THE EFFECT OF ENERGY AND PROTEIN DENSITY ON THE GROWTH OF WEANLING QUARTER HORSES

By

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CHAPTER I

INTRODUCTION

In order to compete in today's horse industry, horsemen have placed increasing demands on young horses. Attempts have been made to grow foals larger at an earlier age so that they may be more competitive at shows and sales. Little research effort has been made to determine optimum protein to calorie ratios for the maximum growth of weanlings. It is unknown as to the effect maximum growth rates may have on bone development and the subsequent soundness of young horses.

Many horsemen believe that weanlings which grow at maximum rates will not stay sound, yet no data is available to support this hypothesis. Veterinary clinicians have indicated that physitis, caused by rapid growth rates, may result in soundness problems (Lewis, 1979). The NRC (1978) states that "the question of how fast a horse should grow for maximum performance and soundness still remains unresolved". Common opinion differs as to the cause of unsoundness problems sometimes seen in rapidly growing horses.

Protein requirements for growing horses have been extensively studied, although little work has been conducted with dietary protein to energy relationships for growing horses. The purpose of this project was to determine the effect of varying protein to energy ratios and amounts on the development and soundness of weanling horses. Therefore, the objectives of this study were: 1. To determine the optimum protein to calorie ratio for maximum growth and optimum densities of protein and energy for maximum growth; 2. To determine the effect of protein to calorie ratio, along with protein and energy densities on bone growth and clinical bone disorders; 3. To provide general estimates of growth parameter responses over time.

CHAPTER II

REVIEW OF LITERATURE

Requirements

The NRC (1978) provides estimated growth curves for horses and ponies of various mature weights. The entire growth curve appears to be a quadratic function from birth to maturity. Most research indicates that growth from birth to about 12 months of age is a linear function which then slows with mature weight being reached from 36-60 months (Cunningham and Fowler, 1961; Reed and Dunn, 1977; Jordan, 1977).

Total body growth consists of skeletal growth, protein accretion and fat accretion. A common measure of growth is weight gained in the horse and most growing horse diets are formulated to take a horse to an estimated mature weight. The NRC (1978) estimate of digestible energy (DE) requirement above that for maintenance is: $Y = 3.8 + 12.3X - 6.6X^2$ where Y is kilocalories of DE per gram of gain and X the fraction of adult weight. The NRC (1978) also estimated the digestible protein (DP) requirement for growth in g/d above maintenance from the equation: (Body protein concentration x g of gain/day)/.45. The NRC (1978) recommends diets of weanlings at 6 month of age to contain 3.1 Mcal of DE/kg with a crude protein (CP) percent of 16. This equates to a protein to calorie ratio of 52 g CP/Mcal DE for weanlings of this age.

Equine Studies

Recently work has been conducted with weanlings and yearlings to measure the effects of protein intake on growth. Foals that received high levels of protein (20% CP) and more energy from increased feed intake grew faster than those fed lower levels of protein (Craxton et al., 1979). Possible explanations for the increased growth observed in that trial may be increased energy intake or the amino acid (aa) requirement for growth was not met at lower levels. Energy intake were not reported and composition of growth was not estimated by those workers. Studies conducted with ponies have shown protein levels above 11% CP to have no significant effect on weight gains through most stages of growth (Jordan and Hackett, 1977; Yoakam et al., 1978; Jordan, 1979). In two related studies, young ponies fed diets containing 14-15.5% CP (220 CP g/day) outgained ponies fed diets containing 11-12% CP (120 CP g/day) from 4-6 months of age. By eight months of age protein levels had no significant effect on average daily gain, and weight gains of the ponies fed at higher levels of protein were either similar or less by one year of age (Jordan and Myers, 1972; Yoakam et al., 1978). Those workers suggested that the 14-15.5 percent crude protein diets were closer to NRC recommendations in their protein to calorie ratios, particularly during more rapid growth phases.

One possible explanation for increased growth, when feeding increased protein diets as in the above studies, is that amino acid requirements for growth are not met at lower protein intakes during rapid growth. In four to five month old ponies, increased lysine levels caused significantly faster rates of gain (Jordan and Hackett, 1977). However, when the same foals were six to eight months of age, higher lysine levels had no effect on gain. It appears that during rapid growth stages protein intakes may affect growth rates, but over long periods of time the effect of protein intake appears to be minimal. Other workers have shown that yearling horses that received lysine intakes of 40 g/d or more have more rapid weight gains when compared with those which received 35 g/d (Ott and Richardson, 1977; Ott et al., 1979). Although work is limited with other amino acids, methionine supplementation has shown no significant differences on growth of young horses as measured by gain, height or cannon length (Godbee et al., 1983; Champe and Edwards, 1983).

Differences in growth seen in studies conducted with ponies or horses may be explained by their composition of gain. Since ponies reach their mature weights in less time than horses, it is difficult to compare horses and ponies at a given day of age. No composition of gain data was reported to compare the horses to ponies of the previously mentioned trials. Furthermore, little composition of gain data is available for horses.

Unlike protein, a limited amount of work has been done varying the level of energy fed to growing horses. Yearlings that were restricted to energy intakes of 85 percent of NRC recommendations versus yearlings fed at 100 percent of NRC recommendations for 100 d showed significant increases in weight gain, heart girth, and height at withers (Coleman and Devlin, 1977). In a trial conducted to determine the effect of creep feeding versus noncreep feeding, Thompson et al. (1985) determined that weanlings fed creep feed had significantly higher weight gains through four months of age.

Energy and Protein Effect on Other Species

Although work conducted on growing horses is limited, several related studies have been conducted on other species.

Swine

Babatunde et al. (1967) conducted a study with growing swine to determine the effects of level of feed intake on chemical composition of the empty body. One group was assigned full-feed intake while two other groups received 1.82 kg/d. The two levels of energy had no significant effect on skeletal growth. However, the high energy diet produced pigs with more absolute protein and a greater percentage of fat. This agrees with previously conducted studies that support these findings (McMeekan, 1941; Elsley et al., 1964; Fowler, 1972; Elsley, 1976). In all studies, variation in fat deposition was affected by level of nutrition but the growth of the muscle, bone and other tissues remained relatively constant compared to each other, and were the same once an allowance was made for the stage of development at which the comparisons were made (Elsley, 1976).

It is known that protein to calorie ratio affects feed intake in swine (Clawson, 1967; Noland and Scott, 1960) and various trials have been conducted to manipulate protein and energy intakes. One method was to hold energy density constant while increasing protein at graded levels. The other method was to increase the absolute amount of energy and crude protein while holding crude protein to calorie ratio constant. Wagner et al. (1963) conducted a trial to determine the effect of protein and energy relationships on carcass composition and average daily gain by increasing protein level and energy density of trial diets in a factorial manner, thus maintaining the same protein to calorie ratio. The data appeared to indicate that once 13% CP had been reached in the diet, energy limited further increases in average daily gain. Increasing protein level in the diet decreased carcass backfat thickness and increased the yield of tissue nitrogen.

In graded protein studies difference in composition of gain and stage of growth have been found (Clawson et al., 1962; Cooke et al., 1972; Leibbrandt et al., 1975). While holding energy relatively constant, protein levels varied from 10 to 27.3 percent CP. In early stages of growth, narrow ratios supported rapid more weight gains (Clawson et al., 1962). This difference was not apparent at market weight. Maximum rate of lean growth and efficiency of feed conversion to lean was reached on diets at about 22 percent CP; whereas, maximum retention of DE was attained in pigs fed lower dietary protein levels. Pigs on lower percent CP diets had a greater percentage of body fat at slaughter when compared with those on higher levels of crude protein.

Other workers have compared different ratios of energy to protein at different concentrations in an effort to establish levels to support maximum growth of lean tissue at a defined level of feed intake (Noland and Scott, 1960; Cooke et al., 1972). In these three trials CP percentage ranged from 12 to 24 percent while energy levels increased. In the early stages of growth, rations with protein to calorie ratio of 50 to 100 g/Mcal DE produced the fastest gains, and gains increased in a linear fashion. When the energy density in the ration increased, the carcass percentage of fat increased. Increased levels of CP produced a greater yield of primal cuts when CP ranged from 16-20%. Noland (1960) noted that pigs fed higher levels of protein with lower levels of energy produced longer and leaner carcasses.

Lodge et al. (1972) formulated swine diets to have approximately the same ratio of CP to DE but with different energy densities and CP levels. His work again indicated that carcass fat content increased linearly with diets that had increasing energy densities. Although the absolute amount of carcass fat increased for the pigs fed diets denser in energy, the percentage of carcass fat was not significantly different when compared to carcasses from pigs fed diets lower in energy.

Beef Cattle

Work similar to that with swine was also done with beef cattle. Again, various levels of feed intake, energy density and protein concentrations were tested in an effort to determine their effect on carcass composition and rate of gain relative to meat production.

In establishing growth patterns of bovine muscle, fat and bone Berg and Butterfield (1968), Guenther et al. (1965), and Hendrickson et al. (1965) all noted effects of plane of nutrition on composition of gain. Berg and Butterfield (1968) indicated as weight increased, fat percentage increase while muscle and bone percentage decreased in cattle fed a high plane of nutrition, although muscle to bone ratios were not clear. On the other hand, feeding a low plane of nutrition resulted in decreased fat and muscle deposition, and unless severe, did not affect bone to any extent (Berg and Butterfield, 1968). In addition, feeding a high plane of nutrition affected muscle weight distribution in early stages of growth but had little effect at maturity (Berg and Butterfield, 1968). Waldman et al. (1971) noted that percentage of fat increased over the entire growth curve when compared to muscle and bone except during stages of rapid muscle accretion. Furthermore, bone development and muscle accretion were associated with stage of growth and not energy density through all stages of growth. Although this may be somewhat contradictory, cattle fed high energy diets had a greater percentage of body fat at slaughter which agrees with findings of Henrickson et al. (1965) and Jesse et al. (1976).

Guenther et al. (1965) reported that external fat increased during the finishing process as absolute amounts of energy increased. In addition, this study also noted that nutritional regime did not significantly influence bone development. There were no significant differences in area or density of bone due to feeding regime. Research indicates that after moderate feeding levels are reached, age and maturity are more positively related to bone growth.

It is evident that even during rapid protein accretion there must be some inherent limit to the daily rate of deposition (Whittemore, 1976). Once requirements for maximal protein accretion are reached, additional increments of protein have no effect on accretion of protein. Whittemore (1976) suggested that rate of protein accretion is related to mature protein mass and a ratio of fat to protein. This ratio probably varies with stage of growth. Energetically it has been theorized that energy is first limiting for bone growth, then muscle accretion, and finally fat deposition. This probably occurs throughout growth in varying degrees, depending on composition of gain.

Bone Growth in Equine

Bone development is especially important in horses because of the stress placed on the developing skeletal system of immature horses, particularly the bones of the leg. The effect of protein to calorie ratios on bone growth of weanlings has not been determined, although the technique is available. Meakim et al. (1981) conducted an experiment to determine the usefulness of radiographs in determining bone mineral content of equine third metacarpals (Mc III). The authors found that radiographs could be used with relatively good success to predict bone mineral content (correlation r =.94, P<.01). Then using radiographs Meakim et al. (1981) followed the growth of the Mc III of foals and found that bone mineral content (BMC) increased curvilinearly during the growing phase. A sex interaction was detected and male thoroughbreds had significantly higher BMC values. This agrees with Raisz and Kream (1981) who found sex hormones are associated with accelerated linear growth and epiphyseal closure. Bone growth appears to be more dependant on androgens than estrogens.

Thompson et al. (1985) conducted a trial to determine the influence of nutrition of normal bone growth patterns. BMC of Mc III and weight gains of weanlings fed 150% of NRC requirements for energy and calcium were higher when compared to those fed 100% of requirements. This data may suggest that as weanlings gain faster, their bones also become more dense.

Bone Disorders

Osteochondrosis can be defined as a disturbance of normal cell differentiation in growing cartilage affecting both metaphyseal growth plates and articular cartilage (Olsson and Reiland, 1978). Cartilage cells grow, but do not mature and vesiculate. Blood vessels fail to penetrate the cartilage and calcification of the bone matrix is inhibited. The defective calcification of cartilage results in a weakened metaphyseal component of the growth plate complex which may result in loss of structural integrity, microfractures and pain which cause callus formations and may lead to enlargement of the physis (Knight et al., 1985). This coupled with the subsequent pain may result in suboptimal soundness in horses.

Some clinicians have theorized that high energy feeding and rapid growth rates may influence the frequency of osteochondrosis (Lewis, 1979; Aver and Martens, 1980). Results of a survey conducted by Knight et al. (1985) indicated that horse farms which fed diets that had nutrient imbalances had increased occurances of bone disorders when compared to horse farms which fed diets that were balanced more closely to NRC recommendations. Reiland et al. (1978) conducted a trial with bulls in which various protein levels were fed with two energy levels, ad libitum and 80 percent ad libitum. All of the bulls in the ad libitum group showed some signs of osteochondrosis, while only 50% of the bulls in the 80% ad libitum group showed signs of osteochondrosis. The authors indicated that energy appeared to have an effect on osteochondrosis but protein did not appear to be an important factor.

Unlike Reiland et al. (1978), Thompson et al. (1985) found no significant differences in the physis of the distal radius of weanlings fed 150% of NRC requirements for energy and calcium when compared to those fed at 100% of requirements. Whether a fair comparison can be made between horses and bulls still remains unclear.

