THE EFFECT OF ENERGY LEVEL AND FORM OF DIET ON GROWTH OF YEARLING HORSES

A thesis submitted to the
Faculty of Graduate Studies and Research
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In partial fulfilment of the requirements for
the degree of Master of Science

by

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Abstract

An experiment was conducted to study the effects of energy level and physical form of the diet on the growth rate, digestibility, and N balance of yearling horses.

Two energy levels (1) NRC (1973) recommended level of D.E. and (2) 85% of the NRC recommended level of D.E.) were used. The energy levels were divided into two treatments per dietary energy level. The treatments were, diet 1-grain pelleted and long hay; diet 2-grain and hay pelleted (Energy Level I): diet 3-grain and straw (pelleted) and long hay and diet 4-grain, straw and hay (pelleted) (Energy Level II). Twelve yearling horses (3 per treatment) were individually fed twice daily for a 100 day feeding period. Average daily gain (DG kg/day), wither height (WH cm); heart girth (HG cm), and dry matter consumption (DMC kg/day) were recorded bi-weekly throughout the feeding period. The following results were obtained: DG 0.76, 0.88, 0.58 and 0.63; WH 7.5, 5.8, 3.9, and 5.1; HG 10.4, 15.4, 6.0 and 7.9; DMC 6.4, 6.5, 7.2 and 6.4 for treatments 1 through 4 respectively.

A digestibility trial was conducted using four male horses. Four periods were used, with each period representing a treatment group. N balance (gm/day), dry matter digestibility (DM %), energy digestibility (ED %), and acid detergent fiber digestibility (ADF %) were: 13.25,

15.0, 14.88 and -2.25; 64, 59, 49, and 46; 67, 58, 48, and 50; 33, 24.5, 27.0, and 21 for treatments 1 through 4 respectively. There was a significant (P<0.01) difference between energy level for DM and energy digestibilities but there were no significant differences (P>0.01) within the energy level (between treatments). N balance was not significantly different between treatments or within treatments. There was no significant difference for ADF digestibilities.

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Dedication

It gives me great pleasure to dedicate my thesis to my parents - especially my Dad who helped me to have as great an interest in horses as I have today - thanks.

The Effect of Energy Level and Form of Diet on the Growth of Yearling Horses

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today are looking for a ration formulation that will be nutritionally adequate and also inexpensive.

With these objectives in mind the following experiment was conducted to determine the effect of decreasing the energy content and energy density of a growing ration on weanling and yearling colts.

The two areas of the experiment involved a feeding trial and a digestibility trial.

The digestible energy (D.E.) in the diets was reduced by replacing a portion of the hay with straw.

To evaluate the diets, weight gains, wither height increases, heart girth increase, feed conversion, and dry matter consumption data was collected over a 100 day feeding period. A digestibility study was used to evaluate the diets as to energy digestibility (%), dry matter digestibility (%), acid detergent fiber (ADF) digestibility (%) and nitrogen balance of the animals.

With the industry change to the feeding of pelleted rations the physical form of the diet was evaluated to determine the effect on animal performance and diet digestibility.

LITERATURE REVIEW

Digestion in the Horse

The digestive tract of the horse is extremely versatile. For many years the horse has existed on a wide variety of feedstuffs depending on where it was located and what was an economical feed at that time (Anonymous 1973). The horse, like other herbivores is able to utilize diets which are high in cellulose (high fiber content). This utilization is brought about by anatomical structures which allow retention of the fibrous portion of the diet in close contact with a microbial population capable of cellulytic digestion. In the horse this area is the cecum and colon which lies posterior to the small intestine (Robinson and Slade 1974).

The secretion of saliva from the parotid gland is initiated when food is chewed (Robinson and Slade 1974). This flow has been recorded in volumes of up to 10 gallons per day. The saliva of the horse contains ptyalin which breaks down starch to form maltose (Ensminger 1969). Also in the parotid saliva there have been found concentrations of sodium, potassium, chloride, and calcium. These mineral concentrations increase linearly with the rate of flow of saliva (Robinson and Slade 1974).

