and especially the muscles. When isotopic creatine is administered, it rapidly merges with all the creatine of the body. The isotope concentrations are the same, not only in the creatine isolated from the muscles and internal organs, but also in the creatinine of the urine (28,pp.111-119). This creatinine must have been formed directly from creatine.

Lindsay (140,pp.79-99), in studying the protein metabolism of the ox and pregnant cow found a urinary excretion of 0.006 to 0.091 gm. creatinine nitrogen per 100 cc. for the ox and 0.044 to 0.087 gm. for the cow. This represents 3.4 to 5.0 percent of the total nitrogen excreted by the ox and 2.8 to 7.4 percent of that of the cow. Dukes (58,p.359) states that Munzer found the creatinine content of ox urine averaged 1.12 gm. per litre. In a study of fasting steers, Carpenter (47,p.542) found an hourly excretion of creatinine ranging from 0.07 to 0.72 gm. and Dinning et al. (57,pp.157-161) reported a daily creatinine nitrogen excretion range of 2.27 to 4.33 gm. in steers receiving nitrogen

from various dietary sources and a range of from 3.16 to 3.94 gm. in steers receiving different amounts of dietary nitrogen.

The creatinine coefficient is the number of milligrams of creatinine nitrogen eliminated daily per kilogram body weight. Lusk (146,pp.235-258) gave values of 8 to 11 for normal adult human males; 5.8 to 9.8 for normal adult human females; 10 for adult dogs. Carpenter's fasting steers (47) gave coefficients ranging from 8 to 9; Ashworth and Brody (13,p.9) found coefficients in the order of 9.5 for dairy cattle; and Dinning et al. (57) found that changes in nitrogen intake and the addition of urea to the rations were without effect on the creatinine coefficients of steers. Dinning et al. reported a mean creatinine coefficient of 11.18. The creatinine coefficient may be taken as an indication of reserve material, i.e., whether the animal is fat or lean, because the fatter the animal the lower will be the creatinine coefficient (70,p.85). High creatinine coefficients may also be due to more active protoplasmic tissue in younger animals.

Blood concentrations of creatinine have been reported by several investigators. Folin and Denis (76,pp.487-491) reported an average creatinine value of 2 mg. per 100 cc. of whole blood. Hayden and co-workers (109,pp.197-203) (110,pp.102-110) and (111,pp.181-191) reported averages of 1.20, 1.37, and 1.84 mg. per 100 cc. while Scheunert and

von Pelchrzim (184,pp.17-29) gave creatinine ranges of 1.2 to 2.5, 1.4 to 1.8, and 1.5 to 1.7 mg. per 100 cc. of blood for cattle. Anderson, Gayley and Pratt (7,pp.336-348) obtained an average of 1.42 mg. per 100 cc. from 59 determinations of dairy cattle blood with values ranging from 1.11 to 1.94 mg. and Dukes (58,p.48) reported a normal blood creatinine range for cattle of 1.0 to 2.07 mg. per 100 ml. of whole blood. Recently, Colby et al. (51,p.652) reported a creatinine average value of 1.32 mg. for beef cattle following a 196-day post-weaning feeding period.

5. Uric Acid.

Purines can be synthesized de novo in the mammal as proven by the formation of nucleic acid and nucleotides during growth when the only food is milk which contains little or no purine (160,p.510). Studies with isotopic phosphorus indicate the rapid incorporation of P^{32} into nucleic acid in the walls of the intestine, with less rapid uptake in the spleen, testes and muscle (Hevesy and Ottesen, 160,p.510). On diets that are largely of animal origin, purine metabolism is partly exogenous. Endogenous purines are derived enzymatically from nucleic acids in body tissues. While the principal purine found in the urine of man is uric acid, its oxidation product, allantoine, largely replaces it in the urine of farm animals. Hunter and Givens (121,pp.403-416) reported that the purine

urinary nitrogen excretion in the cow was composed of 92.1 percent allantoine nitrogen and 7.3 percent uric acid nitrogen. Lindsay (140,pp.79-99), in studying the allantoine excretion of cattle, found ranges of 0.029 to 0.219 gm. per 100 cc. for the cow and 0 to 0.013 gm. per 100 cc. for the ox. This represents a range in the total urinary nitrogen excretion of 2.0 to 9.6 percent for the cow and 0 to 0.8 percent for the ox.

On analysing cattle blood, Folin and Denis (75,pp.29-42) reported a value of 0.2 mg. per 100 cc. for mixed blood at slaughter. Later, using improved methods, Benedict (20,pp.633-640) found that the free uric acid content of blood increased from 2.0 mg. per 100 cc. at the time of collection to 7.15 mg. per 100 cc. upon standing for two weeks. The total uric acid remained the same. Hayden and Tubangui (111,pp.181-191) obtained an average uric acid content of 2.12 with a range of 1.60 to 2.64 mg. per 100 cc.; Hayden and Sholl (110,pp.102-110) obtained an average of 2.08 mg. per 100 cc.; and Hayden and Fish (109,pp.197-203) obtained an average of 2.04 mg. per 100 cc. of blood in studies of dairy cattle. Scheunert and Pelchrzim (184, pp.17-29) found a uric acid range of 1.0 to 4.2 mg. per 100 cc. and Anderson, Gayley, and Pratt (7,pp.338-344) found an average of 2.08 mg. and values ranging from 1.50 to 3.22 mg. per 100 cc. of blood.

In reviewing the literature, ab extra, certain points dominate. First, the desirability of having an index which would permit the highly accurate prediction of future rate and efficiency of gain of immature beef cattle is self evident. Second, attempts to predict such rates and efficiencies on the basis of traditional judging procedures, skeletal measurements, birth and weaning weights, and suckling gains have lacked the necessary degree of accuracy for adoption in production procedures. Third, actual feeding trials through a weight-constant period, while yielding superior results, are as equally expensive as trials through time-constant periods. Fourth, there is little doubt that the ultimate control of rate and efficiency of gain is under the mediation of the endocrine system of the beef animal, the expression of which is evident to a variable degree in the blood and urine levels of nitrogen compounds. Fifth, ad hoc experiments are much more useful in comparing the metabolism of rapidly and slowly gaining beef cattle with the objective of establishing selection criteria of a high order than are attempts to reach the same objective by revaluating data published principally for other purposes.

Therefore experiments were begun at this station embracing an investigation of the normal constituents of the urine and blood of beef cattle tested for rate and

efficiency of gain in the hope that correlations between blood or urine chemistry and rate or efficiency of gain may be established. In addition, a certain by-product is basic information on the blood and urine chemistry of beef cattle.

CHAPTER III

METHODS AND PROCEDURE

"Whatever is worth doing at all, is worth doing well"
Philip Dormer Stanhope.

A. Biological Methods.

The data used in this study were from 45 beef calves at Oregon State College under the Western Regional Beef Cattle Improvement Project. The calves were purebred Hereford and Aberdeen Angus bulls and heifers. All were born during the spring of 1952 and were weaned at 450 pounds live weight, or on December 3, 1952. As the calves reached approximately 450 pounds, they were placed under experimental conditions.

1. General Management.

The management procedures used and recommended (30, p.2) (52,pp.1-6) and (166,p.1) at this station were adopted as the basis for the present study. Individual stall feeding was done twice daily at uniform times and the calves remained tied by neck chains for a total of approximately eight hours. The metabolism stalls used were locally constructed with minor modifications of the design proposed by Briggs and Gallup (36). Mangers were constructed such that calves had access to water at all times through automatic drinking cups. Pens, in which wood shavings were used for bedding, housed the calves in monosexual groups of six.

TABLE 1

DISTRIBUTION OF EXPERIMENTAL ANIMALS BY SIRE, SEX, AND BREED

Breed	Sire	500 lbs.				800 lbs.			
		Males		Females		Males		Females	
		No.	Total	No.	Total	No.	Total	No.	Total
Hereford	38	B 3,B12,	2	B 5,B 6, B 9,B17, B19,B25.	6	(1) B12.	1	B 5,B 6, B 9,B17, B19,B25.	6
	71	B 4,B 8, B13,B16, B20,B21, B22,B28.	8	B 1,B11, B23,B27, B32.	5	B 4,B 8, B13,B16, B20,B21, B22,B28.	8	B 1,B11, (2),B27, B32.	4
	84	B10,B18, B26.	3	B 2,B 7, B15,B29.	4	B10,B18, B26.	3	B 2,B 7, B15,B29.	4
Hereford Totals			13		15		12		14
Aberdeen Angus	101	B55,B56, B57,B60, B63.	5	B52,B61, B66,B68.	4	B55,B56, B57,B60, B63.	5	B52,B61, B66,(3).	3
	117	B51.	1	B50,B53, B58,B59, B64,B65, B69.	7	B51.	1	B50,B53, B58,B59, B64,B65, B69.	7
Aberdeen Angus Totals			6		11		6		10
Grand Total			19		26		18		24

(1) Died at 500 pounds.
(2) Abnormal. Culled at approximately 600 pounds.
(3) Removed at 740 pounds because of the termination of test.

TABLE 2

ANALYSIS OF O.S.C. RATION FOR PERFORMANCE TESTING BEEF CATTLE (166,p.1)
Values Based on Morrison's Standards (163, Appendix I)

FEEDSTUFF	% of Ration	Dry Matter	T.D.N.	Net Energy (Therms)	Dig. Protein	Crude Protein	Ether Extract	Crude Fibre	Ash	N.F.E.
Alfalfa No.2 grade	66.5	90.5	52.7	42.2	11.7	15.8	2.2	27.4	8.5	36.6
Molasses	5.0	80.5	60.8	68.1	4.4	8.4	-	-	8.8	62.0
Rolled Barley	15.0	89.8	78.7	71.4	6.9	8.7	1.9	5.7	2.6	70.9
Ground Oats	5.38	91.2	72.2	80.1	7.0	9.0	5.4	11.0	3.7	62.1
Beet Pulp	3.25	91.9	72.1	70.5	7.1	10.7	0.7	16.0	5.1	59.4
Wheat Bran	2.25	90.5	67.7	57.1	13.0	16.1	4.3	8.7	5.7	55.7
Soybean Meal (44%)	1.75	91.3	78.9	78.4	38.1	45.4	5.3	5.4	5.9	29.3
Linseed Meal (32%)	0.35	90.9	77.4	78.5	33.1	38.0	5.9	7.7	5.6	33.7
Steamed Bone Meal	0.175	96.3	-	-	-	7.1	3.3	0.8	81.3	3.8
Skim Milk	0.20	94.4	80.7	88.8	32.2	34.7	1.2	0.2	7.8	50.3
Yeast	0.009	93.9	70.2	-	41.9	48.7	1.1	5.5	6.4	32.2
Salt	0.15	-	-	-	-	-	-	-	-	-
Average			59.5	52.2	10.8	14.3	2.28	20.5	7.26	45.33

One inch pellets composed of 2 parts half-ground alfalfa and 1 part concentrate comprised the whole ration which made it possible to determine feed consumption and refusal with accuracy. All animals were fed so that there was some weighback daily; thus, ad libitum feeding was simulated. A detailed analysis of the ration is given in Table 2.

All calves were weighed once weekly at a uniform time as well as upon entering and leaving the metabolism stalls.

2. Urine Collection.

Bull urine was collected by means of a Davol rubber funnel (36,p.479) strapped to the animal with a harness and connected to a rubber hose leading to a 5 gallon carboy beneath the false floor of the stall. A 1.5-inch hole drilled in the solid wooden floor accommodated the hose. The urine collecting funnel was cone-shaped with a metal ring at the top and an opening to the cone of 12.5 inches diameter length by 10.5 inches diameter width. The cone was tapered to a depth of 8.5 inches from the top and vents to a bore-in tube of 0.75-inch diameter. Harness straps were of webbing.

Hanzard, Comar and Plumlee (103,pp.13-25) described metabolism units of simple design and operation that fulfilled the essential basic requirements; these were adopted with modifications for this study. The urine conduits for

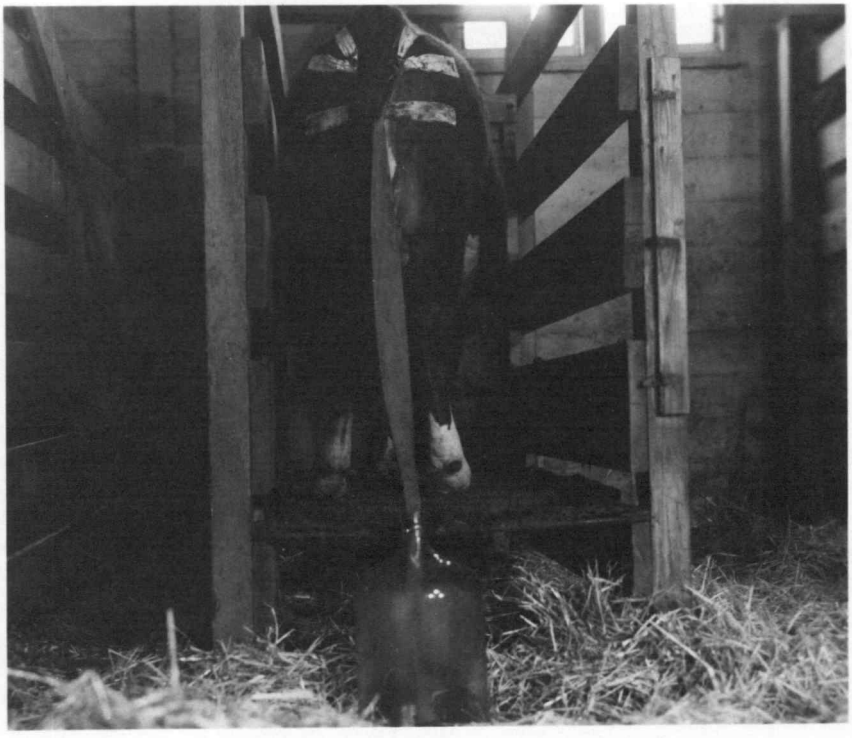


FIGURE 1a. The heifer urine conduit in position, demonstrating attachment.

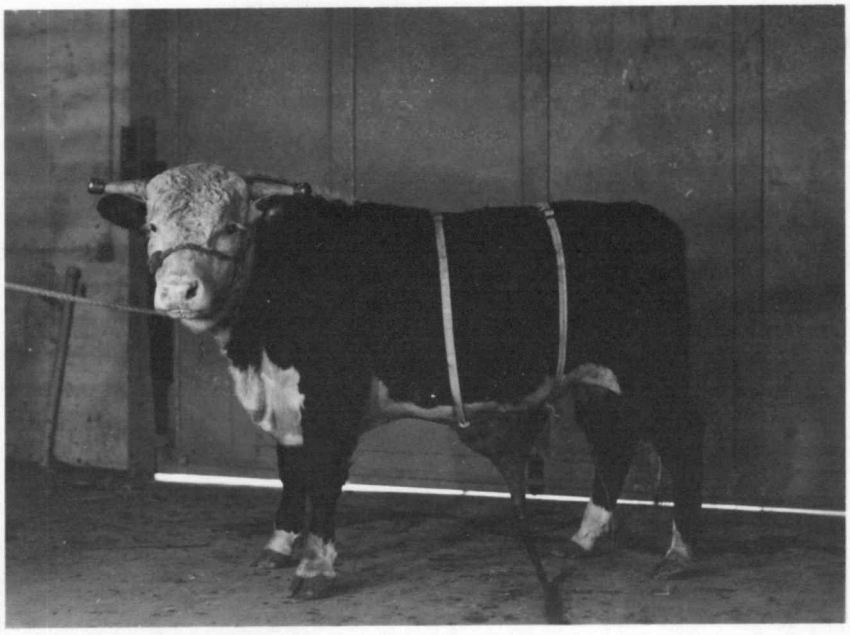


FIGURE 1b. The bull urine funnel in position, demonstrating attachment.

heifers were constructed from a 3-inch seamless rubber tube approximately 4 feet long. Each was prepared for use by making a 3.5 to 5 inch incision along one side of the folded edge of one end of the tube and reinforcing the terminal end with a cold rubber patch.

Attachment and operation were similar to that described for swine and cattle (103,pp.13-25) (104) (102, pp.65-68) and (116,pp.565-570). The split-end of the conduit was placed around the vulva and secured to the heifer by means of 3 pairs of 3-inch webbing straps, each 10 to 12 inches long. The straps were attached to the animal by means of branding cement. The most convenient order to follow in assembling the conduit and making the attachments was that outlined by Hanzard, Comar and Plumlee (103,pp.21-24).