From the previously cited literature it appears that the optimum protein to calorie ratio for growing weanlings is still unknown. Further, no clear data is available to estimate what protein to calorie ratios will provide maximum growth rates for weanlings and, if maximum growth rates are achieved, what effect that might have on bone development. In addition, the effect of maximum growth rates on clinical bone disorders and subsequent soundness remains uncertain.

CHAPTER III

MATERIALS AND METHODS

Fifteen weanling quarter horses, eight fillies and seven colts were weaned in pairs at about 90 d of age. From 90 to 120 d weanlings were subjected to a gentling program in order that they could be handled and worked with minimal stress. During the gentling period the weanlings were taught to lead, brushed, and accustomed to having their legs handled. In addition to being gentled, each weanling was preconditioned on the ration shown in Table I which was fed twice daily until 120 d of age at which time treatments were imposed. The treatment period lasted 180 d. The weanlings were blocked by sex and age in a complete randomized block design experiment and allotted to three treatments of five horses per treatment.

During the trial each weanling was individually exercised and all weanlings were allowed to exercise freely for approximately 1 hour at least every third day. The individual exercise consisted of walking and trotting on a lounge line for approximately 3 hours per week. The weanlings were allowed to gallop while on the lounge line if they desired but were not forced to do so.

Ingredient composition of the trial rations is shown in Table I and nutrient compositions are shown in Table II. The weanlings alloted to treatment 1 received a diet based on oats, soybean meal (SBM), and alfalfa hay, which had a protein to calorie ratio of 52 g CP/Mcal DE, an

TABLE I

INGREDIENT COMPOSITION OF HAY AND CONCENTRATES FED TO WEANLINGS (DM BASIS)

Ingredient	IFN	Pre-cond. diet	% of diet 1	2	3
Alfalfa hay	1-00-059	25.51	25.71	25.96	25.94
Corn	4-02-985	51.02	0	68.82	61.20
Oats	4-03-309	0	55.27	0	0
Soybean meal	5-04-604	18.37	3.45	2.73	10.58
Cotton hulls	1-01-599	0	12.44	0	0
Molasses	4-04-695	3.06			
Limestone	--	1.53	1.23	1.10	1.24
Monophosphate	--	0	.88	0	0
Salt	--	.51	1.03	1.38	1.03
Vitamin A	7-05-143	2200 IU/kg	2200 IU/kg	2200 IU/kg	2200 IU/kg

TABLE II

NUTRIENT COMPOSITION OF HAY AND CONCENTRATES FED TO WEANLINGS (DM BASIS)

Item	Hay	Diet 1	Diet 2	Diet 3
Crude protein, %	21.8	12.4	11.9	14.7
Digestible energy, Mcal/kg*	2.41	2.89	3.73	3.71
Calcium, %	1.51	.87	.82	.90
Phosphorus, %	.49	.75	.52	.58
Zinc, ppm	21.95	10.21	20.34	21.24
Copper, ppm	14.11	5.77	4.97	5.65

*Estimated from NRC (1978).

energy density of 2.9 Mcal DE/kg and 14.5 percent CP. The weanlings allotted to treatment 2 received a diet based on corn, SBM and alfalfa hay which had a protein to calorie ratio of 42.5 g CP/Mcal DE, an energy density of 3.4 Mcal DE/kg and 14.5 percent CP. The weanlings allotted to treatment 3 received a diet based on corn, SBM and alfalfa hay also, but with a protein to calorie ratio of 50 g CP/Mcal DE, an energy density of 3.4 Mcal DE/kg and 18 percent CP. Diets 1 and 3 had similar protein to calorie ratios but in differing absolute amounts (Table III). Diet 2 had the same CP percent as diet 1, but had an energy density similar to diet 3.

Calcium and phosphorus were balanced at a ratio of 2 to 1 with limestone and monosodium phosphate. Calcium was 1.0% while phosphorus was .5% of the diet. Diets were based on 75 percent concentrate and 25 percent alfalfa. The weanlings were offered feed at 2.5 percent of their body weight daily and were allowed 12 hours to consume their rations, at which time any feed refused was weighed back and recorded. All weanlings were fed in equal feedings at 0600 and 1800 hours in individual stalls which measured 3.6 x 3.6 meters.

Beginning at 120 d of age, six measurements were taken weekly as indicators of growth.

I. Height at the withers. The vertical distance from the ground to the highest protruding thoracic vertebra in centimeters (cm).

II. Height at the hip. The vertical distance from the coronary band on the posterior side of the hoof to the furthest protruding point of the buttocks in cm.

TABLE III

PROTEIN TO CALORIE RATIOS (DM BASIS)

	Treatment					
	1		2		3	
Item	Calc.	Actual	Calc.	Actual	Calc.	Actual
Crude protein, %	14.5	14.75	14.5	14.38	18	16.48
DE, Mcal/kg	2.8	2.8	3.4	3.23	3.4	3.28
CP g/Mcal DE	52	52.7	42.5	44.5	52	50.2

III. Height at the hock. The vertical distance from the coronary band on the posterior side of the hoof to the point of the hock (Tubercalcis) in cm.

IV. Height at the shoulder. The vertical distance from the coronary band on the anterior side of the hoof to the point of the shoulder in cm.

V. Height at knee. The vertical distance from the coronary band on the anterior side of the hoof to the end of the distal radius.

VI. Weight. Weight determined at a single weighing, before morning feeding, and recorded to the nearest pound.

All weanlings were evaluated for fat thickness ultrasonicly at three anatomical sites at 0 and 6 months into the trial. The sites evaluated were (1) directly posterior to the midpoint of the scapula, (2) 5 cm lateral from the spinous process between the 12th and 13th ribs, and (3) over the rump 5 cm lateral from the midline at the center of the pelvic bone (Westervelt et al., 1976). On d 0 of the trial an Equiscan 9100[1] was used to determine fat thickness. At 6 months into the trial a scan-o-gram[2] was used to evaluate fat thickness, because the Equiscan was inoperative.

In addition to ultrasonic measurements the weanlings were condition scored at 0 and 6 months into the trial. Body condition scores were evaluated by the method described by Henneke et al. (1981) (Table IV).

The digestibility of energy and protein was determined at 2, 4, and 6 months into the trial. Chromic oxide was fed at a rate of 5 grams per

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[1]Equiscan, Model 9100, Bion Corporation, Fort Collins, CO.

[2]Scan-o-gram, Scanogram Co., Ithaca, NY

TABLE IV

CONDITION SCORE FOR HORSES

Score	
1	Poor. Animal extremely emaciated. Spinous processes, ribs, tailhead and hooks and pins projecting prominently. Bone structure of withers, shoulders and neck easily noticeable. No fatty tissues can be felt.
2	Very Thin. Animal emaciated. Slight fat covering over base of spinous processes, transverse processes of lumbar vertebrae feel rounder. Spinous processes, ribs, tailhead and hooks and pins prominent. Withers, shoulders and neck structures faintly discernable.
3	Thin. Fat built up about halfway on spinous processes, transverse processes cannot be felt. Slight fat cover over ribs. Spinous processes and ribs easily discernable. Tailhead and individual vertebrae cannot be visually identified. Hook bones appear rounded, but easily discernable. Pin bones not distinguishable. Wither, shoulders and neck accentuated.
4	Moderately Thin. Negative crease along back. Faint outline of ribs discernable. Tailhead prominence depends on conformation, fat can be felt around it. Hook bones not discernable. Wither, shoulders and neck not obviously thin.
5	Moderate. Back level. Ribs cannot be visually distinguished but can be easily felt. Fat around tailhead beginning to feel spongy. Withers appear rounded over spinous processes. Shoulders and neck blend smoothly into body.
6	Moderate to Fleshy. Slight crease down back. Fat over ribs feels spongy. Fat around tailhead feels soft. Fat beginning to be deposited along the sides of the withers, behind the shoulders and along the sides of the neck.
7	Fleshy. Crease down back. Individual ribs can be felt, but noticeable filling between ribs with fat. Fat around tailhead is soft. Fat deposited along withers, behind shoulders and neck.
8	Fat. Prominent crease down back. Difficult to feel ribs. Fat around tailhead very soft. Area along withers filled with fat. Area behind shoulder filled in flush. Noticeable thickening of neck. Fat deposited along inner buttocks.
9	Extremely fat. Extremely obvious crease down back. Patchy fat appearing over ribs. Bulging fat around tailhead, along withers, behind shoulders and along neck. Fat along inner buttocks may rub together. Flank filled in flush.

feeding at least five days prior to fecal collections which were conducted randomly over a 3 day period such that each 2 hour interval post feeding was represented. The samples were then frozen for later analyses. All samples were thawed and dried for 72 hours at 73 C. Dry samples were ground with a Wiley mill through a 1 mm screen. The nitrogen content of feed and feces was determined by standard Kjeldahl analysis (A.O.A.C., 1975). Digestible energy values were determined by oxygen bomb calorimetry. Feed and fecal samples were pelleted and burned under 30 atmospheres of oxygen. Energy values were determined by the method described by Parr (1968). The chromium content of the feces was determined colormetricly by the dry ash procedure described by Fenton and Fenton (1979).

Radiographs were taken at 2, 4 and 6 months into the trial. Two radiographs were taken of distal radius (DR) and third metacarpal (MC III), one anterioposterior (AP) and one lateromedial (LM). The procedure followed was described by Meakim et al. (1981) except stationary conventional equipment[3] was used rather than mobile x-ray equipment. Metered readings for voltage and amperage were adjusted to 70 KVP and 100 mA respectively, with a .033 second exposure time at a focal film distance of 101.6 cm. The x-ray film was also changed to Cronex 6+[4] with compatable Cronex Sp[5] screens. All film was processed by a rapid processor[6]. In all views, an aluminum (Al) step

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[3]Picker VTX 1550, Cleveland, Ohio.

[4,5]Cronex-6+ and Cronex SP, E.I. Dupont de Nemours and Co., Wilmington, DE.

[6]Kodak M6AW, Rochester, NY.

wedge[7] was exposed simultaneously as a reference standard (Meakim et al., 1981). Bone densities were estimated at three anatomical sites one centimeter below the nutrient furamen of the Mc III with a Wisconsin Densitometer (Model 211)[8]. The sites measured were: A) the longest path through the bone cortex on the medial side, B) the path midway between the two peaks, and C) the corresponding lateral peak. Direct measurements of bone diameter (BD) and medullary cavity width (M) were taken as described by Meakim et al. (1981). Each radiograph was standardized by background density and all exposed steps of the Al wedge were measured for density. Corresponding values were used in regression equations and radiographic bone aluminum equivalents (RBAE) were determined from these equations for each radiograph.

All radiographs were evaluated by a veterinary clinician with experience in evaluating clinical bone disorders. The emphasis of the study was placed on detection of osteochondrosis and physitis (epiphysitis) of the distal radius. Radiographs for each horse at 0, 3 and 6 months into the trial were evaluated simultaneously for changes over time. Radiographs were evaluated for joint space and clarity of joint margination as well as subchondral bone density and signs of osteochondrosis. Furthermore, physitis of the distal radius was detected by thickening of cortex along the border of the metaphyseal region, and increased lucency of the entire physis. In addition,

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[7] Al stepwedge penetrometer, Atomic Products Corp., Atom Lab Div. Center, Moriches, NY.

[8] Wisconsin Densitometer, Model 211, Nuclear Associates, Carle Placa, NY.

overall conformation and bone densities along with trabecular patterns were observed. A soft tissue assessment was made of joint pouches to detect joint hydrarthrosis and the possibility of bone effuse.

Statistical analyses which were suited to a split plot experiment were performed as recommended by Steele and Torrie (1980). Full models of least squares means were evaluated, and if no tendencies or statistical differences appeared, the model was reduced. Regression analysis was performed to determine best fit models over time for each parameter measured. Regression coefficients were tested for orthogonal heterogeneity of polynomial response curves to determine whether trends were parallel over time.

CHAPTER IV

RESULTS AND DISCUSSION

Intake

Intake of DM, DE and CP are shown in Table V. Although feed intake was designed to be the same as a percentage of body weight per day, feed intake of the weanlings in treatment 2 was significantly less ($P<.05$). This may be due to the protein to calorie imbalance of the diet fed to the weanlings in treatment 2. However, no significant differences were seen in intakes of the weanlings in treatments 1 or 3. Diets 1 and 3 had relatively the same protein to calorie ratios (52.7 and 50.2 g CP/Mcal DE respectively), and it did not appear that the higher energy density of diet 3 limited the weanlings intake. Mean daily average intake of crude protein (CP) were 876, 691 and 986 g for the weanlings in treatments 1, 2 and 3, respectively. Mean average daily intakes of gross energy (GE) were 26.2, 21.0 and 26.1 Mcal, which when multiplied by the energy digestibility coefficients were equal to 16.5, 15.6 and 19.7 Mcal of DE/d for weanlings on treatments 1, 2 and 3, respectively.

Digestibility

The digestibility of DM, DE and protein (ADP) of all diets over time was best described by a first degree polynomial and no significant time effect was seen on any treatment, which indicates digestibility of the diets remained constant. Since there was no difference in

TABLE V

DM INTAKES AND DIGESTIBILITIES OF DIETS FED TO WEANLING HORSES (DM BASIS)

Item	Diet 1	Diet 2	Diet 3	SE
DM intake, kg/day	5.94^{b}	4.83^{a}	6.00^{b}	.3
Crude protein (CP) intake, g/day	876^{b}	691^{a}	986^{c}	45
Digestible energy (DE), Mcal/day	16.5^{d}	15.6^{d}	19.7^{e}	1.2
DM digestibility, %	61.94^{a}	75.13^{b}	75.56^{b}	1.5
Apparent digestible CP, %	73.08^{b}	63.14^{a}	69.70^{b}	2.6
Gross energy digestibility, %	63.10^{a}	74.39^{b}	75.29^{b}	1.8

^{abc}Means in a row with different superscripts differ ($P<.05$).
^{de}Means in a row with different superscripts differ ($P<.10$).

digestibility over time, the data was pooled by treatment and is shown in Table V. Orthogonal contrast of digestibilities are shown in Tables VI, VII and VIII for DM, DE and ADP, respectively.