The stomach of the adult horse has a relatively small capacity. Little is known about gastric digestion and its importance to the horse (Alexander 1963, Robinson and Slade 1974). Work done by Alexander and Benzie in (1951) showed that the stomach of a suckling foal represented a larger portion of the total gastro-intestinal tract than it did in an adult horse (Alexander 1963). The stomach of the immature horse does not empty as quickly as it does in a mature animal (Alexander 1963). Alexander (1963) noted that the food which remained in the stomach underwent fermentation to form lactic acid. This lactic acid was probably produced by bacterial fermentation. It is felt that there would be some absorption of lactic acid in the small intestine but any which reached the large intestine would be fermented to form volatile fatty acids (V.F.A.) (Alexander 1963). Strong gastric contractions have been noted during feeding with recurring contractions after feeding. Feeding did not reduce the contractions but made them more regular (Alexander 1963).

As mentioned before the stomach empties very rapidly in the mature horse. In the small intestine the movement of digesta is also quite rapid (Dougherty 1968). Alexander in 1952 showed there were powerful contractions in the small intestine. These contractions were very frequent after feeding but the frequency decreased when food was withheld (Alexander 1963). In the cranial ileum a substantial amount of sodium, and chloride ions secreted. In the caudal ileum there is an appearance of bicarbonate ions in the intestinal liquor. In conjunction with this there is an absorption of an equivalent amount of chloride ions. It has been suggested that the bicarbonate is secreted in order to buffer the V.F.A.(s) which are produced in the cecum and ventral colon (Alexander 1963, Robinson and Slade 1974).

Enzymes which have been found in the small intestine are amylase, lactase, and maltase. These enzymes are found to show high activity. Those enzymes which show moderate activity are: protease, peptidase and sucrase (Alexander 1963, Robinson and Slade 1974).

Pancreatic juice has been noted to have trypsin activity and it is felt that it is secreted in the active form (Robinson and Slade 1974). In regards to the presence of lipase Robinson and Slade (1974) have noted contradictions as to its actual presence. Some workers have reported that they have been unable to establish the presence of lipase while others have shown it to be present and at a maximum level after feeding of all hay diets.

Hintz et al. (1971) found that the site of digestion of the various components of feed was not influenced by the type of diet fed. The major site of digestion of available carbohydrate was prececal. This digestion resulted in the absorption of glucose and soluble sugars. In this regard the horse could be more efficient than a ruminant, because in the ruminant V.F.A.(s) are absorbed as the major end product of carbohydrate metabolism (Hintz 1974). This digestion occurred regardless of the roughage to concentrate ratio of the diet (Hintz et al. 1971).

The horse is also able to make use of fats via absorption from the small intestine. This occurs by partial hydrolysis of ester bound fatty acids by the pancreatic enzymes in the ileum followed by absorption of the emulsified mixture (Alexander 1963). These fatty acids are absorbed unchanged. The depot fat of the horse is found to contain large amounts of the same unsaturated fatty acids which are found in grass and other forages (Alexander 1963, Bowland and Newell 1974).

The actual site of protein digestion is a major area of disagreement at the present time. Some workers contend that the major site of digestion is prececal (stomach and small intestine). Hintz (1974) suggests that 60-70 percent is absorbed here. Other workers maintain that the large intestine plays a major role in protein digestion (Hintz et al. 1971, Robinson and Slade 1974). The rapid rate of passage from the small intestine allows only limited time for digestion and absorption of protein. (Robinson and Slade 1974). The probable digestion pattern is that the protein is hydrolysed to amino acids and absorbed (Reitnour and Salsbury 1976). Reitnour et al. (1970) showed that there was a positive relationship between the amino acid content of the diet and the animals serum amino acid levels. This has helped to substantiate the role of prececal digestion and absorption of protein (Reitnour et al. 1970).