Because sudden changes of environment affect the feed and water consumption of beef cattle to a varying degree (163,pp.788-789 and 47), all animals were refused both feed and water during confinement in the stalls. To standardize the effects of diurnal rhythms, each animal was placed in the stall at 7 to 7:30 a.m. and removed 24 hours later. The animals were then returned to their respective pens. Urinalysis was initiated immediately upon completion of the collection. All urine samples were collected under toluene.

Total 24 hour volume was measured by means of graduated cylinders while urinometers were used to determine the specific gravity. Temperature was taken at the time of specific gravity determination and the urine solids content was calculated using Long's co-efficient (108, pp.813-814).

3. Blood Collection.

Fifteen ml. samples were drawn from the right jugular vein of each animal 24 hours after it was returned from the metabolism stall. Stainless steel bleeding needles were used and the blood was collected in pyrex tubes (208,p.359) using neutral potassium oxalate at a rate of 1 mg. per ml. in preference to other anticoagulants (180,pp.685-695) (112,p.777) and (108,p.491). Analysis was initiated immediately upon completion of the collection.

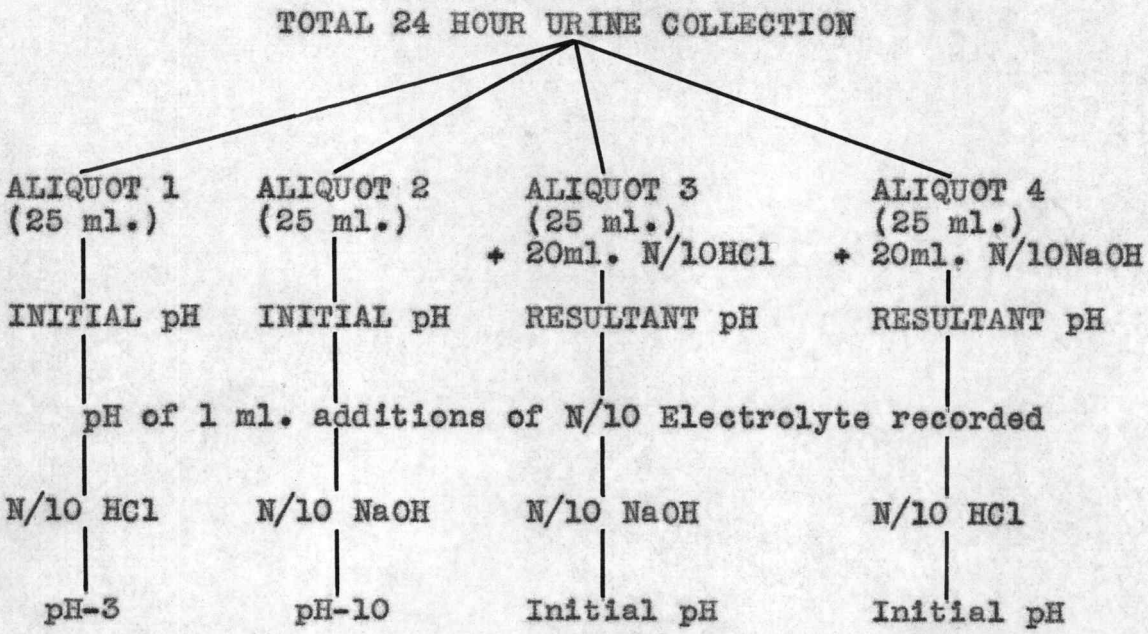
B. Chemical Methods.

The methods used to determine the concentration of the various constituents in the urine and blood of the test calves were those methods that have been developed and extensively employed for analysing urine and blood of the human and other species. For photometric determinations, optical density was determined with a Coleman Photoelectric Photometer employing 1 cm. cuvettes.

1. Urinalysis.

Titratable acidities were determined according to a method suggested by Krueger[1] in preference to other methods (113,pp.305-315 and 108,p.810) since a more exacting analysis was desired. This method of procedure was employed in the manner indicated in Figure 2.

FIGURE 2. TITRATABLE ACIDITY DETERMINATION



The procedure for Kjeldahl nitrogen determinations was undertaken according to the methods outlined by Hawk, Oser and Summerson (108,pp.418-419) and the Association of Official Agricultural Chemists (14,pp.26-27) with the

[1]Krueger, Hugo M. Unpublished method of titratable acidity determination, Corvallis, Oregon State College, Department of Animal Husbandry, 1952.

following modifications recommended by Oldfield[2]: (a) The distillate was collected in 4% boric acid; (b) the indicator was composed of 0.1% bromcresol green in 95% ethyl alcohol (10 ml.) and o.1% methyl red in 95% ethyl alcohol (2 ml.).

Urea was determined according to a modification (108, pp.825-826) of the direct nesslerization method of Folin and Youngburg (78,pp.111-112) and (214,pp.391-394). Ammonia was determined by nesslerization according to the permutit method of Folin and Bell (74,pp.329-335), while the uricase method of Buchanan, Block and Christman (42, pp.181-187) was employed for uric acid determinations.

Creatinine was determined on the basis of the Jaffe reaction (94,pp.1443-1448) (95,pp.103-106) and (96,pp.601-612) using the Folin method in a modified form (108,pp.839-842). Because of the lack of adherence to Beer's law, the creatinine content was established from its photometric density by reference to a standard calibration curve (32,pp.581-591 and 174,pp.179-186). Creatine was determined by difference employing the Folin method (71,pp.469-473) and the calibration described above.

2. Haematology.

For haemoglobin determination oxalated blood was

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[2]Oldfield, J. E. Unpublished modifications of the Kjeldahl procedure, Corvallis, Oregon State College, Animal Nutrition Laboratory, Dept. of Animal Husbandry, 1952.

treated with saponin (168,p.116) and the colour density read in the Spencer Haemoglobinometer. One blood sample was followed through completely rather than setting up a number simultaneously in order to standardize technique.

Oxalated whole blood was employed for glucose determination (193,pp.69-73) by the Somogyi-Shaffer-Hartmann method (190,pp.599-612) outlined by Hawk, Oser and Summerson (108,pp.524-525). Deproteinization was accomplished by laking 1 volume of blood with 7 volumes of water; after adding 1 volume of a 10 percent solution of $ZnSO_4.7H_2O$ the whole was mixed and with continuous shaking, 1 volume of 0.5N NaOH was added. After a few minutes the solution was filtered through a dry filter paper (108,p.524). Values were determined by comparison against a standard.

For other blood constituents Haden's modification (98,pp.469-471) of the Folin and Wu preparation of protein-free filtrate (77,pp.82-86) was used since it required fewer solutions and yielded more filtrate.

Urea was determined according to a method based on an original procedure by Karr (123,pp.329-333) using gum ghatti as a stabilizing colloid (73,pp.231-236 and 142, pp.189-195). Uric acid content was determined according to a method by Brown (41,pp.601-608). The amino acid determination used (108,pp.517-519) was based on an original proposal by Folin with improvements by Danielson (53, pp.505-522) and Sahyun (182,pp.549-551) and methods of

adaptation for photometric measurement by Frame, Russell and Wilhelmi (83,pp.255-270) and Russell (181,pp.467-468).

The Folin and Wu method for creatinine determination (77,pp.81-110) was employed using a creatinine standard prepared according to Hawk, Oser and Summerson (108,pp.508-509) since creatinine color does not follow Beer's law (117,p.2264) exactly at concentrations ordinarily encountered. The picric acid used in both the creatinine and creatine determinations was proposed according to Peters (174,pp.179-186) to enhance the accuracy of determination. While it was recognized that increased specificity in creatinine determination is obtained by the use of the creatinine destroying bacteria of Miller and Dubos (6, pp.169-172) (155,pp.383-391) (156,pp.457-464) and (33, pp.559-574), limited facilities necessitated the employment of the Folin and Wu procedure (108,pp.509-510) based on the Jaffe reaction. Creatine was determined by difference using a standard curve prepared according to the procedure cited previously for creatinine.

CHAPTER IV

RESULTS

"To count is a modern practice, the ancient method was to guess."

Samuel Johnson.

"A reasonably thorough understanding of the basic premises which lead to whatever deductions are to be made is obviously a desideratum of high order."

I. Michael Lerner.

The results presented have been classified according to age, weight[3], rate and efficiency of gain during test, nutrient intake, chemical data from urine and blood analyses, metabolism stall weight changes, and urine excretion. Results of blood analyses have been considered under the following headings: Urea nitrogen, amino acid nitrogen, creatinine, and uric acid. Data from urinalyses have been considered under the headings: Total nitrogen, urea nitrogen, ammonia nitrogen, urea:ammonia nitrogen ratios, creatinine, creatinine coefficients, uric acid, and uric acid coefficients. Blood glucose, creatine and haemoglobin and urine specific gravity, total solids, creatine, and titratable acidity were beyond the scope of the data considered desirable for study in this thesis and were reserved by the writer for subsequent analysis.

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[3]The values 500 and 800 pounds live weight represent the approximate pen weights of the groups studied and are used both to denote weight and period of analysis.

A. Rate and Efficiency of Gain.

As indicated in Figure 3, animals varied considerably in age at the time they reached 500 and 800 pounds body weight. The youngest calf was placed on test at 179 days of age, the eldest at 303 days. Contrary to the findings of Dahmen and Bogart (52,p.16), age put on test had no significant effect on rate of gain during test, but did have a significant effect (at the 1% level) on efficiency of gain. The regression coefficient of 1.55 shows that for every day of age on test above the mean there was required 1.55 pounds more TDN per 100 pounds gain in live weight. Daily gains made by all groups and all individuals exceeded the recommended adequate rates listed by the U. S. National Research Council (165,pp.4-5) for growing bulls and heifers.

It may be seen (Table 3) that the average rate of gain of males exceeded that of females in all groups classified. Hereford females exceeded Angus females while Hereford males exceeded Angus males due mainly to the most satisfactory gains realized by the progeny of Hereford sire 71. The uniformity of the relatively low gains of females sired by Angus bull 101 is noteworthy. This group contributed markedly to the large sex dimorphism of the Angus cattle.

FIGURE 3.

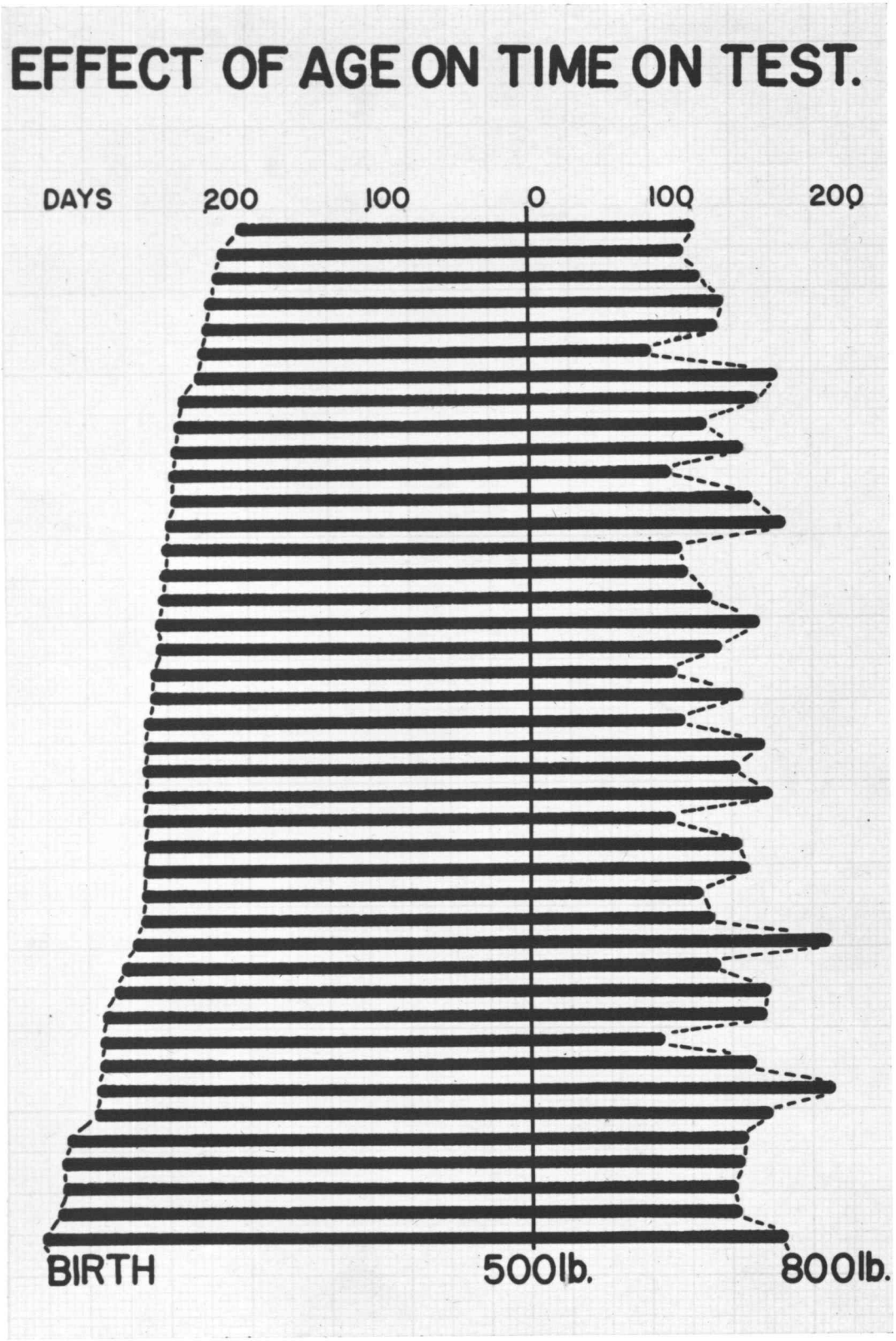

EFFECT OF AGE ON TIME ON TEST.
DAYS
200
100
0
100
200
BIRTH
500lb.
800lb.

TABLE 3

RATE AND EFFICIENCY OF GAIN OF EXPERIMENTAL GROUPS FROM 500 TO 800 POUNDS BODY WEIGHT

GROUP	CALVES	RATE OF GAIN (lb./day)			EFFICIENCY OF GAIN		
		Ave.	High	Low	Ave.	High	Low
All Animals	42	2.46	3.65	1.66	444	300	682
All Males	18	2.90	3.65	2.17	357	300	420
All Females	24	2.14	2.57	1.66	510	397	682
All Herefords	26	2.56	3.50	1.92	417	304	545
All Angus	16	2.31	3.65	1.66	490	300	682
Hereford Males	12	2.92	3.50	2.17	349	304	420
Hereford Females	14	2.26	2.57	1.92	475	397	545
Angus Males	6	2.87	3.65	2.38	372	300	420
Angus Females	10	1.97	2.55	1.66	560	470	682
Bulls by 38	1	2.75			357		
71	8	3.12	3.50	2.72	341	319	367
84	3	2.43	2.80	2.17	369	304	403
101	5	2.84	3.65	2.38	381	300	420
117	1	2.99			327		
Heifers by 38	6	2.22	2.28	2.14	484	464	515
71	4	2.38	2.57	2.22	482	416	545
84	4	2.20	2.57	1.92	453	397	537
101	3	1.78	2.01	1.66	609	571	682
117	7	2.05	2.55	1.80	539	470	598

Inconsistencies in total numbers and unequal numbers of each sex per group (uncontrollable factors to date) make comparisons of total progeny groups of the 5 sires hazardous. Suffice to say, the results obtained from progeny of sire 71 were outstanding.

In a like manner the efficiency of gain of bulls, measured by TDN consumed per 100 pounds gained in body weight while on test, exceeded the average efficiency of gain of females in all groups studied. All Herefords showed greater efficiency than all Angus, Hereford bulls exceeded Angus bulls, and Hereford heifers exceeded Angus

heifers. The uniformity of the relatively low efficiency of the Angus heifers, especially the progeny of sire 101, resulted in approximately 50 percent greater sex dimorphism in the Angus than in the Hereford groups. The efficiency of gain of all groups was judged satisfactory according to the recommendations of the U. S. National Research Council (165,pp.3-7).