Dry matter digestibility of diets fed in treatments 2 and 3 showed no significant difference with mean digestibility percentages of 75.1 and 75.6, respectively. DM digestibility of diet 1 was significantly lower than DM digestibilities of diets 2 and 3 with a mean of 61.9 percent. This data indicates that total digestibility of corn based diets is higher than that of oat and cottonhull based diets. The increase in digestibility is probably due to a higher percentage of foregut and total tract digestion from more soluble starch available in the corn diets. The data are consistent with total digestible nutrient (TDN) values calculated for these types of diets from NRC (1978) values.

Apparent digestible protein values over time were best described by a first degree polynomial and no significant time effect was seen due to treatment. Orthogonal contrast for protein digestibilities (ADP) are given in Table VIII. Comparisons of ADP means showed a significant difference between the digestibility of diets 1 and 2 with means of 73.1 and 63.1 respectively. However, the digestibility of diets 2 and 3 had a tendency to be different ($P < .15$) with means of 63.1 and 69.7, respectively. Furthermore, the digestibility of diets 1 and 3 showed no significant differences in ADP. This data indicates that with these type diets in weanlings as a protein to calorie imbalance becomes more severe ADP may decrease. Protein digestibility appeared to be lower than values calculated from NRC (1978), which estimated digestible protein at 72-75 percent. More information is needed on the effect of nutrient imbalances on ADP in weanling diets.

TABLE VI

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR DRY MATTER DIGESTIBILITY AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	19	822.61		
2	9	47.15		
Total	28	869.76	31.06	
1, 2, 3	29	954.93		
Difference	1	85.17	85.17	2.74
	1 vs. 3			
1	9	540.53		
3	9	263.44		
Total	18	803.97	44.67	
1, 3	19	822.61		
Difference	1	18.64	18.64	.42

TABLE VII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR DIGESTIBLE ENERGY AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	19	1050.97		
2	9	31.06		
Total	28	1082.03	38.64	
1, 2, 3	29	1194.40		
Difference	1	112.37	112.37	3.92*
	1 vs. 3			
1	9	797.60		
3	9	218.38		
Total	18	1015.98	56.44	
1, 3	19	1050.97		
Difference	1	34.99	34.99	.62

*P<.10

TABLE VIII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR APPARENT DIGESTIBLE PROTEIN AMONG GROUPS WERE PARALLEL

		2 vs. 1, 3		
Error	D.F.	S.S.	M.S.	F
1, 3	19	1403.24		
2	9	134.83		
Total	28	1538.07	54.93	
1, 2, 3	29	1566.32		
Difference	1	28.25	28.25	.51
		1 vs. 3		
1	9	970.25		
3	9	345.58		
Total	18	1315.75	73.1	
1, 3	19	1403.24		
Difference	1	87.49	87.49	1.20

Protein to calorie ratios using ADP and DE values for diets 1, 2 and 3 are 38.8, 28.0 and 34.9 ADP/Mcal DE respectively. If conventional protein to calorie ratios are determined CP g/Mcal DE the diets 1, 2 and 3 are 52.7, 44.5 and 50.2 respectively. These values are the best estimate of the protein to calorie ratios used in this trial.

Digestible energy values over time were best described by a first degree polynomial. The digestibility of diets 2 and 3 showed no significant differences with mean values of 74.4 and 75.3 percent respectively. The digestibility of diets 2 and 3 were significantly different from diet 1 which had a mean value of 63.1 percent. This difference was probably due to the higher percentage of fiber in diet 1 of 20.8 percent crude fiber (CF) on a DM basis as compared to 9.6 percent CF for diets 2 and 3. Orthogonal contrast showed no significant difference in response over time except when the digestibility of diets 1 and 3 were compared to 2 ($P<.10$), Table VII. The biological significance of this trend is not clear.

Composition of Gain

Body composition of the weanlings was estimated by condition score and ultrasonic measurement of subcutaneous fat at three anatomical sites as previously described (Table IX). These fat measurements were used as a technique to measure relative body composition changes. Condition scores at 300 d of age were evaluated using initial condition scores (120 d of age) as a covariate. The weanlings on treatments 1 and 3 were not significantly different in the amount of fat covering as detected by condition scores. However, the condition scores of the weanlings on treatment 2 were significantly less than the weanlings on treatments 1

TABLE IX

INFLUENCE OF DIET ON CONDITION SCORES AND FAT THICKNESS OF WEANLING QUARTER HORSES AT 300 D OF AGE USING INITIAL MEASUREMENTS AS A COVARIATE

Parameter	Treatment 1	Treatment 2	Treatment 3	SE
Condition score				
300 d of age	5.76[a]	5.05[b]	5.50[a]	.1
Rump fat, mm				
300 d of age	7.92[a]	6.62[b]	8.01[a]	.3
Back fat, mm				
300 d of age	7.32[a]	6.48[b]	7.21[a]	.2
Rib fat, mm				
300 d of age	7.18	6.92	7.21	.4

[ab]Least square means in a row with different superscripts differ ($P < .05$)

or 3 at 300 d of age. Condition score gains by the weanlings on treatments 1, 2 and 3 were 1, .6 and .7, respectively.

Westervelt et al. (1976) indicated that coefficients of simple correlations between percent fat and ultrasonic fat thickness of mature horses was .90. Whether the composition estimates of mature horses and rapidly growing weanlings, based on subcutaneous fat thicness, is similar is unknown. Ultrasonic fat measurements were used only as relative comparisons of body composition and were not used to estimate body fat percentages. Ultrasonic fat scans for the rump area and back area showed trends similar to condition scores. The weanlings on treatments 1 and 3 were not significantly different for increases of fat in the rump or back area. The amount of fat gained in the rump and back area was 6.26 and 4.47 mm for the weanlings on treatments 1 and 3 respectively. However, the increase in fat thickness for the rump and back area were 4.0 and 4.0 mm respectively for the weanlings on treatment 2 which was significantly less than the weanlings on treatments 1 or 3. No significant differences for fat gained in the rib area were detected for the weanlings on treatments 1, 2 or 3. These data are consistent with those of Westervelt et al. (1976) who found that rump and back fat were highly correlated (r=.99) but rib fat was not as closely associated with either (r=.6).

Bone Growth

All bone measurement values are shown in Table X and were best described by a first degree polynomial. None of the measurements derived from radiographs had any significant difference due to sex or treatment. All radiographic bone aluminum equivalent (RBAE) values for

TABLE X

INFLUENCE OF DIET ON BONE GROWTH
OF WEANLING QUARTER HORSES

	All weanlings combined		
Parameter	Initial	Final	Difference
RBAE point A	17.87	22.76	4.89
RBAE point B	16.28	21.35	5.07
RBAE point C	18.60	23.72	5.12
AP cortical width, cm	3.05	3.32	.27
AP medullary width, cm	1.70	1.59	-.11
LM cortical width, cm	2.54	2.71	.23
LM medullary width, cm	1.56	1.26	.10
Third metacarpal length, cm	27.6	27.9	.3

bone density were combined to estimate changes over time and fit to a combined overall model for each variable measured.

Mean lateral peak values (RBAEA) when viewed AP increased over time from 17.87 at four months of age to 20.65 at 7 months to 22.75 at ten months (Figure 1). Mean values for the midoint peaks (RBAEB) increased from 16.28 to 18.64 to 21.35 at 4, 7 and 10 months respectively (Figure 2). Likewise, mean medial peak values (RBAEC) increased from 18.60 to 21.17 to 23.72 at 4, 7 and 10 months respectively (Figure 3). These data indicate that bone density increases linearly with age to 10 months. Meakim et al. (1981) indicated RBAE value equations were curvilinear, suggesting that the rate of deposition of bone mineral decreased as yearlings reached 470 days of age.

Means of physical measurements taken from AP radiographs showed as outer cortical distance increased from 3.05 cm to 3.21 cm to 3.32 cm (Figure 4) at 4, 7 and 10 months, medullary width decreased in the same fashion from 1.7 to 1.64 to 1.59 cm (Figure 5), respectively at 4, 7 and 10 months of age. From the LM view the mean cortical outer width also increased from 2.54 to 2.60 to 2.71 cm (Figure 6) at 4, 7 and 10 months respectively with a concurrent decrease in mean medullary width at 4, 7 and 10 months to 1.21, 1.21 and 1.19 cm (Figure 7) respectively. LM medullary width did show a tendency ($P<.06$) for a sex by treatment interaction, probably due to the difference in colts and fillies on treatment 3. The colts mean value was 1.35 cm while the fillies was 1.17 cm. Although this interaction was detected there is probably no biological significance to this finding. Third metacarpal length (McIII) increased in a similar fashion from 27.64 to 27.74 to 27.93 cm (Figure 8) at 4, 7 and 10 months respectively. Although an increase of

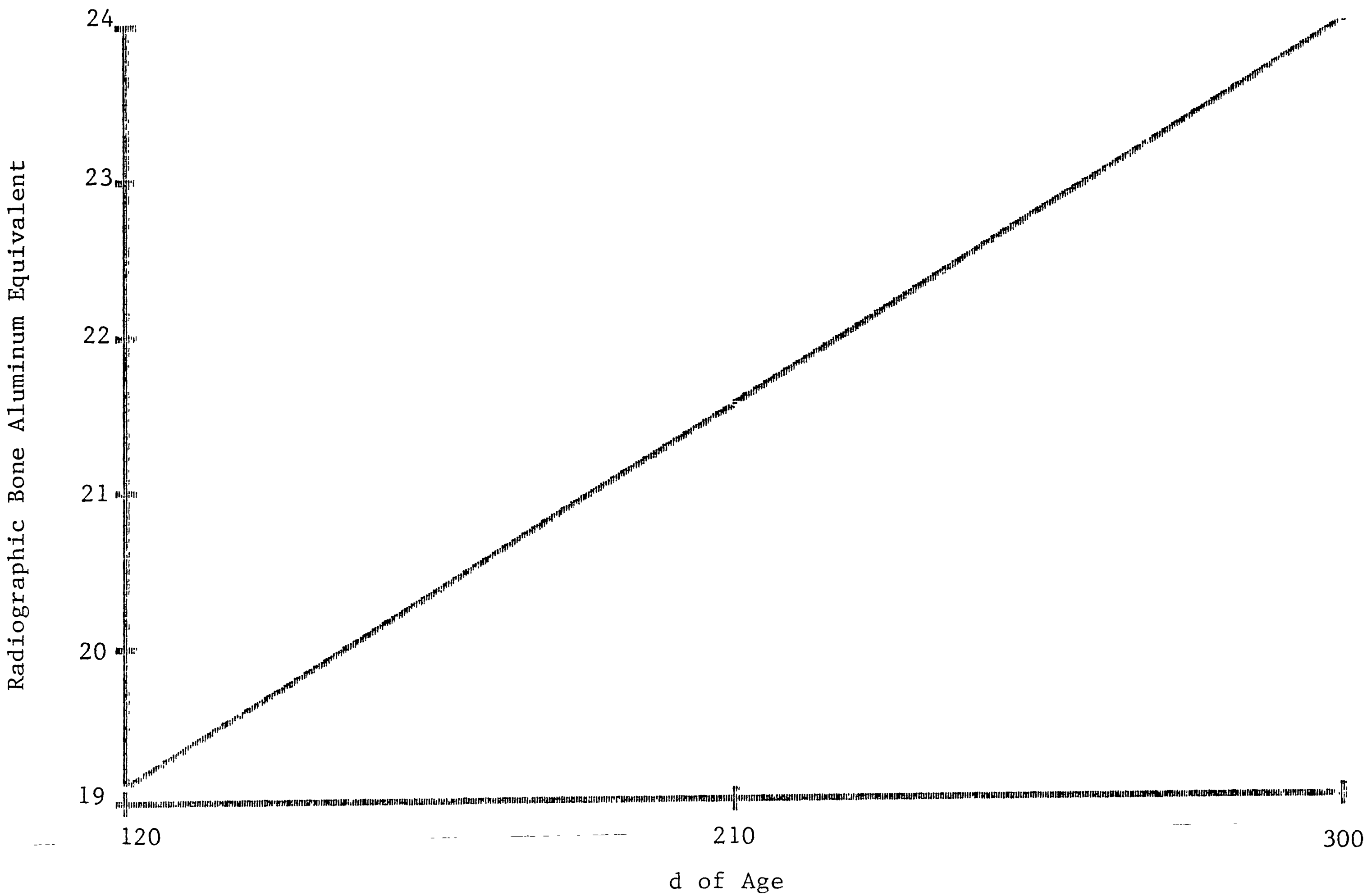

Figure 1. The Response of Bone Density at the Lateral Peak of the Third Metacarpal from the Anterior Posterior View for all Weanlings.