Other work has shown that horses have the ability to increase the apparent digestibility of protein with an increase in dietary nitrogen. With the increase in dietary nitrogen there is a proportional decrease in endogenous nitrogen levels (Reitnour and Salsbury 1976). Hintz et al. (1971) showed that despite the fact that the major site of protein digestion is the small intestine a significant amount of nitrogen is removed from the lower gut. The possible use of this dietary nitrogen by cecal bacteria will be discussed later.

Calcium is the main mineral which is absorbed in the small intestine (Robinson and Slade 1974) but magnesium is also absorbed there (Stillion 1972). Phosphorous is absorbed in the dorsal and small colon (Robinson and Slade 1974). It is not known where the other minerals are absorbed.

The fat soluble vitamins (A, D, E, K) are apparently absorbed in the small intestine but here again very little is known (Stillions 1972).

The function of the large intestine has become clearer with the development of the new fistulation techniques and this is primarily true with cecum function.

The horse as mentioned before is a herbivore that is able to make use of certain feedstuffs because of its ability to digest fiber. This digestion of fiber occurs in the cecum and ventral colon. When high roughage diets are fed there is an effect of diet as to which segment of the digestive tract that is used (Hintz *et al*. 1971). The result of fiber digestion is the production of V.F.A.(s). The main V.F.A.(s) that are produced are acetic, propionic, and butyric. Total V.F.A. production peaks at six hours after feeding when feed is fed in particular amounts twice daily. This peak returns to the minimal level approximately two hours prior to the next feeding. When feeding *ad libitum* the V.F.A. concentration remained high for the complete twenty-four hour period (Stillions *et al*. 1970). The V.F.A.(s) that are produced in the cecum are absorbed in the ventral colon (Alexander 1963). The absorption of V.F.A.(s) has also been noted in the cecum. *In vitro* studies done by Giddings and Stevens (1968) have shown that acetate and butyrate are absorbed from the lumen of the cecum at similar rates, and are transported to the bloodstream. Relatively small amounts of these V.F.A.(s) are metabolized by the tissues to ketone bodies (Giddings and Stevens 1968). Howell and Cupps (1950) noted that with the increase in tone of the cecum due to the presence of food there was also an increase in the vascularity of the cecal mucosa. This would supply an increased blood supply for the transportation of the V.F.A.(s) produced.

Cecal digestion makes use of complex carbohydrates by the action of cecal microbes on the partially digested feedstuff. The complex carbohydrates are metabolized primarily in the cecum and the more mature feed may pass from the cecum before it is completely hydrolysed (Applegate and Hershberger 1969).

Kern *et al*. (1973) did some work to see if any effect could be noticed on the cecal ecosystem with changes in the diet. It was found that the addition of oats to an all forage diet caused an increase in bacterial numbers in the cecal ingesta. This increase was in total number of bacteria, number of viable bacteria and an increase in D.N.A. Many of the bacteria isolated were proteolytic in nature. This proteolytic effect could make it possible for the degradation of cecal bacteria and subsequently the horse to make use of microbial protein (Kern *et al*. 1973).

Slade et al. (1971) using labeled nitrogen ($(^{15}NL\text{-}NH_4)_2SO_2$) to label bacteria isolated from cecal contents and re-administered into the cecum of a pony showed an increase in total amino acids and essential amino acids (lysine) in the blood from the cecal vein. This indicates the possibility that microbial protein can be synthesized, digested, and absorbed in the large intestine. Work has also been done which indicates that only negligible amounts of amino acids can be obtained from microbial protein. Wysocki and Baker (1972) showed only negligible amounts of label in the amino acid fraction. They felt that the possible fate of the amino acids was being converted into V.F.A.(s) and ammonia.