B. Nutrient Intake.

Since the Total Digestible Nutrient (TDN) and Nitrogen contents of the ration were considered constant, comments concerning feed intake apply equally well to TDN and nitrogen intakes. The total and average daily nutrient intakes, respectively, of the experimental groups during the 500 to 800 pound test period are shown in Tables 4 and 5.

Total nutrient intake varied markedly between sexes, with heifers showing a greater intake than bulls, and between breeds, with the Angus group showing a greater intake than the Hereford group. Much of the between breed difference may be accounted for by the high nutrient intake of the heifer group sired by 101.

Data presented in Table 5 are most interesting in that bulls gained at a faster daily rate than heifers, yet consumed less feed (approx. 1.2 lb./day). In a like manner, the Hereford group gained more rapidly than the

TABLE 4

TOTAL NUTRIENT INTAKE OF EXPERIMENTAL GROUPS DURING THE TEST PERIOD

GROUP	CALVES	INTAKE IN POUNDS								
		FEED			TDN*			NITROGEN**		
		Ave.	High	Low	Ave.	High	Low	Ave.	High	Low
All Animals	42	2332	3634	1673	1395	2162	995	53.36	83.15	38.35
All Males	18	1891	2160	1673	1125	1285	995	43.26	49.42	38.28
All Females	24	2663	3634	2161	1597	2162	1286	60.93	83.15	49.45
All Herefords	26	2207	2986	1682	1313	1777	997	50.49	68.32	38.35
All Angus	16	2536	3634	1673	1528	2162	995	58.01	83.15	38.28
Bulls by 38	1	1846			1099			42.24		
71	8	1815	1953	1682	1081	1185	997	41.55	45.56	38.35
84	3	1982	2155	1689	1179	1282	1005	45.30	49.30	38.65
101	5	1998	2160	1673	1189	1285	995	45.72	49.42	38.28
117	1	1726			1027			39.48		
Heifers by 38	6	2579	2648	2450	1535	1576	1485	59.02	60.59	56.07
71	4	2515	2986	2161	1496	1777	1286	57.55	68.32	49.45
84	4	2381	2727	2161	1417	1623	1286	54.47	62.41	49.45
101	3	3210	3634	2975	2010	2162	1770	73.44	83.15	68.08
117	7	2746	2916	2393	1634	1735	1424	62.84	66.72	54.74

* Computed from Morrison, 21st Ed. @ 59.5%
** Computed from Morrison and verified by Kjeldahl analysis.

TABLE 5

AVERAGE DAILY FEED INTAKE OF CALVES DURING THE TEST PERIOD

GROUP	CALVES	INTAKE IN POUNDS								
		FEED			TDN			NITROGEN		
		Ave.	High	Low	Ave.	High	Low	Ave.	High	Low
All Animals	42	17.6	20.3	13.9	10.6	12.1	8.3	.41	.46	.32
All Males	18	16.9	19.3	14.2	10.3	11.5	8.5	.40	.44	.32
All Females	24	18.1	20.3	13.9	10.8	12.1	8.3	.42	.46	.32
All Herefords	26	17.3	20.3	13.9	10.4	12.1	8.3	.40	.46	.32
All Angus	16	18.1	20.1	15.9	10.8	12.0	9.5	.41	.46	.37
Bulls by 38	1	16.5			9.8			.38		
71	8	17.2	18.9	16.7	10.6	11.2	10.0	.41	.42	.38
84	3	14.9	15.8	14.2	8.9	9.4	8.5	.34	.36	.32
101	5	17.9	19.3	16.2	10.7	11.5	9.6	.41	.44	.37
117	1	16.4			9.8			.38		
Heifers by 38	6	18.0	19.3	16.7	10.7	11.5	9.9	.41	.44	.38
71	4	19.1	20.3	17.2	11.4	12.1	10.2	.44	.46	.39
84	4	16.7	18.6	13.9	10.0	11.0	8.3	.39	.43	.32
101	3	18.2	19.2	15.9	10.8	11.5	9.5	.42	.44	.37
117	7	18.4	20.1	16.6	10.9	12.0	9.9	.42	.46	.38

Angus group and consumed less feed (0.8 lb./day) in doing so. The relative superiority of the efficiency of such groups is evident from Table 3.

In comparison with other progeny groups, the surprisingly low daily nutrient intake of both the heifer and bull groups sired by 84 is impressive, and is largely responsible for most of the difference in average daily feed intake between breeds. In spite of the low daily rate of nutrient intake, the most efficient group of heifers was those sired by 84.

C. Blood Values.

1. Urea Nitrogen.

Blood urea nitrogen averages fell well within the normal range presented by Dukes (58,p.49) although several heifers and one bull exceeded the upper limit of the range (27 mg./100 cc.) at 500 pounds body weight. At both 500 and 800 pounds, the average blood urea level of males was lower than that of females and the Hereford group was lower than the Angus. Marked individual variation was evident within each classification group. With the exception of bulls sired by 38 the average blood urea level of all groups decreased with an increase from 500 to 800 pounds body weight. The high average value at 500 pounds for bulls sired by 84 is noteworthy, especially when considered in relation to the relatively low dietary intake of the group during the test period.

TABLE 6

BLOOD UREA NITROGEN LEVELS OF EXPERIMENTAL GROUPS AT 500 AND 800 POUNDS BODY WEIGHT

GROUP	BLOOD UREA NITROGEN (mg./100 cc.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	45	17.66	29.42	6.67	42	15.38	24.17	8.81
All Males	19	15.79	28.04	9.20	18	14.31	19.96	8.81
All Females	26	19.03	29.42	6.67	24	16.19	24.17	9.28
All Herefords	28	16.90	29.42	8.84	26	15.17	23.33	10.03
All Angus	17	18.93	29.42	6.67	16	15.72	24.17	8.81
Bulls by 38	2	12.96	13.48	12.44	1	18.45		
71	8	14.81	18.80	10.20	8	13.93	19.93	10.03
84	3	21.85	28.04	14.48	3	14.55	15.75	10.83
101	5	15.03	20.40	9.20	5	14.38	19.96	8.81
117	1	14.88			1	12.08		
Heifers by 38	6	15.98	26.19	8.84	6	14.56	16.94	11.48
71	5	19.21	27.70	11.44	4	16.74	23.33	11.34
84	4	17.80	29.42	8.84	4	16.65	17.71	14.29
101	4	18.79	29.24	6.67	3	14.40	17.50	9.28
117	7	22.36	29.00	14.56	7	17.76	24.17	14.04

2. Amino Acid Nitrogen.

Like blood urea nitrogen, blood amino acid nitrogen averages for all the groups fell well within the normal range listed by Dukes (58,p.49) for the cow, although one heifer exceeded the upper limit at 500 pounds while another exceeded it at 800 pounds. At both 500 and 800 pounds the average for males was lower than females and the Hereford average was lower than that of the Angus group. Considerable variation within each group was apparent. Detailed study revealed a decrease in blood amino acid nitrogen levels with increasing body weight by calf groups sired by 38 and 71 and the heifer group sired by 101, while all other groups increased throughout the same period. Both

the bull and heifer groups sired by 84 had the lowest average values in their respective classifications at both 500 and 800 pounds while the average for heifers by 117 was definitely the highest obtained in both test periods.

TABLE 7

BLOOD AMINO ACID NITROGEN LEVELS OF EXPERIMENTAL GROUPS AT 500 AND 800 POUNDS BODY WEIGHT

GROUP	BLOOD AMINO ACID NITROGEN (mg./100 cc.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	45	7.10	8.83	4.10	42	7.28	8.66	5.34
All Males	19	6.72	8.03	4.10	18	6.80	8.26	5.34
All Females	26	7.38	8.83	4.76	24	7.64	8.66	6.16
All Herefords	28	6.94	8.10	4.74	26	7.09	8.52	5.34
All Angus	17	7.36	8.83	4.10	16	7.59	8.66	6.98
Bulls by 38	2	7.51	7.82	7.20	1	7.16		
71	8	6.83	8.03	5.36	8	6.66	7.08	5.76
84	3	6.15	6.66	5.49	3	6.48	7.28	5.34
101	5	7.08	7.68	6.58	5	7.12	8.26	7.08
117	1	4.10			1	6.98		
Heifers by 38	6	7.26	8.10	6.13	6	7.48	7.96	6.81
71	5	6.36	7.43	4.74	4	7.51	8.52	6.25
84	4	6.49	8.10	6.13	4	7.36	8.38	6.16
101	4	7.70	8.83	6.53	3	7.57	7.79	7.35
117	7	7.84	8.41	7.31	7	8.02	8.66	7.45

3. Creatinine.

While all group averages fell well within the range given by Dukes (58,p.49), many individual values for blood preformed creatinine surpassed this range at both 500 and 800 pounds body weight. The creatinine average for all animals decreased with increased weight. This decrease in creatinine with increasing weight was also observed in the Male, Female, and Angus groups. Herefords, however, showed

an increase with increased weight due largely to the bulls and heifers sired by 38 and heifers sired by 71 which showed a large average change from 500 to 800 pounds body weight. Very little difference was found between the averages for All Males and All Females at both 500 and 800 pounds but, while all groups of Angus decreased from 500 to 800 pounds, variations in trend were evidenced both within and between Hereford sex and sire groups resulting in a large difference between the All Hereford and All Angus groups at 800 pounds.

TABLE 8

BLOOD CREATININE LEVELS OF EXPERIMENTAL GROUPS AT 500 AND 800 POUNDS BODY WEIGHT

GROUP	BLOOD CREATININE (mg./100 cc.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	45	1.58	2.70	0.80	42	1.39	2.64	0.60
All Males	19	1.59	2.70	0.90	18	1.37	2.64	0.63
All Females	26	1.57	2.70	0.80	24	1.41	2.37	0.60
All Herefords	28	1.51	2.70	0.90	26	1.61	2.64	0.63
All Angus	17	1.69	2.70	0.80	16	1.05	1.24	0.60
Bulls by 38	2	1.13	1.35	0.90	1	2.28		
71	8	1.54	2.19	1.20	8	1.37	2.49	0.63
84	3	1.88	2.70	1.35	3	1.90	2.64	1.51
101	5	1.50	2.31	0.96	5	0.94	1.18	0.69
117	1	2.48			1	1.08		
Heifers by 38	6	1.45	1.68	1.20	6	1.57	1.93	1.09
71	5	1.52	2.25	1.02	4	2.02	2.37	1.77
84	4	1.47	1.68	1.20	4	1.35	1.87	0.92
101	4	1.57	2.40	0.80	3	1.01	1.24	0.60
117	7	1.77	2.70	0.98	7	1.13	1.91	0.63

4. Uric Acid.

While the blood uric acid average for all animals remained virtually constant in tests at 500 and 800 pounds,

comparisons between other classification groups reveal many inconsistencies. Uric acid average values for males decreased (2.06-1.92 mg./100 cc.) while values for females increased (1.92-2.06 mg./100 cc.) approximately the same amount. The average value for Herefords decreased while that for Angus increased with increased weight. Furthermore, while there was an inconsistency in the direction of change of averages of Hereford groups between sires and between sexes, the averages of bull groups by both Angus sires decreased while the averages of heifer groups by the same sires increased with increases in weight from 500 to 800 pounds.

Average uric acid values for the most part occupied the upper portion of the normal blood range for the cow given by Dukes (58,p.49) and many individual observations exceed the upper limit. An explanation of why some blood urea nitrogen, amino acid nitrogen, creatinine, and uric acid values should exceed the range listed by Dukes will be given in the Discussion.

TABLE 9

BLOOD URIC ACID LEVELS OF EXPERIMENTAL GROUPS AT 500 AND 800 POUNDS BODY WEIGHT

GROUP	BLOOD URIC ACID (mg./100 cc.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	45	2.02	3.43	1.19	42	2.00	4.11	0.98
All Males	19	2.06	2.60	1.31	18	1.92	2.72	0.98
All Females	26	1.98	3.43	1.19	24	2.06	4.11	1.05
All Herefords	28	1.84	2.50	1.19	26	1.76	2.35	0.98
All Angus	17	2.31	3.43	1.25	16	2.39	4.11	1.33
Bulls by 38	2	2.03	2.17	1.89	1	2.07		
71	8	1.99	2.30	1.70	8	1.96	2.30	1.90
84	3	1.76	2.50	1.31	3	1.26	1.49	0.98
101	5	2.26	2.45	1.87	5	2.23	2.72	1.64
117	1	2.60			1	1.88		
Heifers by 38	6	1.91	2.50	1.49	6	1.84	2.34	1.22
71	5	1.73	2.26	1.33	4	1.82	2.35	1.35
84	4	1.51	2.03	1.19	4	1.48	2.13	1.05
101	4	2.08	2.60	1.54	3	2.34	3.08	1.44
117	7	2.44	3.43	1.25	7	2.60	4.11	1.33

D. Urine Values.

Urinary excretion data were subject to error because there was no means of ascertaining if the bladders were completely devoid of urine at the beginning and the end of the collection period. An attempt was made to standardize conditions in that each animal was placed in a metabolism stall at approximately 7 a.m. to reduce diurnal effects, and all animals were stimulated to urinate before being harnessed or unharnessed. Conscious of such a possible source of error, the results obtained have been reported on a 24-hour basis for total urinary excretion at 500 and 800 pounds body weight as follows: Urine volume, total nitrogen, urea nitrogen, ammonia nitrogen, creatinine,

and uric acid. Results of calculated nitrogen retention and excretion per kilo body weight, urea nitrogen excretion per kilo body weight, urea:ammonia nitrogen ratios, creatinine and uric acid coefficients, and categorized percentage nitrogen excretion data have also been reported.

TABLE 10

WEIGHT LOSS PER CALF IN METABOLISM STALLS PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 POUNDS BODY WEIGHT

GROUP	CALVES	WEIGHT (In Pounds)				% Loss
		Pen	Metabolism Stall			
			On	Off	Loss	
All Animals	21	463	458	430	29	6.2
All Males	7	465	456	429	27	5.9
All Females	14	462	460	430	29	6.4
All Herefords	15	465	458	431	28	6.1
All Angus	6	456	458	428	30	6.5

TABLE 11

WEIGHT LOSS PER CALF IN METABOLISM STALLS PER 24 HOURS BY EXPERIMENTAL GROUPS AT 800 POUNDS BODY WEIGHT

GROUP	CALVES	WEIGHT (In Pounds)				% Loss
		Pen	Metabolism Stall			
			On	Off	Loss	
All Animals	42	806	784	738	46	5.9
All Males	18	810	791	744	48	6.0
All Females	24	804	779	733	45	5.9
All Herefords	26	808	785	739	46	5.9
All Angus	16	804	782	736	46	6.0

As indicated in Tables 10 and 11, the average weight loss increased from 29 to 46 pounds per head per 24 hours of confinement in metabolism stalls with an increase in weight from 500 to 800 pounds. There was virtually no

accompanying change in percentage weight loss with increase in weight and variations between groups were minor.

1. Total Urine.

The average total urine excretion per 24 hours doubled with an increase from 500 to 800 pounds body weight. Every group classified exhibited some increase but the variation in this increase was great. For example; the group of calves showing the smallest increase in urinary excretion volume was heifers sired by 71 with 28 percent increase and the group with the greatest increase was heifers sired by 101 at 148 percent. Females excreted more urine than males at both weights. Herefords excreted more urine at 500 pounds than Angus, but at 800 the reverse was found. At 500 pounds body weight the bull calves sired by 71 and 84 and the heifer calves sired by 101 and 71 represented the low and high averages in their respective categories. At 800 pounds the bulls sired by 71 continued to represent the low average for the bull groups, but the heifers by the same sire represented the low and not the high average for the heifers.

TABLE 12

TOTAL URINE EXCRETION PER CALF DURING 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	cc. OF URINE EXCRETED/24 HOURS							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	24	3472	7100	1815	41	6992	12025	3525
All Males	10	3439	7100	1815	17	6689	9100	4350
All Females	14	3496	5400	2320	24	7260	12025	3525
All Herefords	18	3597	7100	1815	25	6908	10050	3525
All Angus	6	3098	4500	2320	16	7123	12025	4725
Bulls by 38	1	3610			1	8900		
71	6	2965	4705	1815	7	6295	9025	4350
84	2	4975	7100	2845	3	8090	9100	7000
101	1	3040			5	6015	6900	4725
117	0				1	6400		
Heifers by 38	3	3495	4130	3170	6	7440	10050	5100
71	2	4825	5400	4250	4	6155	8550	4220
84	4	3315	4050	3010	4	6550	9225	3525
101	2	2465	2610	2320	3	6745	7650	5550
117	3	3540	4500	2970	7	8180	12025	6500

2. Total Nitrogen.

Like volume, urinary nitrogen excretion approximately doubled in all groups with an increase from 500 to 800 pounds body weight (Tables 13 and 14). Females excreted more nitrogen than males. Herefords excreted less than Angus at both 500 and 800 pounds body weight. Relative nitrogen intake levels accounted for only a portion of the increased excretion of nitrogen.