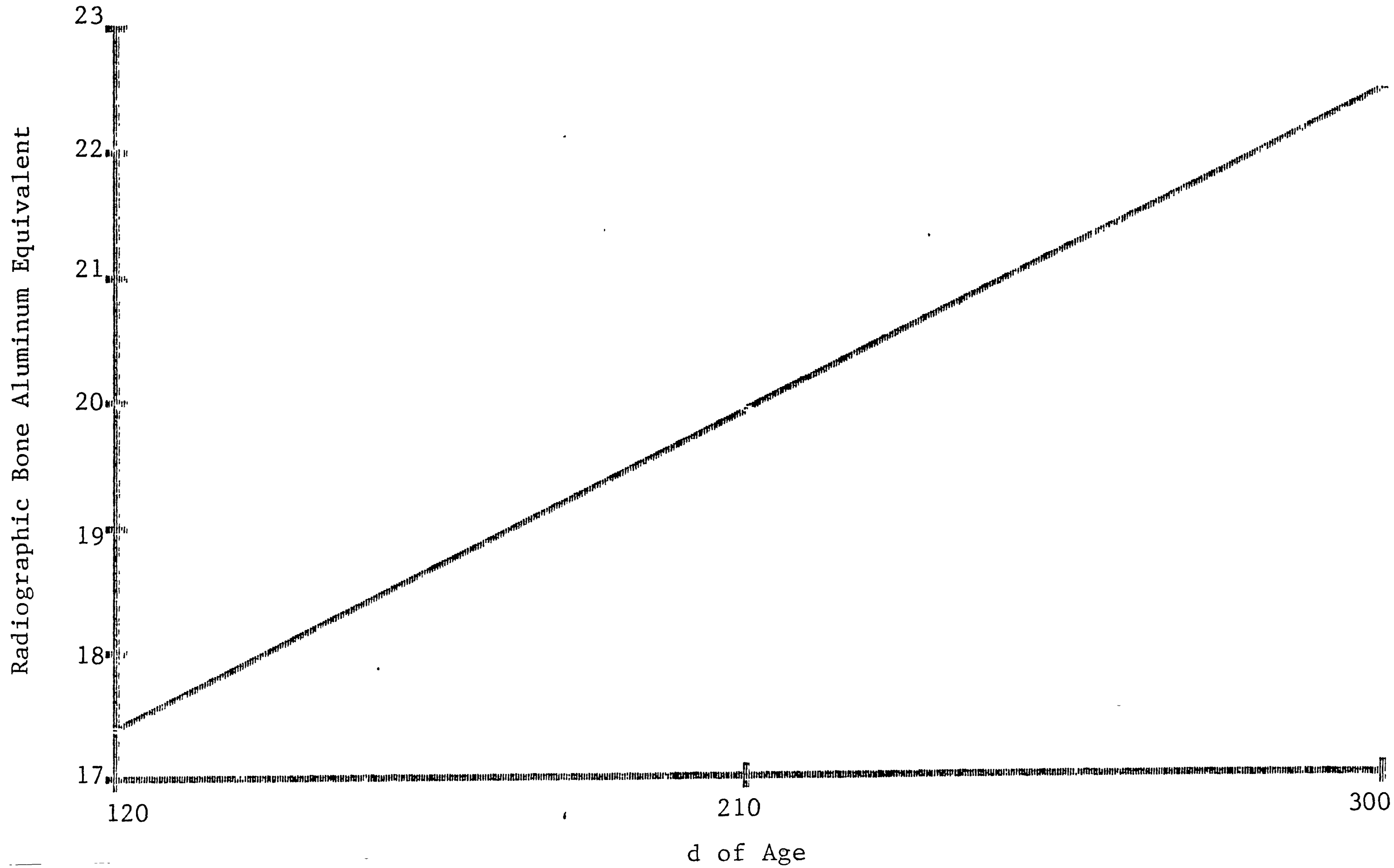

Figure 2. The Response of Bone Density at the Midpoint of the Third Metacarpal from the Anterior Posterior View for all Weanlings.

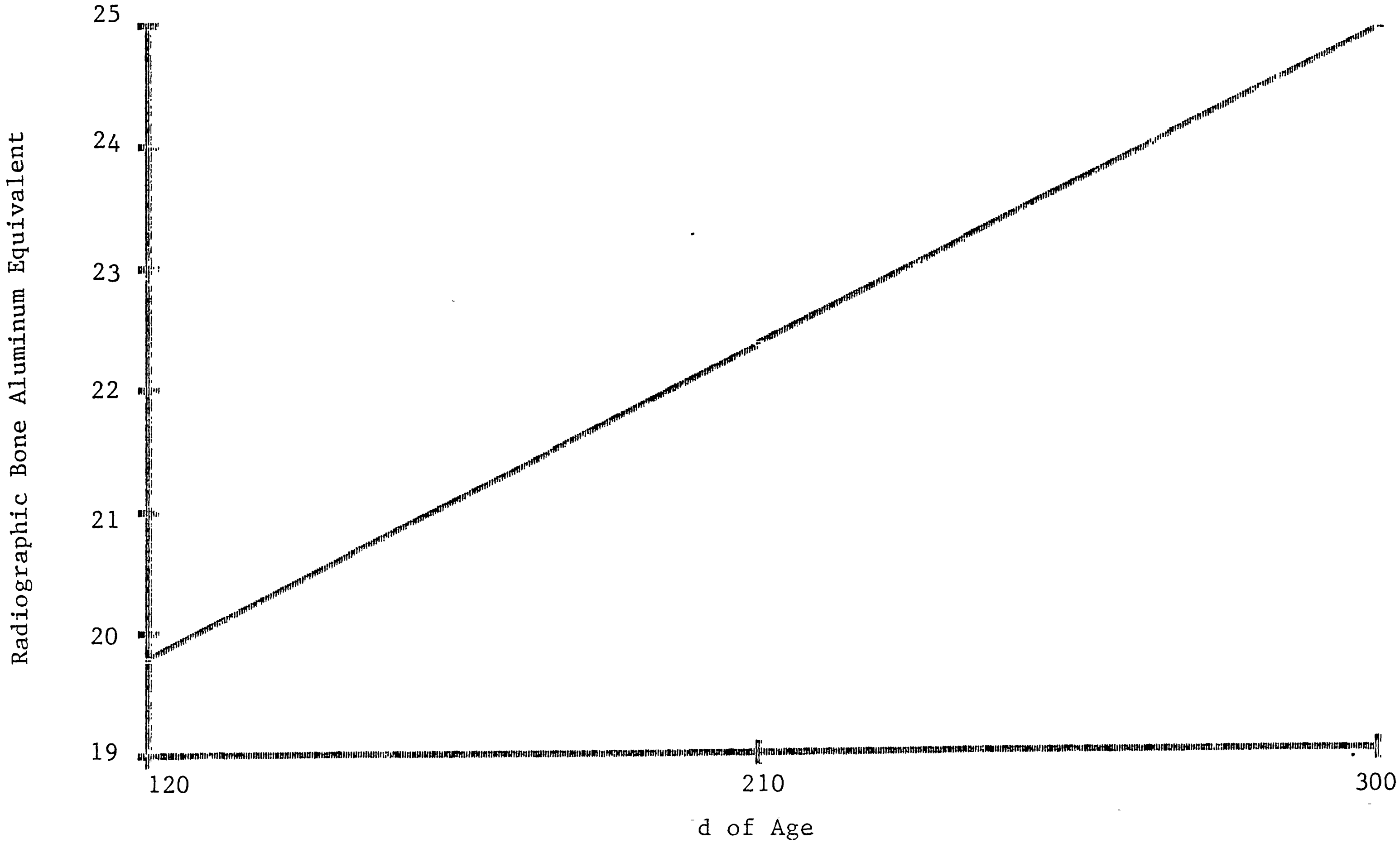

Figure 3. The Response of Bone Density at the Medial Peak of the Third Metacarpal from the Anterior Posterior View for all Weanlings.

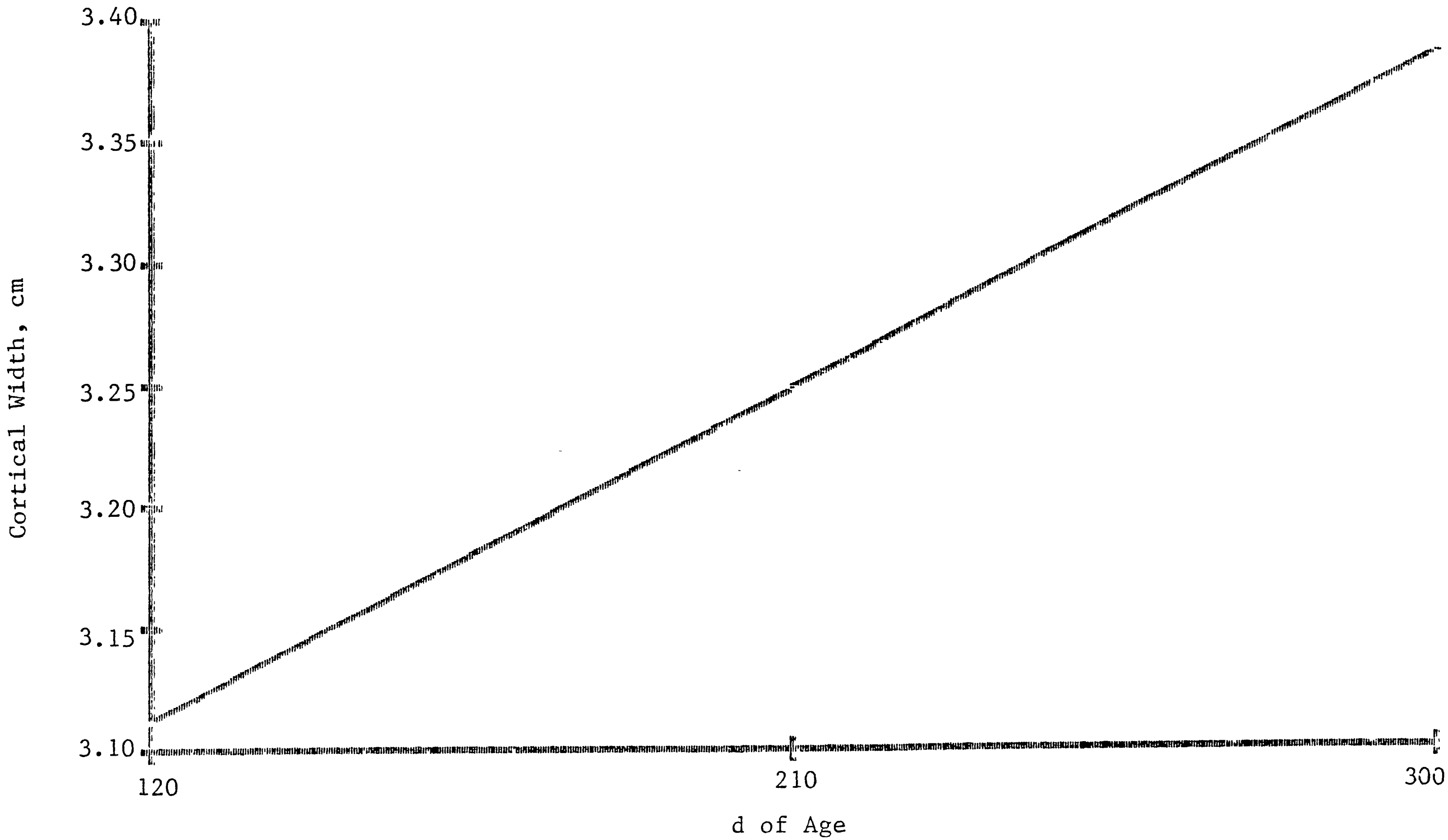

Figure 4. The Response of Cortical Width from the Anterior Posterior View for all Weanlings.

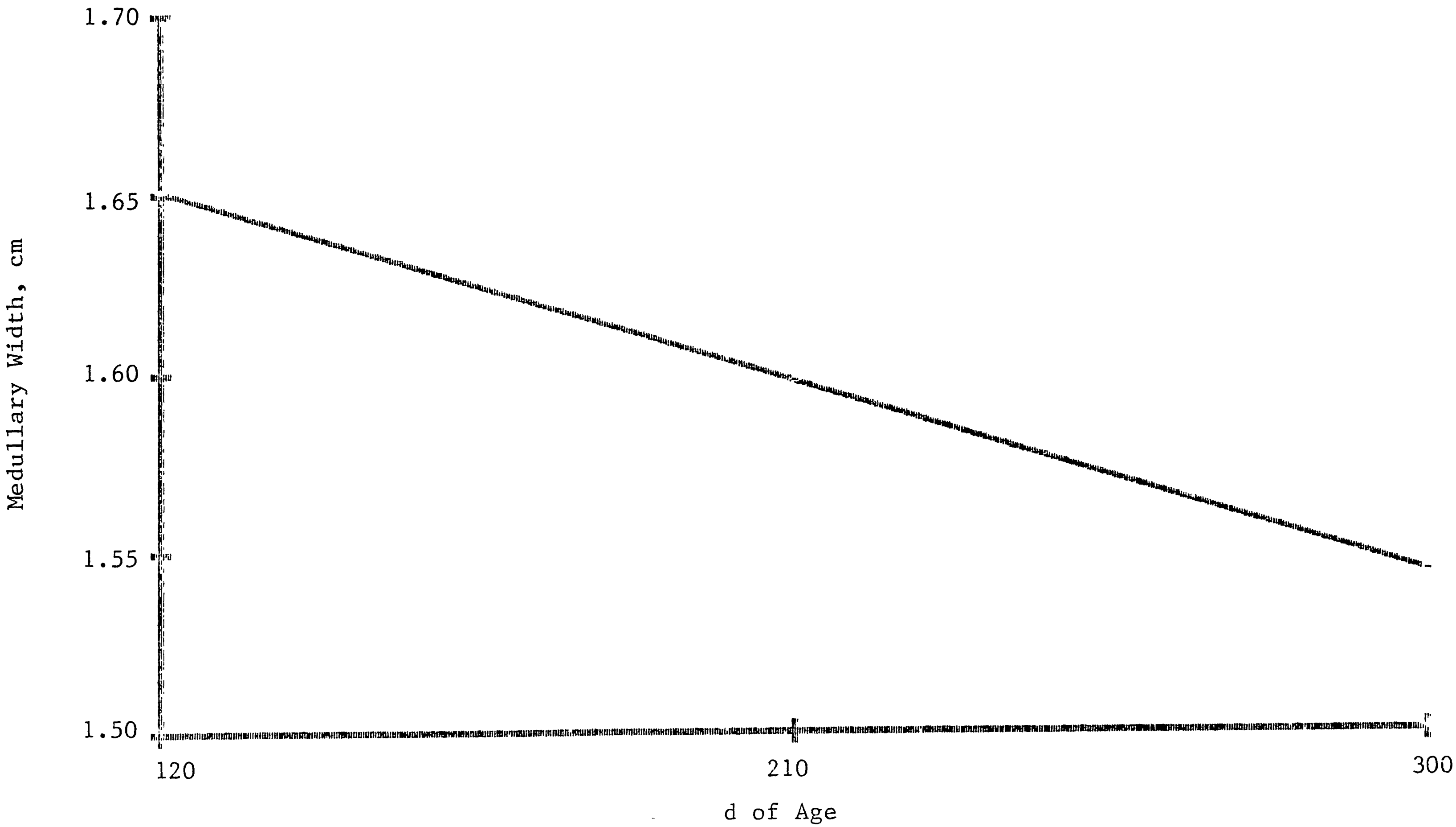

Figure 5. The Response of Medullary Width from the Anterior Posterior View for all Weanlings.