TABLE 13

URINARY NITROGEN EXCRETION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 POUNDS BODY WEIGHT

GROUP	CALVES	NITROGEN EXCRETION (gm.) Ave.	High	Low
All Animals	25	46.19	81.54	19.14
All Males	11	36.75	53.18	19.40
All Females	14	53.60	81.54	38.22
All Herefords	19	45.55	81.54	19.40
All Angus	6	48.19	58.77	32.66
Bulls by 38	2	46.65	51.92	41.37
71	6	33.72	43.38	19.40
84	2	37.96	53.18	22.73
101	1	32.66		
117	0			
Heifers by 38	3	51.03	57.61	42.41
71	2	73.82	81.54	66.09
84	4	48.31	60.75	38.22
101	2	48.91	49.12	48.70
117	3	52.88	58.77	47.97

TABLE 14

NITROGEN INTAKE, URINARY EXCRETION, AND RETENTION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 800 POUNDS BODY WEIGHT

GROUP	CALVES	TOTAL NITROGEN Intake* (gm.)	Excretion gm.	Excretion % of Intake	Retention gm.	Retention % of Intake
All Animals	41	213.4	97.2	45.5	116.2	54.5
All Males	17	210.1	84.3	40.4	126.2	59.5
All Females	24	215.5	106.4	49.4	109.2	50.7
All Herefords	25	213.5	96.1	45.1	117.4	55.0
All Angus	16	213.4	99.0	46.9	114.4	53.1
Bulls by 38	1	149.8	91.7	61.2	58.2	38.9
71	7'	210.4	87.0	41.3	123.4	58.7
84	3	202.8	87.0	42.9	115.8	57.1
101	5	226.1	82.8	36.6	143.3	63.4
117	1	217.9	57.6	26.4	160.3	73.6
Heifers by 38	6	220.2	99.8	45.3	120.5	54.7
71	4	236.1	113.9	48.2	122.2	51.8
84	4	210.0	96.6	46.0	113.4	54.0
101	3	189.2	111.6	59.0	77.7	41.1
117	7	214.0	111.1	51.9	103.0	48.1

* Ave. for 7 days prior to entering metabolism stall.
' Incomplete sampling.

Results of average feed intakes for the 7 days prior to entering metabolism stalls permitted the calculation of estimated daily nitrogen retention rates at 800 pounds. These are reported in Table 14. It may be seen that more nitrogen was retained than excreted by all groups except Angus heifers and the bull sired by 38. Males retained a greater amount and a higher percentage of nitrogen than females. Herefords retained a slightly greater amount and a greater percentage than the Angus group.

TABLE 15

URINARY NITROGEN EXCRETION PER KILO BODY WEIGHT OF CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	NITROGEN EXCRETION (mg./kilo)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	21	234	411	154	41	273	453	129
All Males	7	187	258	154	17	234	324	129
All Females	14	258	411	179	24	300	453	224
All Herefords	15	235	411	158	25	269	453	129
All Angus	6	232	283	154	16	279	384	137
Bulls by 38	1	204			1	257		
71	4	174	201	158	7	242	324	129
84	1	258			3	237	272	200
101	1	154	154		5	230	322	137
117	0				1	165		
Heifers by 38	3	245	267	210	6	282	373	224
71	2	367	411	323	4	321	453	229
84	4	225	271	179	4	271	335	224
101	2	238	244	231	3	314	376	272
117	3	254	283	227	7	315	384	276

Urinary nitrogen excretions per kilo body weight were calculated and have been presented in Table 15. With the exceptions of the bull sired by 84 and the heifers sired by

71, nitrogen excretion per kilo body weight increased in all groups with increased weight. Males excreted urinary nitrogen at a much lower rate than females at both 500 and 800 pounds body weight, but the Hereford group, which excreted slightly more nitrogen per kilo at 500 pounds, excreted slightly less than the Angus group at the higher test weight (800 pounds). Detailed study revealed a marked difference between excretion levels of the bull and heifer groups sired by 71. The heifers by 71 were of further interest in that while their excretion rate was considerably higher (approximately 125 mg. per kilo body weight) at 500 pounds it was only slightly higher than the other heifer groups at the 800-pound level.

3. Urea Nitrogen.

Since urine urea represented by far the largest single factor in total urinary nitrogen excretion during a 24-hour period (Table 24), the averages of urine urea nitrogen paralleled those of total urinary nitrogen fairly closely. Urea nitrogen more than doubled in all groups except heifers sired by 71 with the change in weight from 500 to 800 pounds.

Females excreted more urea nitrogen than males. The Angus group excreted more than the Hereford group at both weights studied. Again the progeny of 71 was of particular interest in that the excretion rate of bull calves

sired by him was only about 25 percent as much as that excreted by the heifer group by this sire. The heifers by sire 71 showed a considerably higher excretion rate than other heifer groups at 500 pounds. At 800 pounds the urea nitrogen values of heifers by 71 were intermediate among the heifer groups.

TABLE 16

URINARY UREA NITROGEN EXCRETION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	UREA NITROGEN EXCRETION (gm.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	25	27.90	59.89	5.86	41	79.90	147.97	19.07
All Males	11	17.83	41.82	5.86	17	65.31	101.29	20.20
All Females	14	35.81	59.89	17.76	24	90.24	147.97	19.07
All Herefords	19	26.77	59.89	5.86	25	77.36	147.97	19.07
All Angus	6	31.48	53.51	12.82	16	83.86	124.08	38.11
Bulls by 38	2	22.73	27.45	18.01	1	83.57		
71	6	13.78	27.25	5.86	7	64.59	99.64	20.20
84	2	27.58	41.82	13.34	3	69.61	82.81	57.82
101	1	12.82			5	63.60	101.29	38.11
117	0				1	47.68		
Heifers by 38	3	29.69	36.01	19.21	6	86.42	116.80	59.21
71	2	59.25	59.89	58.61	4	86.14	147.97	19.07
84	4	29.43	49.57	12.52	4	81.61	109.78	64.65
101	2	37.77	43.69	31.85	3	101.82	124.08	83.69
117	3	33.50	53.51	17.76	7	95.81	113.05	72.54

Urinary urea nitrogen excretion per kilo body weight was also calculated. Scrutiny of Table 17 revealed that, like total nitrogen excretion per kilo body weight, urea nitrogen excretion per kilo body weight increased in all groups with increased weight with the exceptions of the bull calf sired by 84 and the heifers sired by 71. The urinary

excretion of urea nitrogen per kilo body weight was at a lower rate for males than for females at both weights. The relationship of Hereford to Angus followed a similar pattern since Angus calves excreted more urea nitrogen per kilo body weight at both 500 and 800 pounds body weight. Again the bull and heifer progeny groups of 71 represented extremes of urea nitrogen excretion at 500 pounds.

TABLE 17

URINARY UREA NITROGEN EXCRETION PER KILO BODY WEIGHT OF CALVES PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	UREA NITROGEN EXCRETION (mg./kilo)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	21	152	302	41	41	216	404	54
All Males	7	104	203	41	17	163	282	80
All Females	14	176	302	59	24	254	404	54
All Herefords	15	143	302	41	25	204	404	54
All Angus	6	175	258	84	16	236	344	106
Bulls by 38	1	89			1	234		
71	4	71	126	41	7	135	279	80
84	1	203			3	189	225	161
101	1	154			5	177	282	106
117	0				1	136		
Heifers by 38	3	144	178	89	6	244	331	176
71	2	295	302	287	4	242	404	54
84	4	136	221	59	4	229	307	186
101	2	183	206	159	3	286	344	238
117	3	177	258	84	7	271	323	208

4. Ammonia Nitrogen.

Average urinary ammonia nitrogen excretion per calf per 24 hours (Table 18) increased from a weight of 500 to a weight of 800 pounds in all groups with the exception of heifers sired by 71 and 117. Males excreted more ammonia

nitrogen than females. The excretion of the Angus exceeded that of the Herefords at both 500 and 800 pounds. Like the urinary nitrogen products previously reported, bulls and heifers sired by 71 represented the extreme low and high, respectively, in their urinary ammonia excretion at 500 pounds.

TABLE 18

URINARY AMMONIA NITROGEN EXCRETION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	AMMONIA NITROGEN EXCRETION (grams)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	25	0.99	3.42	0.21	41	1.45	3.65	0.21
All Males	11	1.09	2.19	0.21	17	2.17	3.65	0.21
All Females	14	0.91	3.42	0.25	24	0.94	1.91	0.31
All Herefords	19	0.97	3.42	0.21	25	1.41	3.65	0.21
All Angus	6	1.08	2.19	0.33	16	1.51	3.31	0.59
Bulls by 38	2	1.97	2.19	1.75	1	3.65		
71	6	0.72	1.08	0.21	7	1.80	2.35	1.47
84	2	1.20	1.28	1.12	3	2.10	3.08	0.21
101	1	1.37			5	2.25	3.31	1.36
117	0				1	3.01		
Heifers by 38	3	0.45	0.53	0.41	6	1.03	1.91	0.31
71	2	1.95	3.42	0.48	4	0.89	1.03	0.53
84	4	0.61	1.39	0.25	4	0.73	1.11	0.34
101	2	0.50	0.67	0.33	3	0.84	1.06	0.69
117	3	1.37	2.19	0.67	7	1.06	1.90	0.59

5. Urea:Ammonia Nitrogen Ratio.

The ratio of urinary urea:ammonia nitrogen excretion per 24 hours was calculated on the basis of ammonia values taken at unity. The ratios increased during the feeding period in all groups studied (Table 19). While the ratios of the urinary excretions of the Hereford and Angus groups

were virtually the same at 500 pounds, the Hereford group exhibited a moderately higher ratio at 800 pounds body weight. The average ratio of heifers was approximately 3 times higher than the average ratio of bulls at both the lower and higher weights. The significance of this most interesting phenomenon will be enlarged upon in the Discussion.

TABLE 19

URINARY UREA:AMMONIA NITROGEN OF EXPERIMENTAL CALVES AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	UREA:AMMONIA* NITROGEN RATIOS							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	25	44.7	155.8	6.0	41	77.3	296.0	10.3
All Males	11	20.8	59.9	6.0	17	31.6	51.5	10.3
All Females	14	63.4	155.8	12.3	24	109.6	296.0	13.0
All Herefords	19	44.7	155.8	6.0	25	81.0	296.0	10.3
All Angus	6	44.6	98.1	9.4	16	71.5	177.0	13.0
Bulls by 38	2	11.4	12.4	10.4	1	23.3		
71	6	25.4	59.9	6.0	7	38.4	60.8	10.3
84	2	22.2	32.7	11.7	3	26.6	33.4	18.5
101	1	9.4			5	29.8	51.5	14.2
117	0				1	15.9		
Heifers by 38	3	58.6	81.1	35.8	6	103.3	196.5	51.5
71	2	71.5	125.4	17.6	4	121.7	296.0	19.6
84	4	77.7	155.8	12.3	4	136.4	256.0	98.8
101	2	81.3	98.1	64.4	3	121.0	155.1	88.3
117	3	31.9	57.4	14.1	7	87.9	177.0	13.0

* Based on ammonia values reduced to unity.

6. Creatinine.

As indicated in Table 20, urinary creatinine excretion increased with weight in all groups classified; males excreted more than females at both 500 and at 800 pounds live weight and Herefords excreted more creatinine than

Angus at both weights. Since all groups represent growing immature animals, creatinine excretion tended to increase exponentially with body weight increase in contrast with the linear increase of creatinine excretion with body weight in mature animals reported by Brody, Proctor, and Ashworth (40,p.9). The creatinine excretion of heifers sired by 101 was surprisingly low.

TABLE 20

URINARY CREATININE EXCRETION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	CREATININE EXCRETION (gm.)						
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	25	6.32	9.92	3.20	41	8.99	13.62	4.46
All Males	11	6.82	7.59	5.89	17	9.55	13.62	4.46
All Females	14	5.93	9.92	3.20	24	8.59	10.89	5.22
All Herefords	19	6.59	9.92	3.20	25	9.11	13.62	5.43
All Angus	6	5.47	7.56	3.81	16	8.80	11.36	4.46
Bulls by 38	2	7.55	7.59	7.51	1	13.62		
71	6	6.77	7.18	6.38	7	8.56	11.46	5.79
84	2	6.59	7.28	5.89	3	12.36	13.20	11.41
101	1	6.17			5	8.48	11.36	4.46
117	0				1	9.34		
Heifers by 38	3	6.58	9.92	3.20	6	8.83	10.10	7.08
71	2	5.83	6.21	5.45	4	7.54	9.96	6.03
84	4	6.24	7.29	4.64	4	8.49	10.89	5.43
101	2	4.01	4.20	3.81	3	7.60	9.03	5.22
117	3	6.20	7.56	4.37	7	9.47	10.53	6.76

The true creatinine coefficient is the number of milligrams of creatinine nitrogen eliminated daily per kilogram of body weight (58,p.383 and 10,pp.1-13). This definition was applied to obtain the coefficients presented in Table 21. On the average, values obtained at 500 pounds

exceeded the coefficient of 9.5 obtained by Brody and Ashworth (10,pp.2-13) for dairy cattle. However, averages at 800 pounds body weight closely approximated this coefficient value. Males yielded a higher average coefficient at both 500 and 800 pounds than females. The Herefords yielded a higher average than the Angus at both weights. Detailed examination of Table 21 showed that the coefficients of only the bulls sired by 38 and 84 and heifers sired by 101 increased with body weight. The particularly low coefficient at the 500 pound weight of the heifers sired by 101 is noteworthy.

TABLE 21

CREATININE COEFFICIENTS OF GROUPS OF EXPERIMENTAL CALVES AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	CREATININE COEFFICIENT							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	21	11.00	18.18	5.82	41	9.39	14.21	4.51
All Males	7	11.96	18.88	10.12	17	9.88	14.21	4.51
All Females	14	10.52	17.12	5.82	24	9.04	11.32	5.37
All Herefords	15	11.51	18.88	5.82	25	9.49	14.21	5.82
All Angus	6	9.74	13.29	6.69	16	9.23	11.86	4.51
Bulls by 38	1	13.76			1	14.21		
71	4	12.26	18.88	11.53	7	8.87	11.94	5.98
84	1	10.12			3	12.61	13.43	11.82
101	1	10.83			5	8.78	11.86	4.51
117	0				1	9.91		
Heifers by 38	3	11.71	17.12	5.82	6	9.33	11.18	7.50
71	2	10.76	11.30	10.22	4	7.90	10.15	6.32
84	4	10.76	12.07	8.05	4	8.87	11.32	5.82
101	2	7.25	7.80	6.69	3	8.00	9.56	5.37
117	3	11.03	13.29	7.80	7	9.97	11.07	7.21

7. Uric Acid.

The average uric acid excretion per 24 hours increased

with increased body weight in all groups studied with the exception of heifers sired by 71 (Table 22). The marked similarity in average values between male, female, Hereford, and Angus groups at 500 pounds is surprising in view of the variations evident within and between progeny groups. At 800 pounds the Angus group excreted more uric acid than the Hereford group. Heifers sired by 101 excreted uric acid at a very low level in comparison with other heifer groups.

TABLE 22

URINARY URIC ACID EXCRETION PER CALF PER 24 HOURS BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	URIC ACID EXCRETION (gm.)							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	25	1.01	1.73	0.64	41	1.72	2.80	0.81
All Males	11	0.99	1.73	0.75	17	1.73	2.55	1.20
All Females	14	1.02	1.43	0.64	24	1.72	2.80	0.81
All Herefords	19	1.01	1.73	0.75	25	1.56	2.55	0.81
All Angus	6	1.00	1.43	0.64	16	1.98	2.80	1.32
Bulls by 38	2	1.27	1.73	0.81	1	2.55		
71	6	0.95	1.20	0.75	7	1.64	2.05	1.20
84	2	0.85	0.94	0.76	3	1.46	1.57	1.36
101	1	1.00			5	1.79	2.19	1.33
117	0				1	2.00		
Heifers by 38	3	1.00	1.19	0.86	6	1.66	2.47	1.35
71	2	1.27	1.29	1.24	4	1.19	1.69	0.81
84	4	0.94	1.09	0.81	4	1.45	1.86	0.99
101	2	0.75	0.86	0.64	3	1.56	1.92	1.32
117	3	1.16	1.43	0.94	7	2.29	2.80	1.37

Uric acid coefficients, defined as the number of milligrams of uric acid nitrogen eliminated daily per kilogram body weight, are presented in Table 23. The average coefficient for all cattle increased moderately with weight

due mainly to the large increase in uric acid with increased body weight of the male average. The coefficient of females was much higher than that of the males at 500 pounds, but was virtually the same at 800 pounds body weight. While values for Herefords remained constant, coefficients for the Angus group increased with weight. The progeny of 71 represented the extremes in their respective group classifications at 500 but not at 800 pounds. Heifers sired by 117 recorded high coefficients at both weights.

TABLE 23

URIC ACID COEFFICIENTS OF GROUPS OF EXPERIMENTAL CALVES AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	URIC ACID COEFFICIENT							
	CALVES	500 lb.			CALVES	800 lb.		
		Ave.	High	Low		Ave.	High	Low
All Animals	21	1.51	2.31	0.99	41	1.61	2.66	0.76
All Males	7	1.27	1.93	1.33	17	1.60	2.38	1.10
All Females	14	1.63	2.31	0.99	24	1.62	2.66	0.76
All Herefords	15	1.47	2.17	1.26	25	1.45	2.38	0.76
All Angus	6	1.61	2.31	0.99	16	1.86	2.66	1.23
Bulls by 38	1	1.33			1	2.38		
71	4	1.11	1.93	1.51	7	1.52	1.91	1.10
84	1	1.51			3	1.33	1.45	1.22
101	1	1.61			5	1.65	2.03	1.23
117	0				1	1.91		
Heifers by 38	3	1.62	1.86	1.42	6	1.57	2.32	1.25
71	2	2.09	2.17	2.00	4	1.12	1.53	0.76
84	4	1.45	1.68	1.26	4	1.36	1.73	0.95
101	2	1.22	1.45	0.99	3	1.47	1.77	1.25
117	3	1.86	2.31	1.47	7	2.17	2.66	1.30

Several generalizations may be drawn from the percentage of nitrogen excreted by the experimental groups (Table 24) in the form of: Urea plus ammonia, urea,

ammonia, creatinine and uric acid. The percentage of nitrogen excreted as urea plus ammonia and urea increased with increased body weight in all groups. However, the percentage of nitrogen excreted as ammonia and creatinine decreased with increased body weight. At 800 pounds, females excreted a higher percentage of nitrogen as urea plus ammonia and urea but a lower percentage as ammonia, creatinine, and uric acid than males. The Angus group excreted a higher percentage of nitrogen in the form of urea plus ammonia, urea, and ammonia, but a lower percentage as creatinine than the Hereford group. This was true both at 500 and at 800 pounds body weight.

E. Nutrient Intake in Relation to Rate and Efficiency of Gain.

As indicated in Table 3, the differences in average rate and efficiency of gain of the major classification groups were distinct. The average daily gain in pounds for these major groups was: Males 2.90, Herefords 2.56, All Animals 2.46, Angus 2.31, and Females 2.14. The average efficiency of gain expressed as pounds of TDN per 100 pounds gain in body weight for these major groups was: Males 357, Herefords 417, All Animals 444, Angus 490, and Females 510. By employing the averages in rate and efficiency of gain and the averages obtained from chemical analyses, it was possible to graphically plot rate of gain and efficiency of gain against nutrient intake and

TABLE 24

PERCENTAGE OF NITROGEN EXCRETED IN THE FORM OF UREA PLUS AMMONIA, UREA, AMMONIA, CREATININE AND URIC ACID BY EXPERIMENTAL GROUPS OF CALVES AT 500 AND AT 800 POUNDS BODY WEIGHT

GROUP	CALVES		PERCENTAGE OF TOTAL NITROGEN EXCRETED									
			Urea & NH_3		Urea		Ammonia		Creatinine		Uric Acid	
	500	800	500	800	500	800	500	800	500	800	500	800
All Animals	24	40	59.94	82.46	57.70	80.90	2.2	1.7	5.7	3.6	0.7	0.7
All Males	10	16	48.50	79.96	45.37	77.46	3.0	2.9	7.7	4.4	0.7	0.9
All Females	14	24	68.12	84.12	66.51	83.19	1.7	0.9	4.3	3.1	0.7	0.6
All Herefords	18	24	57.07	80.94	54.86	79.57	2.2	1.7	6.1	3.7	0.7	0.7
All Angus	6	16	68.55	84.77	66.23	82.89	2.3	1.8	4.5	3.5	0.7	0.7
Bulls by 38	1	1	47.8	97.1	43.6	93.1	4.2	4.0	6.7	5.5	1.3	2.4
71	6	6	41.5	74.0	38.9	71.6	2.4	2.4	7.9	3.9	0.5	0.7
84	2	3	72.4	84.6	68.7	84.1	3.7	3.1	8.0	5.4	0.9	0.6
101	1	5	43.4	79.3	39.3	76.3	4.2	3.0	7.0	3.9	1.0	0.8
117	0	1		88.0		82.8		5.2		6.0		1.2
Heifers by 38	3	6	61.7	87.2	60.7	86.1	1.0	1.0	4.8	3.4	0.7	0.6
71	2	4	83.5	71.3	81.5	70.4	2.5	0.9	3.0	2.5	0.6	0.4
84	4	4	58.4	84.8	57.0	84.1	1.4	0.8	4.9	3.2	0.7	0.5
101	2	3	78.2	92.1	77.2	91.3	1.1	0.8	3.1	2.7	0.5	0.5
117	3	7	70.5	85.0	67.9	84.0	2.6	0.9	4.5	3.2	0.7	0.7

concentrations of blood and urine constituents. Averages of each metabolite, both at 500 and at 800 pounds body weight, were entered on the same graph to illustrate quantitative changes associated with weight increase. These have been presented in Figures 4.1 to 4.17.

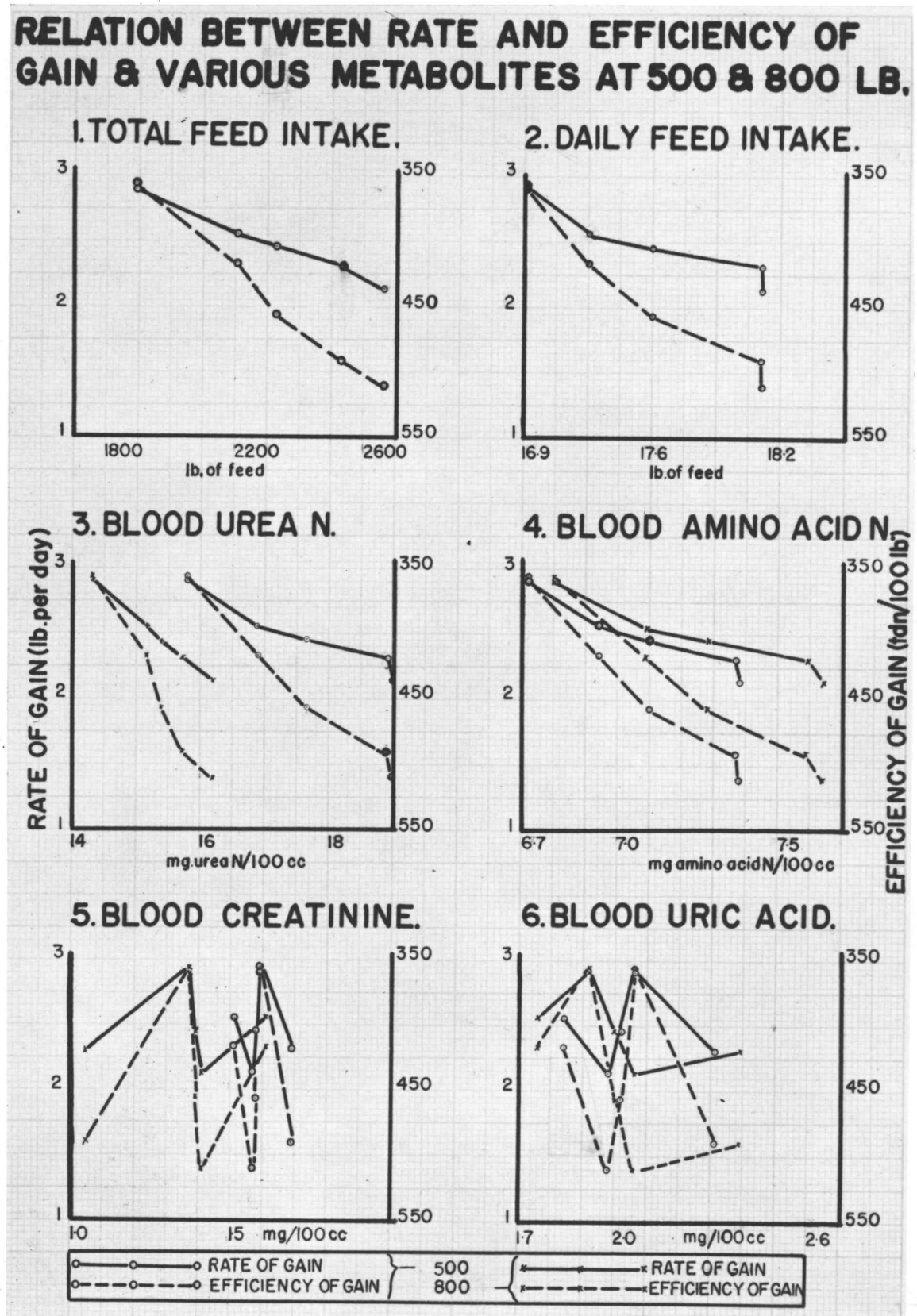
1. Rate of Gain.

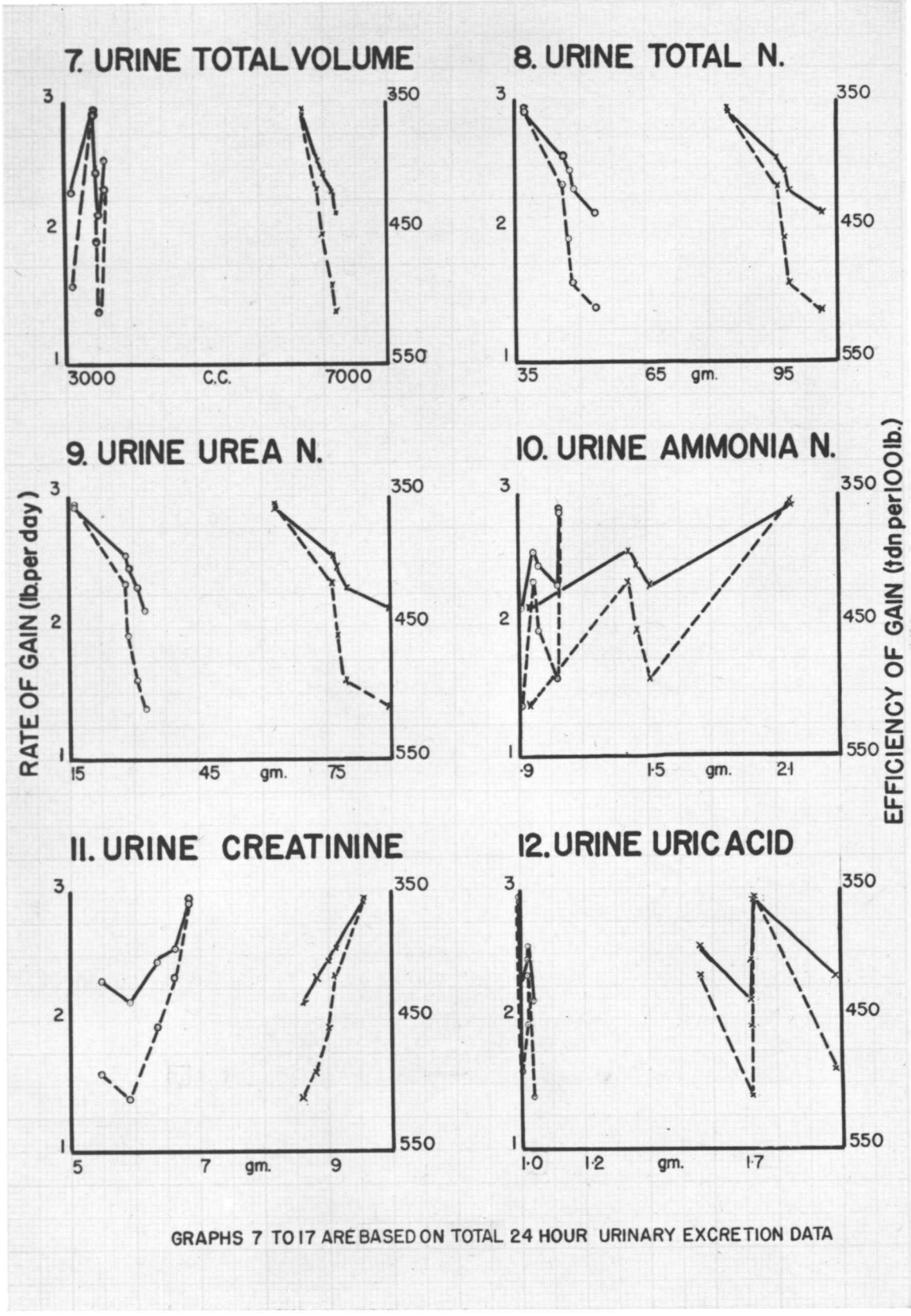
The graph in which rate of gain is plotted against total feed intake showed that as daily rate of gain decreased total feed intake increased for the experimental period during which the animals gained 300 pounds body weight. This relationship was linear (Figure 4.1).

The graph (Figure 4.2) in which daily feed intake is plotted against daily rate of gain showed that as average daily rate of gain decreased, the average daily feed intake increased with the exception of the Angus and Female groups which consumed the same amount daily but gained at different rates. The variation in rate of gain must, therefore, be explained on the basis of differences in feed efficiency rather than daily feed consumption.