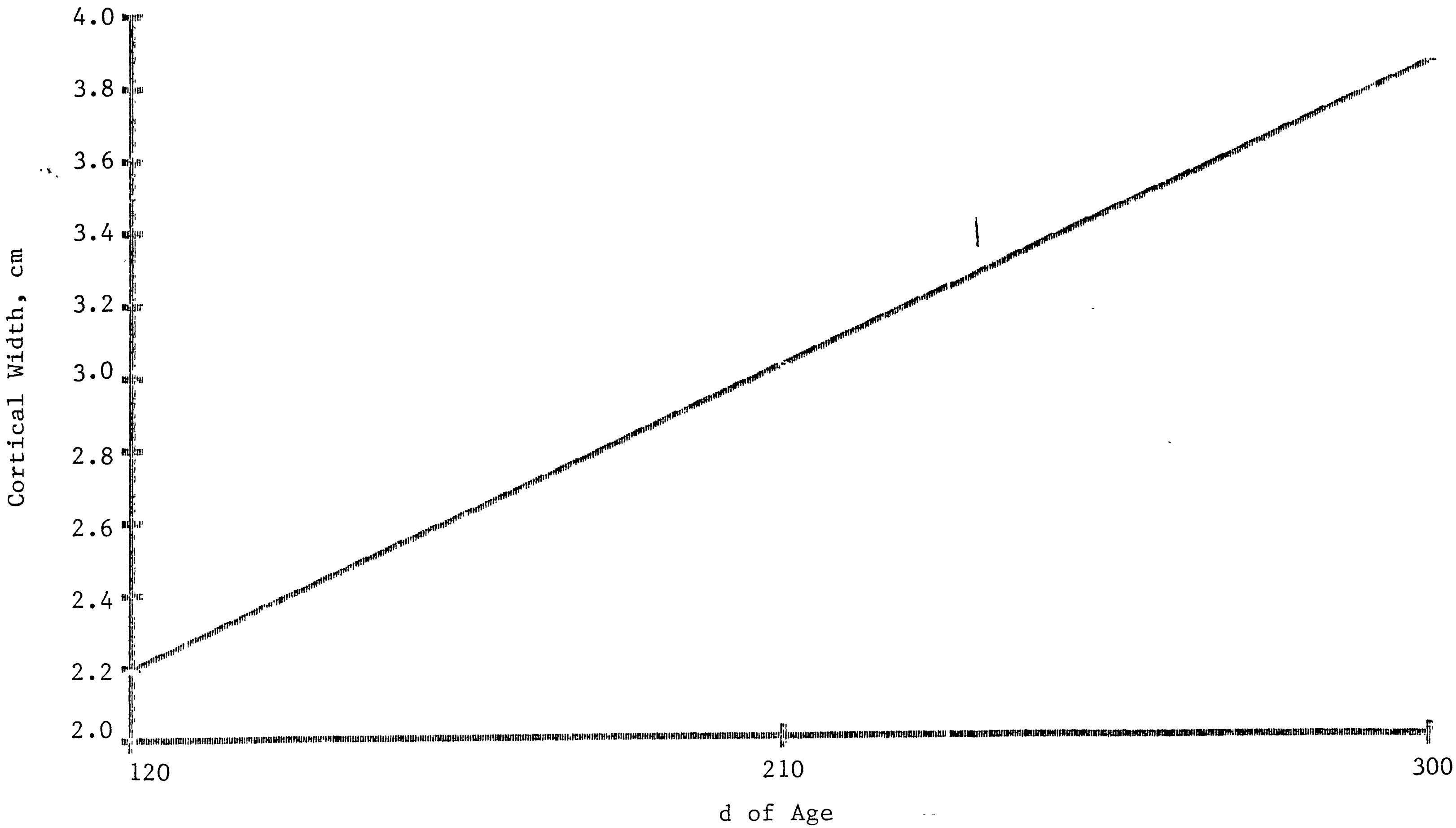

Figure 6. The Response of Cortical Width from the Laterial Medial View for all Weanlings.

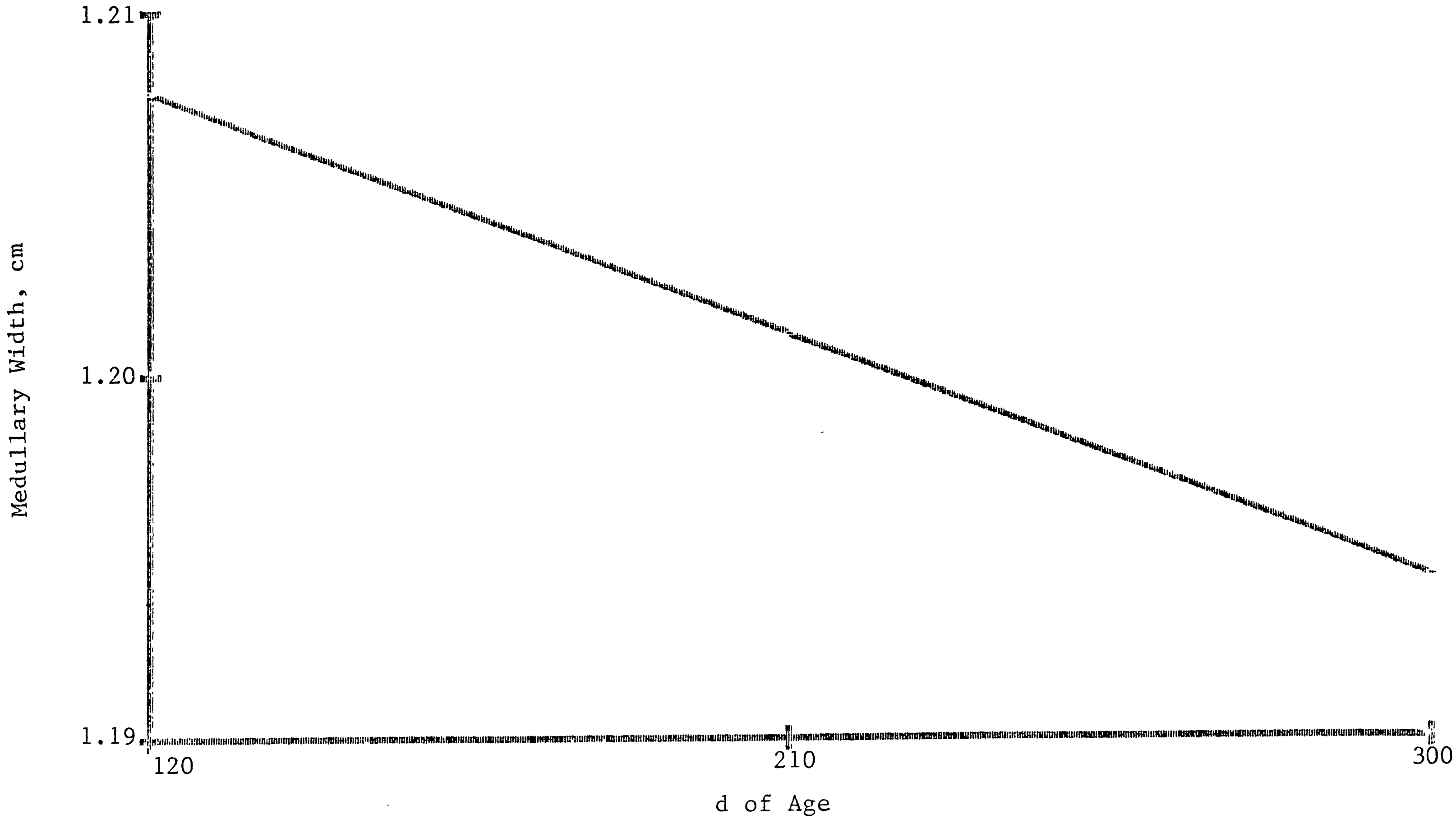

Figure 7. The Response of Medullary Width from the Lateral Medial View for all Weanlings.

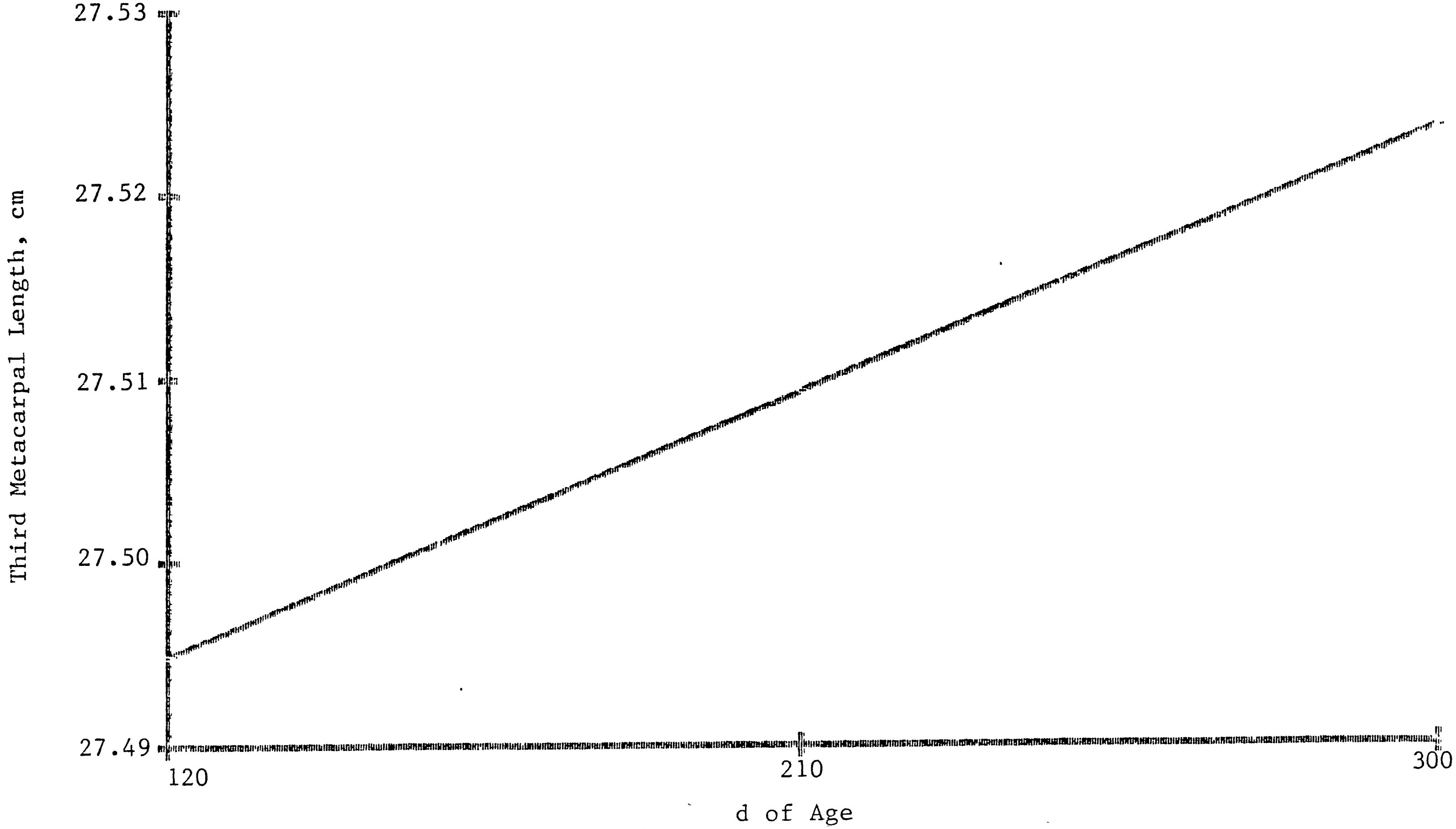

Figure 8. The Response of Third Metacarpal Length for all Weanlings.