2. Efficiency of Gain.

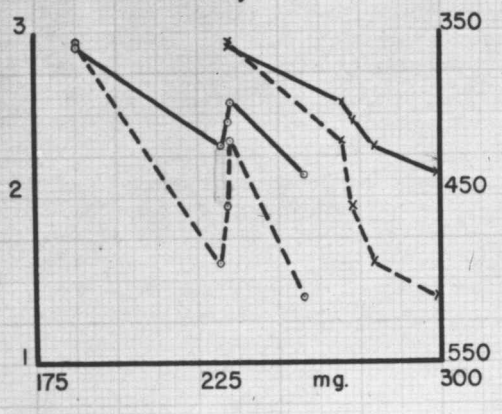
Efficiency of gain plotted against total feed intake during the test period (Figure 4.1) revealed that the greater the feed intake necessary to gain 300 pounds body weight, the lower the efficiency of gain. In a like manner, efficiency decreased with increased daily feed intake


RELATION BETWEEN RATE AND EFFICIENCY OF GAIN & VARIOUS METABOLITES AT 500 & 800 LB.
1. TOTAL FEED INTAKE.
2. DAILY FEED INTAKE.
3. BLOOD UREA N.
4. BLOOD AMINO ACID N.
5. BLOOD CREATININE.
6. BLOOD URIC ACID.
RATE OF GAIN (lb. per day)
EFFICIENCY OF GAIN (tdn/100 lb)
lb. of feed
mg. urea N/100 cc
mg amino acid N/100 cc
mg/100 cc
RATE OF GAIN
EFFICIENCY OF GAIN
500
800

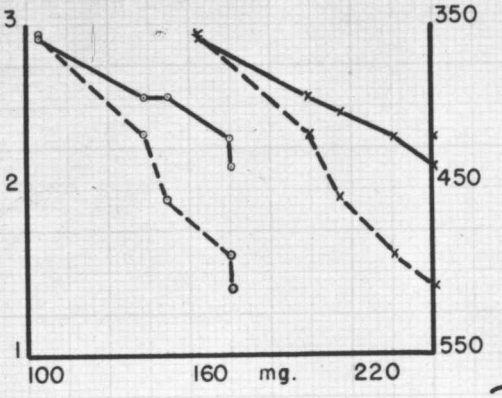


GRAPHS 7 TO 17 ARE BASED ON TOTAL 24 HOUR URINARY EXCRETION DATA

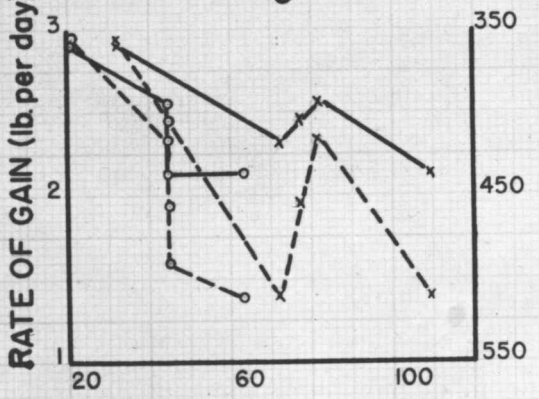
13. TOTAL N. / KILO



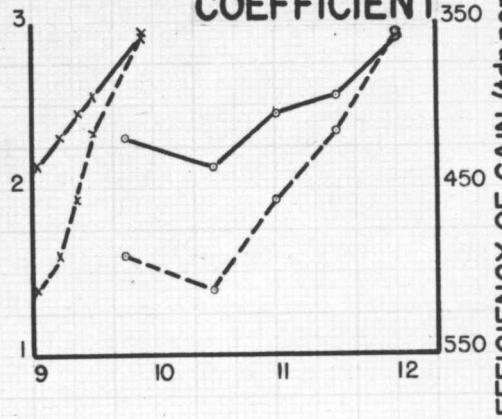
14. UREA N. / KILO



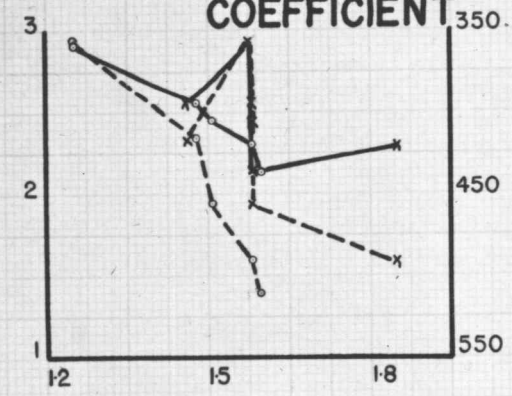
15. UREA: NH_3 N. RATIO



16. CREATININE COEFFICIENT



17. URIC ACID COEFFICIENT



(Figure 4.2) with the exception of the "All Female" group which was less efficient than the "All Angus" group but did not exhibit a greater daily feed intake on test.

Thus both rate and efficiency of gain were found to be negatively related to both total and daily feed intake. In short, the faster an animal gained the less feed it consumed on test and the less it ate per day. Also associated with smaller daily feed intake and greater rate of gain was the more efficient utilization of feed. With decreasing rate and efficiency of gain an increasing divergence between these two factors was evident when plotted against the factors mentioned above.

F. Blood Values in Relation to Rate and Efficiency of Gain.

1. Rate of Gain.

Rate of gain was plotted against four blood factors, namely: Urea nitrogen, amino acid nitrogen, creatinine and uric acid. Blood urea nitrogen showed some degree of linearity when plotted against rate of gain at both 500 and at 800 pounds and especially at the larger body weight. Of particular interest was the fact that while the graph pattern was quite similar at both weights, the values at 800 pounds body weight were considerably lower than those at the 500-pound weight. At both weights, as the rate of gain decreased, the urea nitrogen concentration per 100 cc. of blood increased (Figure 4.3). This is in keeping with

the results of work by Evans and others reviewed in the literature (81, 199, 86, 67 and 151).

Like blood urea nitrogen, amino acid nitrogen concentration increased with reduced rate of gain at both 500 and at 800 pounds body weight (Figure 4.4). The linearity found with amino acid nitrogen concentration in relation to rate of gain at 500 pounds was closely paralleled at 800 pounds body weight. In contrast to blood urea nitrogen, however, amino acid nitrogen concentration increased with the increase in size from 500 to 800 pounds body weight.

Linearity did not result when rate of gain was plotted against creatinine concentration per 100 cc. of blood at either 500 or at 800 pounds body weight (Figure 4.5). Furthermore, the creatinine concentration graph pattern at 500 pounds was almost opposite to that presented at 800 pounds body weight.

Like creatinine, uric acid concentrations per 100 cc. of blood did not show linearity when plotted against daily rate of gain (Figure 4.6). The graph of uric acid plotted against rate of gain was of further interest in that the pattern established was similar to that established for creatinine at both 500 and 800 pounds body weight.

Thus, it was found that the average blood urea nitrogen and blood amino acid nitrogen levels of the groups studied increased in a linear manner as daily rate of gain in body weight decreased, while no linear relationship was

obtained from graphing rate of gain against blood creatinine and uric acid concentrations.

2. Efficiency of Gain.

Like rate of gain, efficiency of gain was plotted against four blood factors, namely: Blood urea nitrogen, amino acid nitrogen, creatinine, and uric acid. The graph of efficiency of gain plotted against blood urea nitrogen concentration (Figure 4.3) showed that, like rate of gain, the urea nitrogen concentration per 100 cc. of blood increased as efficiency of gain decreased. Or, expressing it in another way, blood urea nitrogen concentration increased as the TDN requirements per 100 pounds of gain increased at both 500 and 800 pounds body weight. The values of urea nitrogen per 100 cc. of blood at 800 pounds were considerably lower than the values at 500 pounds. Graphic linearity of efficiency plotted against urea nitrogen was evident at both weights.

Concentration of amino acid nitrogen also increased in a linear manner as the efficiency of gain decreased at both 500 and 800 pounds body weight. This was graphically illustrated in Figure 4.4. Concentration of amino acid nitrogen increased moderately with the increase in body weight from 500 to 800 pounds.

Like rate, the graph in which efficiency of gain is plotted against creatinine concentration per 100 cc. of

blood did not show a straight line relationship at either 500 or 800 pounds body weight (Figure 4.5). Again, the opposite pattern of that established at 500 pounds was discerned at 800 pounds upon graphing the creatinine concentration values against efficiency of gain.

Uric acid concentrations per 100 cc. of blood also failed to exhibit a straight line relationship with efficiency of gain when graphed (Figure 4.6). Uric acid concentration plotted against efficiency of gain followed a pattern similar to that described for creatinine at both 500 and at 800 pounds body weight. Average concentrations remained virtually constant as body weight increased from 500 to 800 pounds.

In summary, it may be stated that both rate and efficiency of gain increased linearly as blood concentrations of urea nitrogen and amino acid nitrogen increased. This was true both at 500 and 800 pounds body weight. No relationship was found for creatinine and uric acid when plotted against rate or efficiency of gain.

G. Urine Values in Relation to Rate and Efficiency of Gain.

1. Rate of Gain.

Rate of gain was plotted against six urine factors which were obtained by direct chemical analyses and four factors which were obtained from calculations based on "per-kilo" body weight relationships with urine excretion.

These six factors obtained by chemical analysis were: Total volume of urine voided during 24 hours, total nitrogen, urea nitrogen, ammonia nitrogen, creatinine and uric acid. The four factors obtained from calculations were: Per kilogram body weight excretion of total nitrogen and urea nitrogen, and the creatinine and uric acid coefficients. The ratio of urea:ammonia nitrogen excretion was also plotted against rate of gain.

Rate of gain plotted against total urinary volume excreted per 24 hours revealed two facts. First, the animals excreted approximately twice as much urine at 800 pounds as they did at 500 pounds. Second, although a straight line relationship between rate of gain and volume of urine voided was found at 800 pounds, no linear relationship between these two factors could be found at 500 pounds. As indicated in Figure 4.7, rate of gain decreased as urinary excretion increased at 800 pounds.

Rate of gain was plotted against total urinary nitrogen excretion per 24 hours and the result is shown in Figure 4.8. The difference in total nitrogen excretion at 500 and at 800 pounds body weight is immediately apparent. Of great interest is the fact that rate of gain showed a straight line relationship with total nitrogen excretion at 500 pounds even though total volume of urine at that weight did not give such a relationship when plotted against rate of gain. At both the 500 and 800 pound weights, rate of

gain decreased as total urinary nitrogen excretion increased in a linear manner.

Since urea nitrogen represents the nitrogenous excretion product which is present in urine in, by far, the greatest concentration, one would expect the graph in which urea nitrogen is plotted against rate of gain to parallel the graph of total nitrogen plotted against rate of gain. Such was the case (Figure 4.9). All groups excreted much more urea nitrogen at 800 pounds than at 500 pounds body weight and at both weights urea nitrogen excretion per 24 hours increased as rate of gain decreased. This was a reasonably straight line relationship at both body weights.

The graph in which ammonia nitrogen is plotted against average daily rate of gain (Figure 4.10) indicates that in general, ammonia nitrogen increased as rate of gain increased both at 500 and at 800 pounds body weight. On closer scrutiny it may be seen that ammonia nitrogen excretion actually increased as rate of gain decreased for the groups of intermediate rate of gain. With the exception of the "All Females" group, each group excreted more ammonia at 800 than at 500 pounds body weight. The pattern of ammonia excretion in relation to rate of gain at 500 pounds was repeated at 800 pounds but in a much more exaggerated manner.

When rate of gain was plotted against urinary creatinine excretion per 24 hours it was found that creatinine excretion increased as daily rate of gain increased. This relationship was exceptionally good at 800 pounds, and it approached linearity, with the exception of the All Angus group, at 500 pounds body weight (Figure 4.11). The creatinine excretion of the All Angus group was low in relation to daily rate of gain when compared with the other groups. Daily creatinine excretion was greater at 800 than at 500 pounds body weight.

Like the urine excretory products mentioned above, urine uric acid excretion increased considerably with the increase from 500 to 800 pounds body weight. The graph (Figure 4.12) of daily rate of gain plotted against daily excretion of uric acid failed to yield a straight line relationship between these two factors. In fact, there was very little difference in average excretion between the groups of cattle at 500 pounds body weight. At 800 pounds body weight the uric acid pattern was of interest since it represented an exaggeration, quantitatively, of the pattern for the 500 pound values.

Rate of gain was plotted against total urinary nitrogen excretion per 24 hours per kilogram body weight (Figure 4.13). The result showed that there was a linear relationship at 800 pounds body weight whereby total nitrogen excretion per kilo body weight increased as rate of gain

decreased. At 500 pounds the intermediate groups showed an increased nitrogen excretion with increasing rather than decreasing daily rate of gain. Total nitrogen excretion per kilogram body weight was higher at 800 than at 500 pounds body weight.

The graph (Figure 4.14) in which urea nitrogen excretion per kilo body weight is plotted against rate of gain per day shows that at 800 pounds a high relationship was found. Urinary urea nitrogen per kilogram per 24 hours increased as daily rate of gain decreased. This relationship was also present at the 500-pound level with the exception that the two groups representing the lowest rates of gain were virtually the same in rate of excretion of urea nitrogen. Like total nitrogen, urea nitrogen excretion increased with the increase from 500 to 800 pounds body weight.

The urea:ammonia nitrogen ratio represents the ratio of nitrogen excreted as urea to the nitrogen excreted as ammonia. As indicated previously, urea nitrogen excretion increased linearly as rate of gain decreased, but ammonia nitrogen excretion increased in a non-linear fashion as rate of gain increased. Therefore, when the factors of this ratio were plotted against rate of gain, the ratio increased as rate of gain decreased but in a non-linear manner (Figure 4.15). This failure was due mainly to the intermediate groups in which the ratio increased rather

than decreased with rate of gain. Of further interest was the fact that the pattern of the graph of the ratio plotted against rate of gain at 800 pounds body weight was the reciprocal of the pattern of the graph of ammonia nitrogen plotted against rate of gain at 800 pounds body weight.

The graph in which the creatinine coefficients are plotted against rate of gain followed the same pattern as the graph of total creatinine excretion plotted against rate of gain at both 500 and 800 pounds body weight. Again it was found that creatinine excretion increased as daily rate of gain increased. The relationship was exceptionally good at 800 pounds and approached linearity at 500 pounds body weight with the exception of the All Angus group. The creatinine coefficient of the All Angus group was low in relation to daily rate of gain when compared with the other groups. The creatinine coefficients were lower at 800 pounds than at 500 pounds body weight.

Uric acid coefficients showed a general increase with an increase in body weight. At 500 pounds, uric acid coefficients showed linearity when plotted against daily rate of gain with the coefficient increasing as daily rate of gain decreased. At 800 pounds, the uric acid coefficient graph pattern was not linear but followed a sequence that was approximately the reciprocal of the graph in which urine uric acid excretion was plotted against rate of gain (Figure 4.12).

In summary, it was found that a lower daily rate of gain at 500 pounds body weight was linearly associated with increases in urinary total nitrogen and total urea nitrogen excretion per day, urea nitrogen excretion per kilo body weight, and the uric acid coefficient. Decreases in rate of gain at 800 pounds body weight were linearly related to increases in total urine volume, total nitrogen, urea nitrogen, and total urea nitrogen excretion per kilo body weight. Creatinine excretion and creatinine coefficients increased linearly with rate of gain at 800 pounds and relatively linearly though to a lesser degree at 500 pounds. The other factors studied were not related to rate of gain in a linear manner.

2. Efficiency of Gain.

Efficiency of gain was plotted against 6 urine factors which were obtained by direct chemical analyses and 4 factors which were obtained by calculations based on per kilogram body weight relationships with urine excretion. The 6 factors obtained by chemical analyses were: Total urinary volume excreted during 24 hours, total nitrogen, urea nitrogen, ammonia nitrogen, creatinine and uric acid. The four factors which were calculated are: Total nitrogen excreted per kilogram body weight, urea nitrogen, creatinine coefficients and uric acid coefficients. The urea:ammonia nitrogen excretion rate was also plotted against feed efficiency.

Efficiency of gain, when plotted against the various factors listed above, gave similar results to those reported in graphs in which rate of gain was plotted against the urinary products. There was the exception, however, that a greater divergence was noted between the plotted values for the group with the low values than with the group with the high rate and efficiency.

Two facts became obvious on plotting efficiency of gain against total volume of urine excreted during 24 hours. First, a straight line relationship existed between efficiency and total urine excretion at 800 pounds in which the volume of urine excreted increased as the efficiency of gain decreased. Second, the relationship just mentioned did not exist at the 500-pound level.

As indicated in Figure 4.8, efficiency of gain was plotted against total nitrogen excretion per 24 hours. Like rate, efficiency of gain showed a straight line relationship with total nitrogen excretion at 500 pounds even though total urinary excretion did not give such a relationship when plotted against efficiency of gain at the same weight. At both weights total urinary nitrogen excretion increased as efficiency of gain decreased.

As one might anticipate, urea nitrogen excretion paralleled that of total nitrogen when graphed against efficiency of gain. All groups excreted more urea nitrogen at 800 pounds than at 500 pounds body weight. Also, as

the efficiency of gain decreased, urea nitrogen excretion per 24 hours increased in a linear manner at both weights.

In contrast to excretion of total and urea nitrogen, ammonia nitrogen excretion showed a general increase as efficiency of gain increased at both 500 and 800 pounds body weight. A detailed examination of Figure 4.10 revealed, however, that the groups of intermediate efficiency of gain actually excreted more ammonia nitrogen as efficiency of gain decreased. This was true at both 500 and 800 pounds body weight. The graph pattern which resulted from plotting ammonia nitrogen excretion against efficiency of gain at 500 pounds was repeated at 800 pounds body weight but in a much more exaggerated manner.

When efficiency of gain was plotted against urinary creatinine excretion per 24 hours, it was found that creatinine excretion increased as efficiency of gain increased. These results, then, were similar to the pattern established by excretion of ammonia and in contrast with patterns of total and urinary nitrogen excretion. The relationship between efficiency of gain and creatinine excretion approached linearity at 800 pounds body weight but the agreement was not so marked as when creatinine excretion was plotted against daily rate of gain. This relationship of creatinine excretion with efficiency also approached linearity at 500 pounds with the exception that the All Angus group in which the creatinine excretion was

low in relation to efficiency of gain when compared with the other groups.