3 mm was found, this data does not support the findings of Thompson et al. (1985), who observed significant differences between weanlings of mixed Quarter Horse and Thoroughbred breeding fed 100 and 150% of NRC requirements for DE.

The overall fits and mean values all suggest linear responses for weanlings during this stage of development. It was assumed that bone growth should be a quadratic function; however, the inflexion point of these overall growth curves for bone were likely not reached in this trial. It is apparent that bone growth must slow down somewhere after 10 months of age in Quarter Horses. This agrees with Meakim et al. (1985) in that decreased mineralization occurs after 10 months of age.

Bone Disorders

No signs of osteochondrosis existed for any weanling on any treatment at the distal radius or carpus region. One colt on treatment 1 showed signs of mild physitis of the dorsolateral aspect of the distal radial growth plate, which worsened slightly until 210 d of age. The physitis detected was evident before the weanling began on treatment and diet did not appear to aggravate his condition. No physical signs of lameness were detected at any time.

Although not an object of this study, some incidental findings were observed. One colt on treatment 2 was detected to have mild hydrarthrosis of both the right intercarpal joint and the right metacarpophalangeal joint at 210 d of age. By 300 d of age complete resolution of the right metacarpophalangeal joint hydrarthrosis had occurred, but no change was seen in the right intercarpal hydrarthrosis. One colt on treatment 3 showed signs of hydrarthrosis of the metacarpophalangeal joint at 120 d of age which was not evident by 210 d of age. One colt on treatment 1 showed signs of mild hydrarthrosis of the metacarpophalangeal joint at 210 d of age which was reduced to within normal limits at 300 d of age. The bones of all three previously mentioned weanlings were unremarkable. The hydrarthrosis seen in these weanlings was probably due to trauma encountered sometime during the trial. None of the weanlings showed any detectable signs of lameness.

One filly on treatment 2 showed incidental signs of physitis of the distal Mc III growth plate with thickening and slight widening of the cortex along the dorsal border in the metaphyseal region, and increased lucency of the entire physis at 120 d of age. By 210 d of age no evidence of active physitis existed, as the physis was about 90 percent closed at this time. The filly showed no visible signs of lameness through the trial.

Incidental findings of osteochondrosis were found in one colt on treatment 3. Lesions existed on the dorsal aspect of the median ridge of the Mc III at the metacarpophalangeal joint at 120 d of age. By 210 d of age a cartilage flap and subchondral sclerosis, along with hydrarthrosis of the metacarpophalangeal joint were evident. No interval change was detected by 300 d of age. The colt showed no visible signs of lameness throughout the trial. One filly showed slight flattening of the palmar aspect of the Mc III condyles, suggestive of osteocondrosis at 120 d of age. By 210 d of age the dorsal aspect of the median ridge of Mc III also seemingly became involved along with hydrarthrosis of the metacarpophalangeal joint. At 300 d of age the filly showed signs of osteochondrotic lesions and possible early signs of secondary degenerative joint disease (osteoarthrosis). During the trial the filly showed no signs of lameness. One filly on treatment 3 appeared to have essentially normal studies of the carpus and metacarpus at 120 d of age. However, by 210 d of age probable osteocondrotic lesions appeared on the dorsal aspect of the median ridge of the distal end of the Mc III bone with mild metacarpophalangeal joint hydrarthrosis manifested by mild roughening of periarticular margin of the dorsal aspect of the proximal end of the first phalanx. By 300 d of age progressive worsening of the osteocondrotic legion had occurred along with worsening of the periarticular osteophytes of the 1st phalanx. No evidence of lameness was detected throughout the trial.

Although the bone disorders found in this trial were incidental it may prove useful to future research to more closely follow the metacarpophalangeal joint. It also appears that radiographs will be needed from weanlings at earlier ages to detect initial signs of bone disorders. This data does not support any hypothesis that diet can or will cause bone disorders in weanlings. This agrees with Thompson et al. (1985) in that no evidence of bone disorders were seen by the feeding of diets which contained 150% of NRC (1978) requirements for DE.

Physical Measurements

Mean height at the knee is shown in Table XI. Weekly measurements for height at the knee were best described by a fourth degree (quartic) polynomial (Figure 9). It is assumed that the true response curve for height at the knee should be quadratic, but to find this type of response, measurements would be needed before 120 and after 300 d of age. Treatments 1, 2 and 3 showed no statistical difference in height gained at the knee. A sex by treatment interaction was detected ($P<.05$)

TABLE XI

INFLUENCE OF DIET ON HEIGHT AT THE KNEE, SHOULDER, HOCK AND HIP IN WEANLING QUARTER HORSES

	All weanlings combined		
Parameter	Initial	Final	Difference
Height at the knee, cm	41.06	44.11	3.05
Height at the shoulder, cm	88.78	99.11	10.33
Height at the hock, cm	53.70	58.76	5.06
Height at the hip, cm	104.43	118.22	13.79

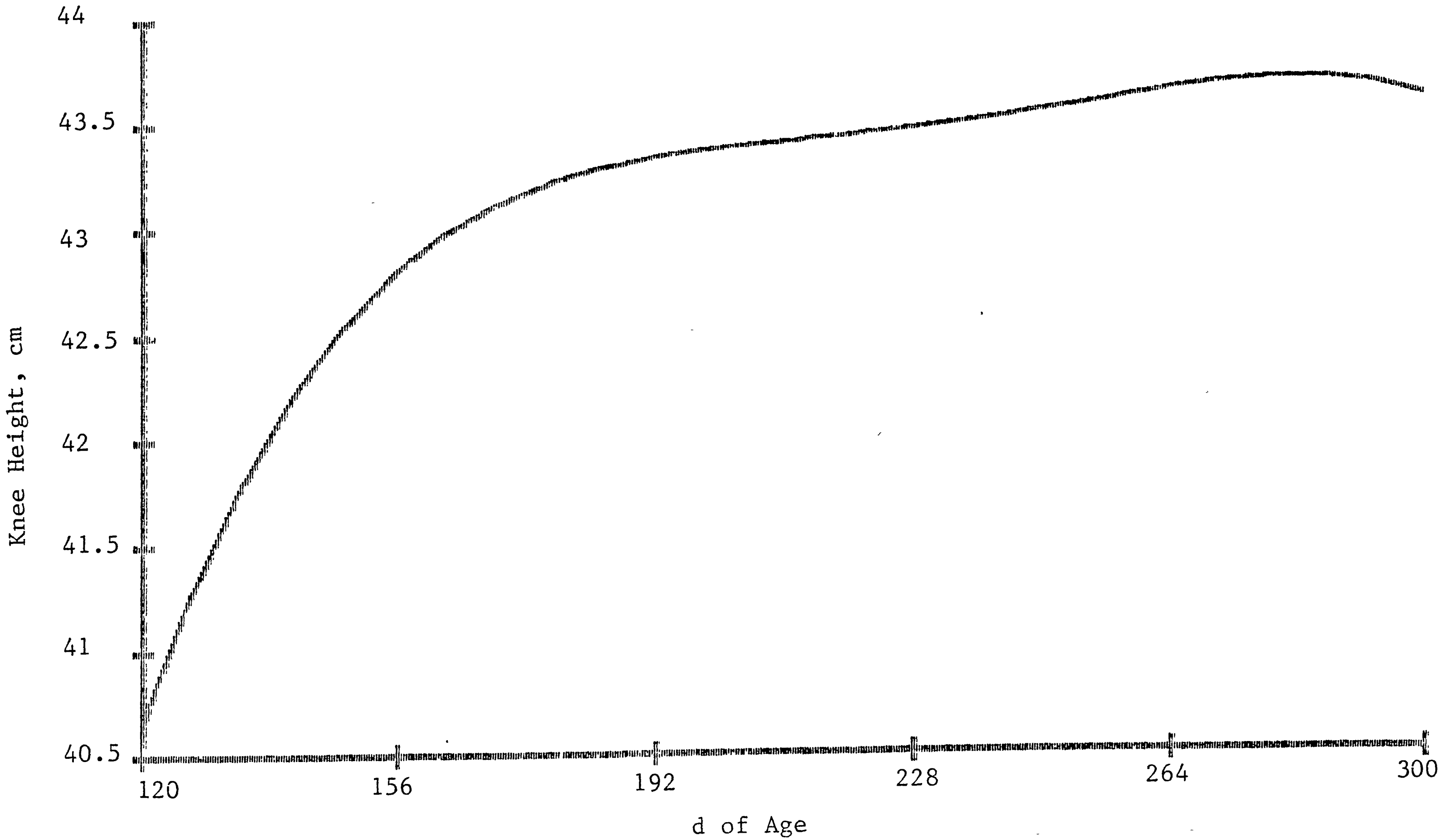

Figure 9. The Response of Height at the Knee for all Weanlings.

due to the response of colts on treatment 3. Initial and final height at the knee values were 41.06 and 44.11 cm for all weanlings combined, which appeared to be greater than means reported by Cunningham and Fowler (1961); this may be due to the genetic development of Quarter Horses in the last 25 years. Orthogonal comparisons (Table XII) indicated no significant difference between the weanlings on treatments 1 and 3 over time, but when the weanlings on treatments 1 and 3 were compared to the weanlings on treatment 2 they indicated significantly different responses over time, which may be due to the colts on treatment 3. This interaction would probably not be seen if larger numbers of weanlings had been used. Since the overall responses show that height at the knee increased from 41.06 cm at 4 months to 44.12 cm at 10 months of age, it appeared from the fit of the overall curve that height at the knee increases at a decreasing rate over time after approximately 170 d of age.

Mean height at the shoulder is shown in Table XI. The best fit for height at the shoulder was a third degree polynomial (Figure 10). Treatments 1, 2 and 3 had no significant differences in height at the shoulder. A treatment by sex interaction was detected ($P<.05$) on treatment 3 due to the response of the colts on that treatment. Orthogonal contrasts indicated that response over time was significantly different for the weanlings' height at the shoulder on treatments 1 and 3 (Table XIII). When height at the shoulder of the weanlings on treatments 1 and 3 were compared to 2 no significant difference in response over time was seen. It appears that the weanlings on treatment 3 continued to grow at a faster rate than did the weanlings on treatment 1 when height was measured at the shoulder. Overall response curves

TABLE XII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR HEIGHT AT THE KNEE AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	246	74.06		
2	122	12.67		
Total	368	86.73	.24	
1, 2, 3	372	91.38		
Difference	4	4.65	1.16	4.93*
	1 vs. 3			
1	121	28.24		
3	121	43.99		
Total	242	72.23	.51	
1, 3	246	74.06		
Difference	4	1.83	.46	.90

*P<.05

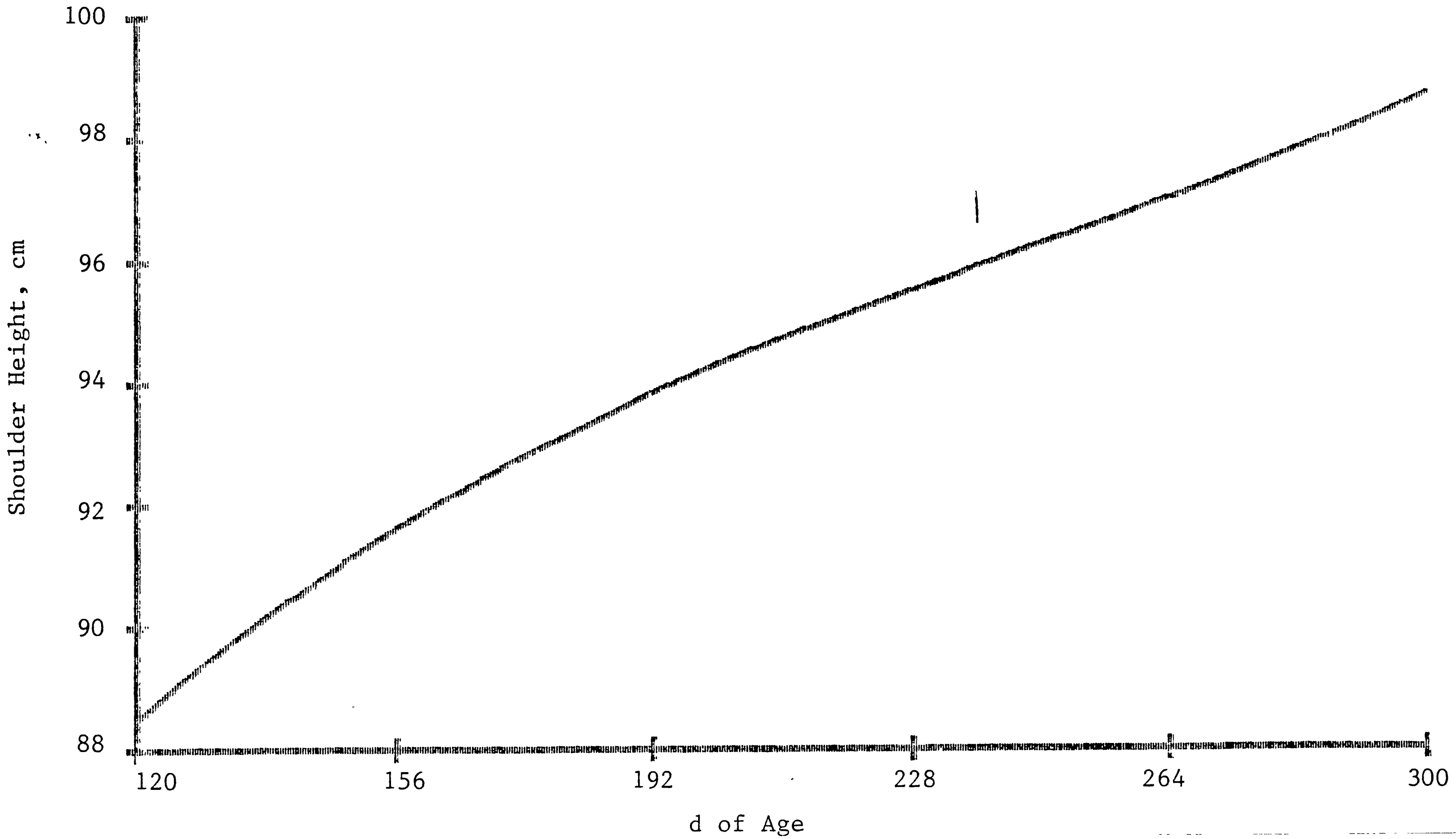

Figure 10. The Response of Height at the Shoulder for all Weanlings.