Like rate of gain, efficiency of gain failed to exhibit a straight line relationship when plotted against daily uric acid excretion (Figure 4.12). There was very little difference between groups in average uric acid excretion at 500 pounds body weight. This excretion rate was much higher at 800 than at 500 pounds but the patterns in which uric acid excretion was plotted against efficiency were basically the same. However, the pattern established at 800 pounds body weight showed more exaggeration in the amounts excreted.

When efficiency of gain was plotted against total urinary nitrogen excretion per 24 hours per kilogram body weight, the results showed that there was a linear relationship at 800 but not at 500 pounds body weight. At 800 pounds, total nitrogen excretion per kilogram body weight increased as the efficiency of gain decreased. However, at 500 pounds the groups representing intermediate efficiency of gain showed an increased nitrogen excretion with increasing rather than with decreasing efficiency of gain. Nitrogen excretion per kilogram was higher at 800 pounds than at 500 pounds body weight.

The result of graphing excretion of urea nitrogen per 24 hours per kilogram body weight against efficiency of gain have been presented in Figure 4.14. Excretion of urea

nitrogen per kilogram body weight at 800 pounds increased as efficiency of gain decreased in a relatively linear manner. This relationship also existed at 500 pounds with the exception of the two groups representing the lowest efficiencies of gain.

As indicated previously, urea nitrogen excretion increased linearly as efficiency of gain decreased but ammonia nitrogen excretion increased with increased efficiency of gain in a non-linear fashion. Because of this, the ratio increased as the efficiency of gain decreased in a non-linear manner. This failure was again due mainly to the intermediate groups in which the ratio increased rather than decreased with efficiency of gain. Like rate of gain, the pattern of the ratio, when plotted against efficiency of gain, was almost the reciprocal of the pattern of the graph of ammonia nitrogen against efficiency of gain at 800 pounds body weight.

The graph of creatinine coefficients plotted against efficiency of gain followed a similar pattern to the graph of total creatinine excretion plotted against efficiency and rate of gain at both 500 and 800 pounds body weight. Similarly, the creatinine excretion increased as efficiency of gain increased. This relationship was good at 800 pounds and approached linearity at 500 pounds with the exception of the All Angus group.

Uric acid coefficients showed a general increase with the increase in body weight from 500 to 800 pounds. When the average uric acid coefficients were plotted against efficiency of gain, a linear relationship was approximated at 500 but not at 800 pounds body weight. At 500 pounds the uric acid coefficients increased as efficiency of gain decreased, whereas at 800 pounds the pattern of the graph was approximately the reciprocal of the graph in which urine uric acid excretion was plotted against efficiency of gain (Figure 4.12).

In summary, it was found that at 500 pounds body weight a decrease in efficiency of gain was linearly related to increases in total urinary nitrogen and total urea nitrogen excretion per day, urea nitrogen excretion per kilogram body weight, and the uric acid coefficients. At 800 pounds body weight, decreases in efficiency of gain were linearly related to increased excretion of total urine volume, urinary nitrogen, urea nitrogen, total nitrogen per kilo and urea nitrogen per kilo body weight. Creatinine excretion and creatinine coefficients increased linearly with increased efficiency of gain at 800 pounds and to a relatively linear degree at 500 pounds body weight. Other factors studied were not linearly related to efficiency of gain.

CHAPTER V

DISCUSSION

> "In any discussion of a problem in the light of insufficient knowledge, the real danger is not that a particular conclusion may be wrong, for that is a transient fault, but rather that the facts themselves may be so distorted as to be valueless to others when the conclusions that they are used to show have been discarded."
> William Bateson.

Work with the larger species of domestic animals has disadvantages, the most serious of which is probably the time and money involved. In order to follow metabolic effects in beef cattle through a well defined growth period it is necessary that at least several months must pass before the results become known. If smaller laboratory animals are used, a comparable physiological period may often be covered within a month and at a much lower cost. On the other hand, experimental work with the larger farm animals is desirable since results obtained may be applied directly to the breeds and species in question.

In nutrition and biochemistry, differences between individuals have been recognized for many years but unfortunately attention has been focused more upon the metabolic requirements common to all animals rather than on the bases for individual differences. Fortunately, a few isolated investigators in these fields have worked to determine the causes of such individual differences. One

of the more important of these was Garrod, whose classic "Inborn Errors of Metabolism" stressed the hereditary origin of biochemical differences between individuals. More recently this field has come into its own as a tool making possible new approaches to the intricate problem of measuring genetic potential in cattle.

Since every animal in the present experiment was individually studied, the data obtained permitted careful analyses on an individual basis. The data clearly illustrated that differential growth and feed intake expresses itself through the intermediary metabolic products of the blood and those excreted in the urine. If the genetics and metabolism of differential growth are to be understood, attention must be given not only to the species, sexes, and breeds as groups, but also to the individual animals (the substrates). The concept that individuals or groups of individuals are standardized pieces of protoplasm must be reconsidered since all individuals in this study represented some degree of deviation from the average in one or more of the blood and urine constituents studied. In fact, it is because of deviations from the mean in concentrations of blood and urine constituents and feed intakes that the cause of metabolic differences in rate and efficiency of gain may be explained.

A. Nutrient Intake.

That the animals studied varied considerably in age upon reaching body weights of 500 and 800 pounds is shown in Figure 3. The fact that age put on test had no significant effect on rate of gain may lead one to immediately suggest that the polygenic complexes responsible for rate of gain at an early age differed from those finding expression during the test period following weaning. This is not necessarily the case since differential rates of milk production of the dams and non-duplicatable pasture and feeding conditions subjected each calf to environments that were relatively unique, especially during the suckling period. Further evidence of the strong effect of the environment and gene-environmental interactions is furnished by Dahmen and Bogart (65,pp.1-23). They found that age on test did have a significant effect on rate of gain while on test. These men did their work at this station with calves, many of which were closely related to the calves used in the present study. Thus it is not possible to state from the present study whether the polygenic complexes responsible for rate of gain during suckling also control growth during the test period (500 to 800 pounds).

It may be argued that since the age of the calf when put on test did have a significant effect on efficiency of gain on test, the older animals were discriminated against in a weight-to-weight test period but would not have been

discriminated against in an age-to-age test. However, since all animals were the same weight at the initiation of the test, the maintenance requirements of all animals should have been similar. The fact that the animals that took longer to reach 500 pounds also required more TDN to reach 800 pounds is indicative that either the older animals suffered some environmentally introduced, irreversible, metabolic disturbance from which complete recovery was impossible, or that the polygenic complexes that made the older animals inefficient while on test were also functional, making these animals inefficient, hence slower growing at earlier ages as well.

That studies of rate and efficiency of gain on an age-to-age basis are less able to differentiate animals of differing abilities to grow is well explained by Brody (39, pp.664-706). He stated that the increase in size of a given animal would be expected to increase the energy cost of its maintenance and reduce, correspondingly, the total efficiency of growth unless this increase in maintenance is compensated for by an increase in growth rate. The increase in size associated with increasing age in an animal, however, is not compensated for by an increase in growth rate. Thus, in an age-to-age experimental period this decrease in gross efficiency of growth with increasing weight is a discrimination against the faster growing animals.

All experimental groups were of known breeding and were exposed to a uniform environment while on test, yet marked sex differences were apparent in their rate and efficiency of gain. Such marked differences are not unique to this study, however. Bogart et al. (31,pp.173-181 and 29,pp.355-371) demonstrated the influence of the sex hormones on rats whereby estrone retarded and progesterone accelerated the rate of growth. In similar studied with beef cattle, Bogart and co-workers (44) (25) (45,pp.1-13) and (183,pp.513-514) found steers and heifers treated with testosterone gained more rapidly than controls and that treated steers gained more rapidly than treated heifers. In another study they also found that under adverse conditions sex of the calf had no effect on weight at weaning. Gramlich and Thalman (92,pp.3-50) found that heifers will not gain as rapidly nor will they gain as efficiently as steer calves since they show fleshing at an earlier age. In the present study the lower rate and efficiency of gain of female and Angus groups measured by gain in body weight only, could not be explained on the basis of feed consumption alone since the female and Angus groups consumed more nutrients per day than the faster growing, more efficient male and Hereford groups. Morris, Palmer and Kennedy (162,pp.1-55) reported that for growing rats there is a decided difference between the two sexes in the efficiency with which they utilize the food of an identical

diet. The female rat consumed much more dry matter per unit of gain than did the male when measurements were made during the most rapid growth. During a six week period, the average female rat required 1.7 times the feed consumed by the male to gain at an equivalent rate. Therefore, other reasons for this difference in rate and efficiency of gain between the groups must be entertained.

Nelms[4] determined the digestibility of the experimental ration using 3 bulls of approximately 850 pounds body weight. He found that the total digestibility of the ration was higher for bulls than that calculated from Morrison (163,pp.788-789). Unfortunately, whether differences in digestibility between the sexes was a major contributing factor or whether the improved digestibility was general and due to the mechanics of pelleting could not be resolved since an equivalent digestibility study with heifers was not undertaken. Furthermore, the evidence reported previously by Dunlop (59 and 60,pp.155-159) and Baker, Colby and Lyman (16,pp.726-732) tends to discredit the possibility of differences in digestibility between experimental groups.

Williams, Krueger and Bogart (209,pp.1-4), in studying rectal temperatures of the calves used in this study, found

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[4]Nelms, George E. Unpublished data on 850 pound beef bulls fed a completely pelleted ration, Corvallis, Oregon State College, Department of Animal Husbandry, 1953.

that the regression of average rectal temperature on average rate of gain was significant (at the 5 percent level) only in the Angus heifer group. Body temperature cannot be considered a major factor contributing to the sex differences in rate and efficiency of gain. Thus a more intensive study of the intermediary metabolism, represented by metabolites found in blood and urine, is necessary to determine the cause of differences in rapidly and slowly gaining groups of beef cattle.

B. Blood Constituents.

The literature reported in a previous section indicated that rate of growth, measured by increase in weight, and type of growth, measured by tissue composition, are subject to the direct influence of the anterior pituitary growth hormone which increases nitrogen retention and thereby increases the body protein content. Teel and Watkins (199,pp.662-685) reported a drop of 20 to 30 percent in blood non-protein nitrogen (NPN), following injections of growth extracts from the anterior pituitary of which 70 percent of the decrease in NPN was accounted for by decreases in amino acid and urea nitrogen. An examination of the results of the present study indicated that the faster gaining groups of cattle had lower blood urea nitrogen and amino acid nitrogen levels than the slower gaining groups. Furthermore, this was a negative straight line relationship

at both 500 and 800 pounds body weight (Figure 4.3 and 4.4). These results would suggest that the faster gaining groups were under the influence of the anterior pituitary growth hormone to a greater degree or under the influence of the adrenocorticotrophic hormone to a lesser degree than the slower gaining groups. The data further suggest that the slower gaining groups must have tended to lay on finish (fat) starting at a weight of less than 500 pounds. Thus less nutrients were left for growth in the protein sense. Since the cost of gain in body weight through fat deposition is energetically very expensive, the calf laying on greater amounts of fat would be judged less efficient on a weight-gained basis than the calf that is still growing through protein synthesis. These same groups of cattle (Figure 4.3 and 4.4) showed a negative straight line relationship between efficiency of gain and urea nitrogen concentration per 100 cc. of blood. A similar relationship was found for blood amino acid nitrogen. The suggestion that the higher concentrations of blood urea nitrogen and amino acid nitrogen are simply the result of the higher daily nitrogen ingestion by the calves exhibiting a lower rate and efficiency of gain is invalidated by the work of Steele, Reynolds and Bauman (195,pp.124-132). They found that diets may cause significant alterations in the amounts of amino acids in mouse urine without any comparable change in the blood levels.

The relationship of blood creatinine and uric acid to rate and efficiency of gain is not readily resolved. Creatinine and to a lesser extent uric acid represent end products of endogenous protein metabolism (39,p.353). Both present similar patterns when plotted against rate and efficiency of gain at 500 and 800 pounds body weight. However, total urinary creatinine excretion per 24 hours tended toward a linear relationship with rate and efficiency of gain while total urinary uric acid excretion followed the uric acid blood pattern at both 500 and 800 pounds body weight when plotted against rate and efficiency of gain. At present no explanation of this phenomenon is available.

Throughout the results mention has been made of a few animals in which blood urea nitrogen, amino acid nitrogen, creatinine or uric acid concentration failed to achieve or exceeded the normal range listed for the cow by Dukes (58, p.49). Such values are not necessarily representative of abnormal animals or faulty laboratory technique. Dukes' range of the chemical constituents of whole blood of the cow was prepared by Dr. C. E. Hayden and is founded on his own work and that of other early investigators, many of whom were quoted in the Review of Literature. Unfortunately, the vast majority of the data reported by Hayden was obtained from mature, lactating, dairy cows by methods which have since been succeeded. The present study

involved young growing beef bull and heifer calves. The work of Turner and Herman (203,pp.1-60) illustrated the effects of age and lactation on blood volume in dairy cattle. These workers found that mature cows averaged 7,768 cc. of blood per square meter of body surface compared to 4,035 cc. per square meter of body surface in growing cattle. Blood comprised 5.81, 6.38 and 8.11 percent of the total weight of growing (200-900 pounds), non-lactating, and lactating dairy cattle, respectively. It would be hard to imagine that such changes in blood volume would occur without changes in concentration of blood constituents.

C. Urine Constituents.

The general increase in urinary excretion with an increase from 500 to 800 pounds body weight cannot be attributed entirely to increases in weight, age, or both weight and age. Collections of urine at 500 pounds body weight were made during the late fall and winter months; whereas the final, or 800 pound body weight collection period, was during the spring and summer months. Several investigators have found that season of the year influenced the volume of urine excreted by cattle. For example, Ashworth and Brody (13,pp.5-7) found that animals which often excreted over 20 liters of urine daily during the summer would only excrete 3 or 4 liters during the winter.

Nor can the increased excretion be attributed entirely to the season of the year. Fuller (84,pp.1-30) and Keith (125,pp.37-48) while studying dairy cattle found that heifers excreted 3.5 to 20.3 liters of urine per day while mature cows excreted 12 to 50 liters per day.

Simultaneous observations of urea excretion rates, urine volumes and blood urea concentrations were made by Austin, Stillman and Van Slyke (15,pp.99-104) and Möller, McIntosh and Van Slyke (161,pp.485-495). They showed that the urea clearance, defined as the amount of urea excreted in one minute, was little affected by urine flow changes in normal human subjects when the flow per 1.73 square meters of body surface area exceeded an "augmentation limit". The "augmentation limit" was usually about 2 cc. per minute. When the urine flow fell below this limit the urea clearance fell with the urine flow, the clearance then becoming approximately proportional to the square root of the flow (205,pp.1159-1167). Fitting the equation $Y = aX^b$ (where Y = surface area, a = 0.13, X = body weight in kilos and b = 0.56) to the data in the present study the surface area of 500-pound and 800-pound calves was determined to be 2.70 and 3.54 square meters, respectively (39,p.403). If one assumes the "augmentation level", reported by Van Slyke (205,pp.1159-1167) for humans, applies equally well to beef cattle, the calves at 500 pounds should have excreted 4,495 cc. of urine and the calves at 800 pounds should have

excreted 5,895 cc. of urine per 24 hours to achieve the basic "augmentation level". The results of this study showed that all groups failed to reach the "augmentation level" by about 1000 cc. per day at 500 pounds body weight and all groups exceeded it by about the same amount at 800 pounds body weight. This could constitute the basic reason why blood urea levels were generally higher at 500 than at 800 pounds body weight. The values for urinary total and urea nitrogen excretion and total and urea nitrogen excretion per kilo body weight per 24 hours are possibly without absolute significance since nitrogen excretion in these forms (unlike creatinine excretion) is largely a function of nitrogen excretion above the amount utilized for growth and maintenance, and biological value of the protein ingested. Nevertheless, they are interesting from comparative points of view.

The values obtained in this study may be compared with Carpenter's results (47,pp.519-551) on fasting steers. His steers had average total nitrogen coefficients of 115 and 62 for animals that had been on pasture and submaintenance diets, respectively, before fasting. Results from this study may also be compared with studies by Ashworth and Brody (10 and 12,pp.1-19) in which rats were used as experimental animals. On normal stock diets, rats showed coefficients as high as 800 to 1000 on the low protein diet, and 1500 to 4000 on the high protein diet. That rats

tend to have higher nitrogen coefficients than cattle is obvious.