TABLE XIII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR HEIGHT AT THE SHOULDER AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	247	141.98		
2	123	55.94		
Total	370	197.92	.54	
1, 2, 3	373	199.44		
Difference	3	1.52	.51	.95
	1 vs. 3			
1	122	62.96		
3	122	66.00		
Total	244	128.96	.53	
1, 3	247	141.98		
Difference	3	13.02	4.34	8.21*

*P<.05

indicate that shoulder height increases most rapidly from birth to about 150 d of age.

Mean height at the hock is shown in Table XI. Height at the hock was best described by a third degree polynomial (Figure 11). The weanlings' response to treatments 1, 2 and 3 were not significantly different, when differences in height gained at the hock were compared. Again, a sex by treatment interaction was detected ($P<.05$) primarily due to the response of colts on treatment 3. The difference in initial and final mean values for height at the hock was 5.06 cm for all weanlings combined. These values appear to be consistent with the findings of Cunningham and Flower (1961) and Reed and Dunn (1977). Orthogonal contrast (Table XIV) indicated the weanlings on treatments 1 and 3 responded differently over time ($P<.05$), additionally when the weanlings on treatments 1 and 3 were compared to the weanlings on treatment 2 a significant response over time was detected ($P<.05$). It appears that the weanings on treatment 3 continued to grow faster for a longer period of time when height at the hock was measured as a growth response. The overall response indicates that increase in hock height appears to be most rapid before 170 d of age.

Mean height at the hip is shown in Table XI. Height at the hip was best described by a third degree polynomial (Figure 12). The weanlings on treatments 1, 2 and 3 showed no significnat differences in growth as measured by height at the hip. A sex by treatment effect was detected primarly due to the colts on treatment 3 ($P<.05$). Initial and final mean values for height at the hip were 104.43 and 118.22 cm respectively. Hock height values appear to be consistent with the findings of Cunningham and Flower (1961). Orthogonal contrast showed no

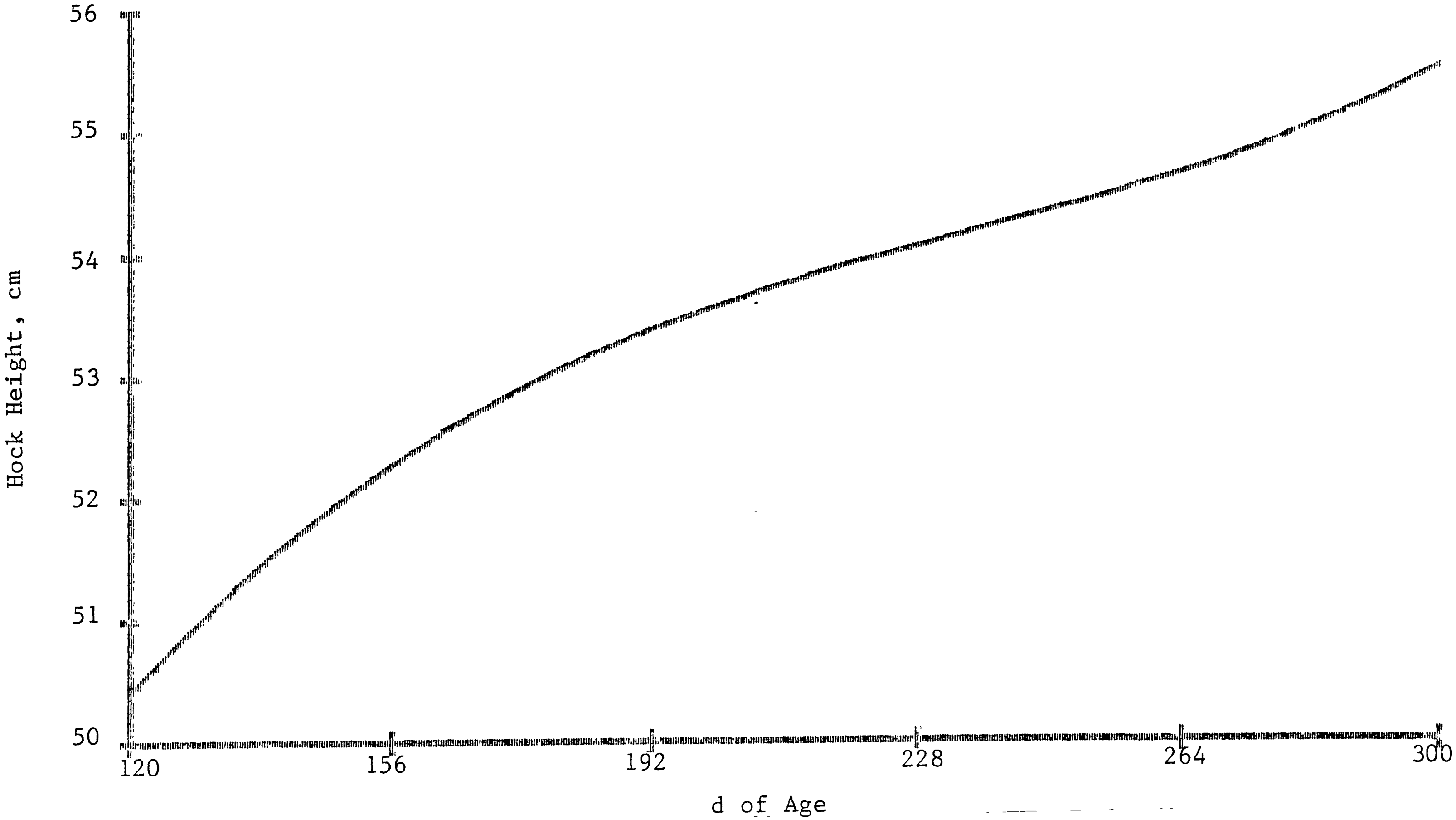

Figure 11. The Response of Height at the Hock for all Weanlings.

TABLE XIV

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR HEIGHT AT THE HOCK AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	247	90.87		
2	123	35.72		
Total	370	126.59	.34	
1, 2, 3	373	136.03		
Difference	3	9.44	3.15	9.20*
	1 vs. 3			
1	122	35.80		
3	122	37.93		
Total	244	73.73	.30	
1, 3	247	90.87		
Difference	3	17.14	.571	18.91*

*P<.05

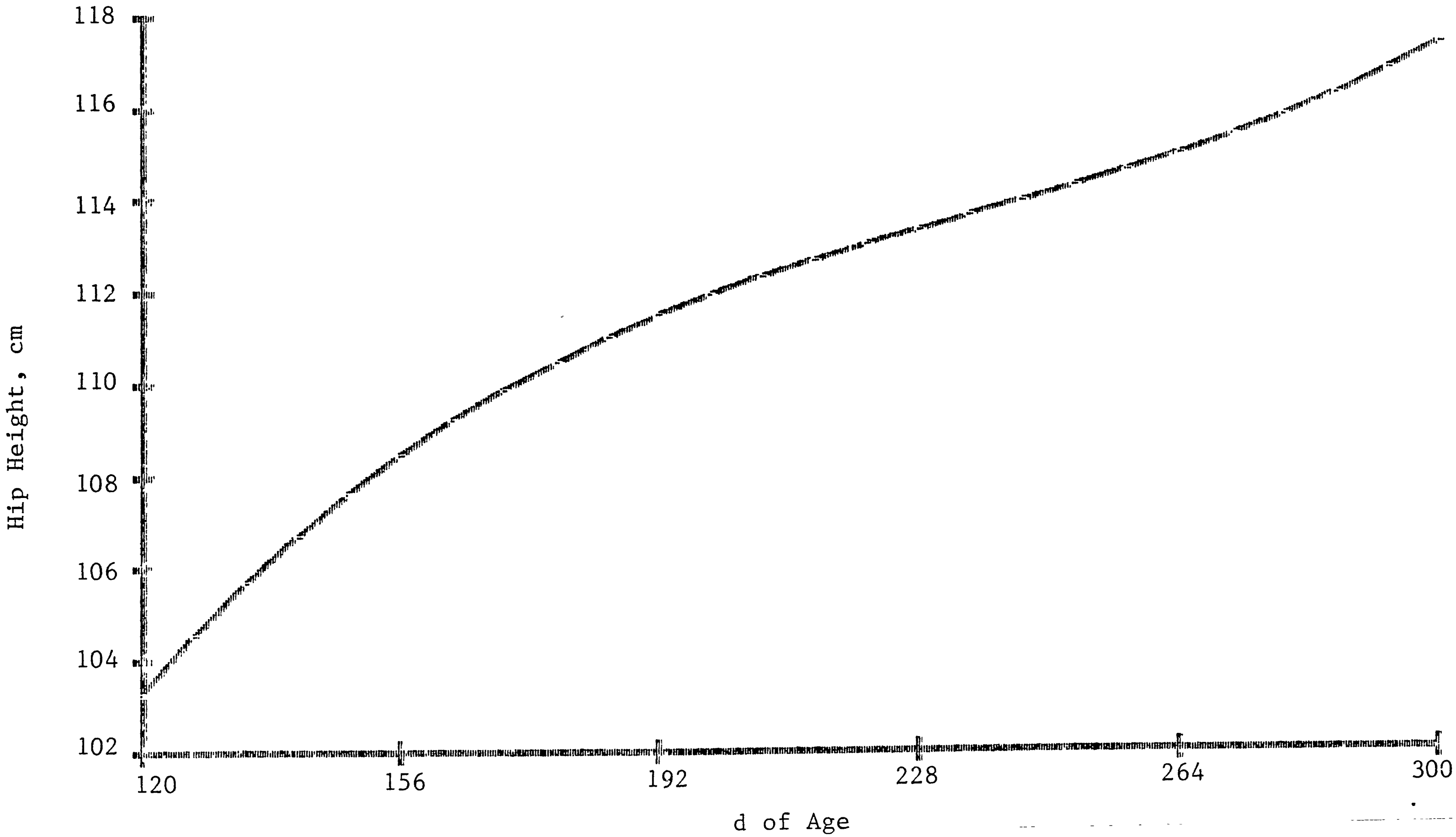

Figure 12. Response of Height at the Hip for all Weanlings.

significant differences over time when the weanilngs on treatments 1 and 3 were compared, or the weanlings on treatments 1 and 3 were compared to 2 (Table XV).

Values for height at the withers are shown in Table XVI. Height at the withers was best described by a second degree polynomial. Height at the withers for the weanlings on treatments 1 and 2 were not significantly different from each other, but both 1 and 2 were significantly different from 3 (Figure 13). Again a sex by treatment interaction was detected primarily due to the colts on treatment 3. By 300 d of age mean values for height at the withers were 136.4, 136.2 and 141.0 cm respectively for the weanlings on treatments 1, 2 and 3. Orthogonal contrast indicated no difference in response over time when treatments 1 and 3 were compared, or when 1 and 3 were compared to treatment 2 (Table XVII). Data indicates that all weanlings grew at the same rate over time when measured by height at the withers. The mean values are greater than those found by Cunningham and Flower (1961) probably due to the genetic development of Quarter Horses over the last 25 years. Mean values were also greater than those found by Reed and Dunn (1977), probably due to the smaller size of Arabians. Responses over time for height at the withers appeared to be similar to those found by Reed and Dunn (1977).

Average daily gains (ADG) are shown in Table XVI. Weight gains were best described by a second degree polynomial which is consistent with NRC (1978) in that response over time for weight gain to any mature weight should be a quadratic function. Orthogonal contrast indicated that the weanlings on treatments 1 and 3 responded differently over time ($P<.05$). When weight gains of the weanlings on treatments 1 and 3 were

TABLE XV

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR HEIGHT AT THE HIP AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	247	555.41		
2	123	234.29		
Total	370	789.70	2.13	
1, 2, 3	373	799.88		
Difference	3	10.18	3.39	1.59
	1 vs. 3			
1	122	263.98		
3	122	288.12		
Total	244	552.10	2.26	
1, 3	247	555.41		
Difference	3	3.31	1.10	.49

TABLE XVI

INFLUENCE OF DIET ON HEIGHT AT THE WITHERS AND AVERAGE DAILY GAIN IN WEANLING QUARTER HORSES

	Treatment			
Parameter	1	2	3	SE
Height at the withers, cm	131.06[b]	129.47[b]	135.35[a]	1.0
Average daily gain, kg	.71[bc]	.59[bd]	.85[a]	.04

[ab]Least square means in a row with different superscripts differ (P<.05).

[cd]Least square means ina row with different superscripts differ (P<.08).

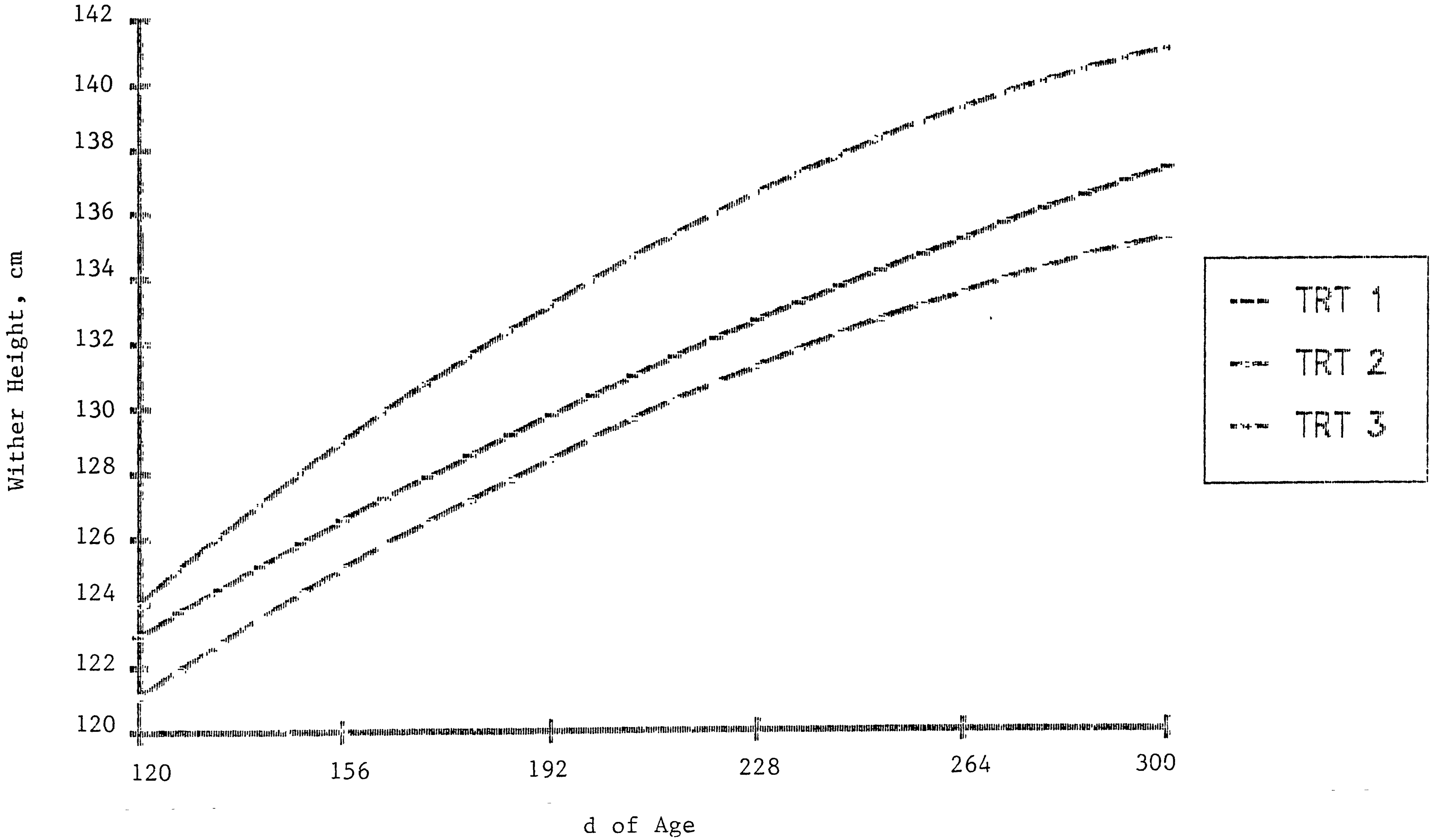

Figure 13. The Response of Wither Height of Weanlings by Treatment.

TABLE XVII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR HEIGHT AT THE WITHERS AMONG GROUPS WERE PARALLEL

		2 vs. 1, 3		
Error	D.F.	S.S.	M.S.	F
1, 3	248	9566.02		
2	124	107.52		
Total	372	9673.54	26.0	
1, 2, 3	374	9692.87		
Difference	2	19.33	9.07	.37
		1 vs. 3		
1	123	66.24		
3	123	9444.99		
Total	246	9511.23	38.66	
1, 3	248	9566.02		
Difference	2	54.79	27.40	.71

compared to the weanlings on treatment 2 a significant difference over time (Table XVIII) was also detected. These data indicate that three different responses over time exist (Figure 14). In this trial the weanlings on treatment 3 gained weight significantly faster than the weanlings on treatments 1 or 2. In addition the weanlings on treatment 1 gained weight more rapidly ($P<.08$) than did the weanlings on treatment 2. The difference in growth rates of the weanlings on treatments 1 and 2 may be explained by the lower daily intakes of protein by the weanlings on treatment 2, which may have been the limiting factor. The composition of gain of the weanlings on treatments 1 and 3 were not significantly different but treatment 3 had significantly greater response in weight gain and height at the withers over time. Feed intakes of the weanlings on treatments 1 and 3 were not significantly different, but intake of CP and DE was significantly higher for the weanlings on treatment 3. Therefore, it appears increased intakes of CP and DE can increase skeletal height as measured by height at the withers. Although increased skeletal height is reflected by weight gain, it may be that not all of the increased gain can be attributed to skeletal growth. One may conclude that some of the increased gain may be additional muscle accretion. It appears that growth of weanling horses may be altered by increasing protein and energy density of the diet as long as the protein to calorie ratio CP/Mcal kg remains above 50.

TABLE XVIII

ORTHOGONAL COMPARISONS USED TO TEST FOR HETEROGENEITY OF REGRESSION COEFFICIENTS FOR POLYNOMIAL RESPONSE CURVES TO DETERMINE WHETHER TIME TRENDS FOR WEIGHT GAIN AMONG GROUPS WERE PARALLEL

	2 vs. 1, 3			
Error	D.F.	S.S.	M.S.	F
1, 3	248	65026.78		
2	124	16312.62		
Total	372	81339.4	218.65	
1, 2, 3	374	132846.93		
Difference	2	51507.53	25753.77	117.85*
	1 vs. 3			
1	123	29181.15		
3	123	17663.54		
Total	246	46844.69	190.43	
1, 3	248	65026.78		
Difference	2	18182.09	9091.05	47.74*

*$P<.05$

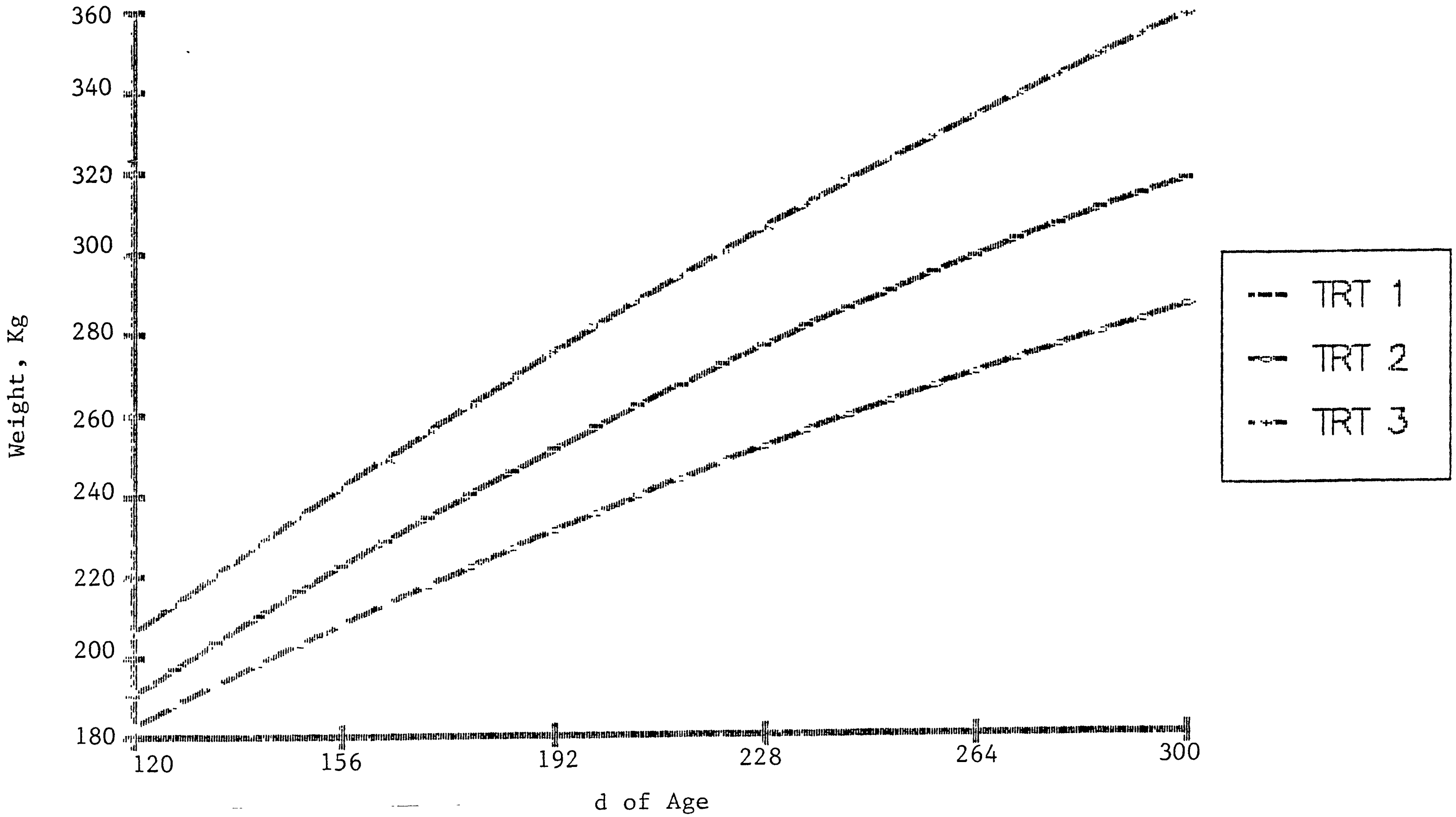

Figure 14. The Response of Weight Gain of Weanlings by Treatment.

CHAPTER V

SUMMARY

When promoting maximum growth rates in weanlings the most limiting factor is probably feed intake. Minimum protein to calorie ratios appear to be 48-50 g CP/Mcal DE to support maximum growth rates and the NRC (1978) recommendations of protein intakes for weanlings appear to be correct. However, greater intakes of energy may promote more rapid growth, as measured by height and weight. If protein to calorie ratios fall below 44-45 g CP/Mcal DE, feed intake may be significantly decreased as evident by the weanlings fed a diet with a ratio of 44.5 g CP/Mcal DE in this trial.

Dry matter digestibility values were reasonable and compare well with calculated estimates using NRC (1978) values. Diets which contain higher amounts of crude fiber can be expected to yield lower digestibility energy coefficients for weanlings. DE values derived from the NRC (1978) appear to be correct for alfalfa hay and corn or oat based diets when fed to weanlings. However, digestible protein values derived from NRC (1978) feed tables may be over estimated by approximately 10% in weanling diets.

During growth studies composition of gain must be considered. Visual appraisal with the use of a condition scoring method appears to be relatively accurate when compared to ultrasonic fat scanning, even though low correlations were detected between condition scores and

ultrasonic measurements. These low correlations may have been due in this study to the relative similarity of all the weanlings. Ultrasonic scans of rump and back fat are probably good estimates of body condition in weanlings and were highly correlated to each other. However, rib fat measurements alone would probably provide a poor method of estimating body condition.

Bone disorders do not appear to be affected by the protein to calorie ratios, protein level, or energy density used in this experiment. No evidence is available to support that diets balanced to NRC (1978) recommendations can or will cause bone disorders.

Bone growth parameters did not appear to be affected by the diets fed in this trial. Since no differences were seen in bone growth parameters it must be assumed that the energy and protein intakes in this trial were sufficient for bone growth at relatively high rates. Bone growth appears to increase linearly to 300 d of age for weanlings.

A good comparison of protein and energy densities can be concluded from this trial for weanling Quarter Horses. It appears that growth rates may be increased by increasing protein level and energy density, as long as the proper protein to calorie ratios are maintained. This becomes evident by the weanlings that were fed diets higher in energy and protein, especially when response over time was measured by weight gain and height at the withers. Since no significant differences were seen in feed intakes of the weanlings fed diets with similar protein to calorie ratios, differences seen in weight gains and height at the withers are probably due to higher intakes of absolute amounts of energy and protein. Furthermore, since no significant differences were detected in body condition as measured by condition scores or ultrasonic fat scans, the relative composition of gain can be assumed to be the same. Although weight accounts for increased skeletal growth along with muscle and fat not all of the increased weight gain may be due to skeletal growth as measured by height at the withers. Some of the increased gain may be due to a more rapid rate of protein accretion. Although no conclusive measurements of muscle mass were taken in this trial, it could be possible that diets highly dense in energy with a protein level of 17% CP may allow weanlings to grow at more rapid rates from 120 to 300 d of age.

Since no significant differences in the composition of gain were detected in the weanlings fed similar protein to calorie ratios, it may be assumed that the weanlings which had higher ADG did not have a greater percentage of body fat. These data suggest that weanlings may be raised at fast growth rates with no adverse effects. Further research is needed to further quantify the optimum levels of energy and protein in the diet of weanlings to promote maximum, sound growth to maturity.

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