By far the majority of nitrogen metabolism studies conducted in the past concerned fasting steers. The work of Ashworth and Brody (13,pp.1-18) is an enlightening exception. Mitchell (159,pp.1-84) in a careful review of the early literature cited data from Forbes (80,pp.15-27) to the effect that the total nitrogen coefficient for cows after 5 and 9 days of fasting is approximately 100. This agrees with Carpenter's (47,pp.519-551) values for fasting steers that had previously been on pasture but were higher than his values for fasting steers that had previously been on a submaintenance ration. Mitchell also cited Bull and Grindley (43,pp.241-255) who brought steers on to nitrogen balance on a low protein diet with a resulting average total nitrogen coefficient of 47; Titus (202,pp.2-51), who obtained coefficients of from 42 to 52 in steers; Steenbock, Nelson and Hart (196,pp.2-19), who obtained a minimum coefficient of 45 on calves; and Hart, Humphrey and Morrison (107,pp.133-153), who obtained a coefficient of 30 to 36 upon feeding 300 to 400 pound heifers.

If we assume from the foregoing that a urinary total nitrogen coefficient of 50 is a reasonable minimum for adult maintenance requirements under normal dietary conditions for cattle, and if we further accept Ashworth and Brody's (13,p.11) assumption that the minimum nitrogen

excretion on a diet compatable with normal growth is 150 mgm. per kilo body weight per day rather than the 50 mgm. assumed for adult animals, all our experimental groups had wasted from 35 to 150 mgm. of nitrogen per kilo body weight per day. Crude protein quantity is certainly not lacking in the Oregon State College calf testing ration and represents a 15 percent crude protein intake above the allowance for growth proposed by Ashworth and Brody (13,p.11).

If one accepts the hypothesis that the blood urea and amino acid nitrogen concentrations varied between the fast and slow gaining groups of calves because of differences in anterior pituitary growth or adrenocorticotrophic hormone activity, urinary non-protein nitrogen excretion should also be affected (86,p.46) (90) (152) and (138,p.222). An examination of the results indicates that such was the case. Urinary excretion of total and urea nitrogen per day and per kilo body weight increased at both 500 and 800 pounds as rate and efficiency of gain decreased (Figure 4.8, 4.9, 4.13 and 4.14). Further support for this hypothesis may be found in Table 14. An examination of nitrogen intake, urinary nitrogen excretion, and nitrogen retention per 24 hours by experimental groups of calves at 800 pounds body weight indicates that faster gaining, more efficient groups retained more nitrogen and a higher percentage of total nitrogen ingested than slower gaining, less efficient groups. Using groups representing the extremes in

rate and efficiency of gain as examples, it may be seen (Table 14) that the All Male group retained 126.2 gm. (59.5% of intake) of nitrogen per day while the All Female group retained 109.2 gm. (50.7% of intake) of nitrogen per day at 800 pounds body weight. If one assumes that the entire difference in nitrogen retention (17 gm.) per day was incorporated as muscle tissue it would represent 0.97 to 1.17 pounds of gain in body weight per day (22,pp.1015-1021 and 210,p.27). The actual difference between these groups in average daily gain for the entire test period was 0.76 pound per day.

According to Folin (70,pp.65-115), the urea-plus-ammonia nitrogen excretion of a human on a high, but meat free, protein diet is 90 percent of the total urinary nitrogen; while on a nitrogen-free diet it is 73 percent of the urinary nitrogen. Smith reported a minimum of 37 percent urea-plus-ammonia nitrogen on the 24th day of a nitrogen-free diet (146,p.360). Ashworth and Brody (13, p.4) found that the average urea-plus-ammonia excretion for Holsteins is 78 percent, and for Jerseys is 80 percent of the total urinary nitrogen excretion. The values from the present study agree closely with the urea-plus-ammonia values obtained by Ashworth and Brody (13,p.14) at 800 pounds but gave lower values at 500 pounds body weight. Carpenter's (47,p.540) steers on pasture gave a percentage ratio for urea-plus-ammonia nitrogen to total urinary

nitrogen of about 77 and steers on submaintenance diets gave a ratio of about 63.

The results of the ratio of urinary urea:ammonia nitrogen deserve mention. In 1898, Winterberg (211,pp.202-235) showed conclusively that rabbits fed on oats could protect themselves against mineral acids by coupling these with ammonia and excreting the ammonium salts through the urine. Accompanying this utilization of ammonia for purposes of neutralization, there was a reduction in the output of urea. It has further been established by McCollum and Hoagland (148,pp.299-315) that an animal is able to maintain tissue neutrality or at least raise the ammonia production on a nitrogen free diet when fed mineral acids. Such a diet results in an increased ammonia production in the urine with decreased urea output and increased total nitrogen excretion. Apparently, then, ammonia and urea production will rise and fall, depending on the balance of base and acid radicals in the ration or in the tissues of the animals. In the present study, all animals received the same ration which was alkaline mainly because of the high alfalfa content (Table 2). Therefore, other reasons must be sought to explain the large sex dimorphism in the ratio of urea:ammonia nitrogen. Males excreted less urea and more ammonia nitrogen than females at both 500 and 800 pounds body weight (Tables 16 and 18). Because of this the females exhibited ratios of urea:ammonia nitrogen that

were 3 times higher than those of the males at both 500 and 800 pounds body weight. Results presented by McCollum and Hoagland (148) suggest that since the rations fed were similar, there must be a tendency toward greater tissue acidity in the males than in the females. Such a deduction is not unreasonable if one accepts the hypothesis that the bulls tended relatively toward a protein metabolism while the heifers tended toward a fat metabolism during the course of this study. A complete explanation and evaluation of the worth of urea:ammonia nitrogen ratios must await further study.

Madison (150,pp.657-687) found a definite difference between male and female mice in urine creatinine excretion per unit body weight with female mice excreting larger quantities than males. In the present study, heifers excreted less creatinine per unit body weight than bull calves.

Dinning, Gallup and Briggs (57,pp.157-161) studied the effect of protein intake on the excretion of creatine and creatinine. They found that the excretion of total nitrogen and creatinine nitrogen by individual steers on a uniform nitrogen intake is relatively constant from day to day as compared to the differences between individuals. Their results also showed that changes in nitrogen intake and the addition of urea to the rations were without effect on the creatinine coefficients. Ashworth and Brody

(10,pp.3-66) found that the creatinine coefficient of the rat is not appreciably affected by dietary protein level.

It is now established with certainty that the excretion of preformed creatinine is constant and is not influenced by the dietary protein level. According to Folin (70,pp.66-115), the creatinine nitrogen in humans on a nitrogen free diet is approximately 17 percent of the total urinary nitrogen. If the same is true of beef cattle, the endogenous urinary nitrogen excreted by cattle may be calculated by multiplying the creatinine nitrogen excretion by 6. Deuel obtained a creatinine nitrogen percentage of 33 under similar circumstances. If his findings are applicable to beef cattle, the endogenous urinary nitrogen could be computed by multiplying the creatinine nitrogen excretion by 3. If obviously justifiable doubts are further surpressed by assuming that the ratio of creatinine to endogenous urinary nitrogen is constant, this ratio could be of metabolic importance.

The application of these ratios, using the average values of preformed creatinine coefficients obtained in this study, would permit the calculation of endogenous urinary nitrogen excretions of our animals. Such has been calculated and the results are shown in Table 25.

TABLE 25

CALCULATED DAILY EXCRETION OF ENDOGENOUS URINARY NITROGEN OF CALVES BY EXPERIMENTAL GROUPS AT 500 AND AT 800 POUNDS BODY WEIGHT (mgm./kilo)

GROUP	500 lb.			800 lb.		
	Creatinine Coefficient	Endogenous Urinary N. Excretion		Creatinine Coefficient	Endogenous Urinary N. Excretion	
		Folin	Deuel		Folin	Deuel
All Animals	11.00	66.00	33.00	9.39	56.34	28.17
All Males	11.96	71.76	35.88	9.88	59.28	29.64
All Females	10.52	63.12	31.56	9.04	54.24	27.12
All Herefords	11.51	67.06	34.53	9.49	56.94	28.97
All Angus	9.74	58.44	29.22	9.23	55.38	27.69

The preformed creatinine coefficient of these cattle falls slightly with increased body weight. Since the creatinine coefficient is indicative of muscle metabolism this result suggests the formation of higher percentages of adipose tissue as the animals mature. This again is in keeping with the hypothesis that the growth rate of these groups of experimental calves was a reflection of growth hormone activity. The results indicate (Figure 4.16) that as rate of gain decreases the creatinine coefficient also decreases. This phenomenon was particularly notable at 800 pounds body weight. These results suggest that the faster gaining more efficient groups of calves were still growing in the protein sense while their counterparts entered a phase of relatively reduced protein growth activity at an earlier age and had layed on greater amounts of fat by the time they reached 800 pounds body weight. That both rapid and slow gaining groups exhibited higher

creatinine coefficients at 500 pounds than at 800 pounds suggests that all groups entered a stage in which metabolism shifted somewhat from a protein toward an adipose type of growth as body weight increased. Total urinary creatinine excretion per day (Figure 4.11) indicates that since creatinine excretion is considered an index of tissue and muscle metabolism (21,p.639) and since average creatinine excretion increased with increased rate and efficiency of gain, the faster gaining, more efficient groups were more active than the slower gaining, less efficient groups.

The mean creatinine coefficient was 11.00 at 500 pounds and 9.39 at 800 pounds body weight. The value at 500 pounds was in keeping with the mean creatinine coefficient value of 11.18 reported by Dinning, Gallup and Briggs (57,pp.157-161) for steers and the value at 800 pounds was in keeping with the mean creatinine coefficient value of 9.5 reported by Ashworth and Brody (13,p.9) for dairy cattle. These values are also quite close to the published values for humans and dogs. Lusk (146,pp.253-258) gave values of 8 to 11 for normal adult human males; 5.8 to 9.8 for normal adult human females; and 10 for normal adult dogs. Carpenter's (47,p.538) steers gave average creatinine coefficients ranging from 5.5 to 10.0 for fasting steers that had previously been on pasture.

From the foregoing it would appear that the rate of <u>net</u> anterior pituitary growth hormone activity (defined as

anterior pituitary growth hormone activity minus adrenocorticotrophic hormone activity) holds the key to selections for rate and efficiency of gain in beef cattle where these two production factors are measured by body weight increase and where plane of nutrition is not a limiting factor. The problem, then, is to develop some economically feasible method through which to measure net anterior pituitary growth hormone activity at physiologically critical points in the growth sequence. It is possible that methods can be developed employing the more promising metabolites considered in this study through which a measurement of hormone activity could be obtained in the individual herd replacement animal. Such a method would greatly enhance selection for rate and efficiency of gain in beef cattle.

CHAPTER VI

SUMMARY AND CONCLUSIONS

> "If we are confronted still with a formidable array of problems not yet solved, we may take courage from the certainty that we shall solve a great number of them in the future as so many have been solved in the past."
>
> Edmund B. Wilson.

1. The association of nitrogenous products in blood and urine with rate and efficiency of gain in 45 purebred Hereford and Aberdeen Angus bull and heifer calves which were fed ad libitum through a test period from 500 to 800 pounds body weight has been studied.

2. Average daily gain in pounds from 500 to 800 pounds body weight for the major calf groups was: Males 2.90, females 2.14, Herefords 2.56, Angus 2.31, and all animals 2.46.

3. Average efficiency of gain, expressed as pounds of TDN per 100 pounds gain during the 500-to-800-pound test period, for the major calf groups was: Males 357, females 510, Herefords 417, Angus 490, and all animals 444.

4. As daily rate of gain decreased total feed intake increased for the experimental period during which the animals gained 300 pounds body weight.

5. As daily rate of gain decreased daily feed intake increased. Therefore, rate of gain must be explained on the basis of differences in feed efficiency rather than

daily feed consumption.

6. As efficiency of gain decreased total feed intake increased for the experimental period from 500 to 800 pounds body weight.

7. As efficiency of gain decreased daily feed intake increased in the calf groups studied.

8. On the basis of nitrogen excretion, all experimental groups exceeded the crude protein intake allowance for growing cattle proposed by Ashworth and Brody.

9. Age of a calf when put on test at 500 pounds live weight had no significant (1% level) effect on efficiency of gain. This indicates that either the older animals suffered some irreversible, metabolic disturbance from which complete recovery was impossible or that the polygenic complexes that made the older animals inefficient while on test were also functional, thus making the animals inefficient and slower growing at earlier ages.

10. Age of calf when put on test at 500 pounds live weight had no significant effect on rate of gain during the test.

11. Rate of gain was plotted against four nitrogenous constituents of the blood, namely: Urea nitrogen, amino acid nitrogen, creatinine and uric acid.

12. As rate of gain decreased, urea and amino acid nitrogen concentration per 100 cc. of blood increased in

a somewhat linear manner at both 500 and 800 pounds body weight. The difference in blood urea concentration with higher levels at 500 than at 800 pounds body weight may be explained on the basis of Van Slyke's urine volume excretion "Augmentation levels."

13. Linearity did not result when rate of gain was plotted against creatinine and uric acid concentrations at 500 and 800 pounds body weight.

14. As efficiency of gain decreased, urea and amino acid nitrogen concentration per 100 cc. of blood increased in a linear manner at both 500 and 800 pounds body weight.

15. When efficiency of gain was plotted against creatinine and uric acid concentrations at 500 and 800 pounds body weight, no linear relations could be established.

16. Results of blood analyses indicate that the faster gaining groups were under anterior pituitary growth hormone influence to a greater degree or under adrenocorticotrophic hormone influence to a lesser degree than the slower growing groups.

17. Blood data further suggest that slower gaining groups tended to lay on finish (fat) starting at a weight of less than 500 pounds.

18. Blood values for amino acid nitrogen and blood creatinine per 100 cc. increased with the increase in body weight from 500 to 800 pounds. Blood urea nitrogen

concentrations decreased during the same period.

19. A lower daily rate of gain at 500 pounds body weight was linearly associated with increased excretion of urinary total nitrogen, urea nitrogen, urea nitrogen excretion per kilo body weight, and the uric acid coefficient.

20. Decreases in rate of gain at 800 pounds body weight were linearly related to increases in total urine volume, total nitrogen, urea nitrogen, total nitrogen excretion per kilo body weight and urea nitrogen excretion per kilo body weight.

21. Creatinine excretion and creatinine coefficients increased linearly with increases in rate of gain at 800 pounds and approximately linearly at 500 pounds body weight.

22. Decreases in efficiency of gain were linearly related to increased excretion of total urinary nitrogen, urea nitrogen, urea nitrogen excretion per kilo body weight, and uric acid coefficients at 500 pounds body weight.

23. At 800 pounds body weight, decreases in efficiency of gain were linearly related to increased excretion of total urine volume, urinary nitrogen, urea nitrogen, total nitrogen per kilo body weight and urea nitrogen per kilo body weight.

24. Creatinine excretion and creatinine coefficients increased linearly with increased efficiency of gain at 800 pounds and to an approximately linear degree at 500 pounds

body weight.

25. Urine excretion values for total volume, total nitrogen, total nitrogen per kilo body weight, urea nitrogen, urea nitrogen per kilo body weight, ammonia nitrogen, urea:ammonia nitrogen ratios, creatinine and uric acid increased with the increase in weight from 500 to 800 pounds body weight. Creatinine coefficients decreased during the same period.

26. Nitrogen retention rates per 24 hours indicated that at 800 pounds live weight the faster gaining, more efficient groups retained more dietary nitrogen and a higher percentage of nitrogen than the slower gaining, less efficient groups.

27. Results of urinalyses substantiate the hypothesis that the faster gaining groups were under net anterior pituitary growth hormone influence to a greater degree than the slower gaining groups.

28. Creatinine coefficients suggest that while all groups had shifted somewhat from a protein to an adipose metabolism, the faster gaining, more efficient groups of calves were still growing in the protein sense while their counterparts entered a phase of reduced protein growth activity at an earlier age and had laid on more fat by the time they reached 800 pounds body weight.

29. It is entirely probable that methods can be developed, employing the more promising nitrogenous factors

studied, through which selection for rate and efficiency of gain in beef cattle may be enhanced.

CHAPTER VII

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