The cecum is able to allow the cecal bacteria time to work on the food because of a basic motility pattern. This motility pattern is made up of large peristaltic contractions and smaller local contractions. This motility pattern is related to the movement of food through the tract. As food or water enters the stomach it causes an emptying of the cecum. In general the pattern of motility suggests that the cecum acts as a reservoir for partially digested food and this is coordinated to move ingesta to the large intestine as more food is consumed (Howell and Cupps 1950).

In the large intestine there is a decrease in the level of sodium, chloride and bicarbonate from the colon liquor (Alexander 1963, Robinson and Slade 1974). This loss of the bicarbonate, sodium, and chloride is compensated for by the secretion of potassium and phosphorous (Alexander 1963, Robinson and Slade 1974). The phosphate is secreted to act as a buffer in the dorsal colon (Alexander, 1963, Dougherty 1968), and phosphorous is subsequently absorbed in the small colon (Robinson and Slade 1974). As mentioned before the motility patterns of the cecum can be altered by the presence of feed and water (Howell and Cupps 1950). The withholding of food reduced the frequency of contractions in the cecum and in the ventral colon (Howell and Cupps 1950, Alexander 1963). Alexander (1963) noted that withholding feed does not affect the motility pattern of the dorsal colon. It is felt that this is because digesta remains in the dorsal colon for the longest period of time.

The large intestine is also important for the production of the B complex vitamins. Certain of these vitamins occur in the large intestine and seem to be of bacterial origin (Alexander 1963). The B vitamins found in this area are: thiamine, riboflavin, pantothenic acid, nicotinic acid, pyridoxine, folic acid, biotin, and Vitamin B_{12} (Alexander 1963, Stillions 1972).

Net water absorption also takes place in the large intestine. The contents of the dorsal colon have been found to be higher in moisture than the cecum and ventral colon (Alexander 1963, Robinson and Slade 1974). This would indicate that the cecum and ventral colon are the major areas for net water absorption.

Growth

Little is known about the growth and development of the light horse. The experimental data which is available is limited and pertains mainly to the draft breeds. Recently, work using the Quarter Horse and the Arabian has been directed at developing growth patterns. These growth patterns were not developed to indicate the perfect horse but rather to be used as an aid for evaluating one animal's conformation and size with respect to its expected mature size, and to serve as an index for correct nutritional and managerial practices for the most critical periods of growth (Cunningham and Fowler 1961; Heird 1973; and Reed and Dunn 1977).

The pattern of growth was described by the size attained at various stages in the animal's life span. Environment, plane of nutrition, inherent growth potential, sex, type and chance variation are all important factors in the growth and development of the horse (Cunningham and Fowler 1961). Male horses tend to be larger than females for most of the body measurements with the exception that females are longer in the body than males (Reed and Dunn 1977). This has been previously aluded to by Cunningham and Fowler (1961) and Heird (1973) who noted that females were larger in the depth of foreflank and hindflank.

The earliest maturing measurements were observed in the leg. The distance from the knee to ground, and hock to ground are maximum by 18 months (Cunningham and Fowler, 1961, Heird 1973 and Reed and Dunn 1977). Cannon bone development reached a maximum width by 24 months

(Cunningham and Fowler 1961), and wither height was at a maximum at 36 months of age (Cunningham and Fowler 1961, Heird 1973). The most critical growing time was from birth to 18 months of age as the majority of the measurements had reached 92-98 percent of the mature size (Table 1). Body weight, however, was only about 78 percent of the mature weight.

Body weight was the most variable of all measurements and was the longest to reach maturity (Cunningham and Fowler 1961, Heird 1973 and Reed and Dunn 1977). The values at 18 months of age are presented in Table 1. Work done by Dawson *et al*. (1945) showed the effect of inadequate feeding during the winter period on mature size. Less effect after 18 months was shown for mature body size, than for mature body weight, and would indicate that the stunting of a young horse was likely to occur prior to 18 months of age.

The period from birth to 18 months was the most critical for growth and development in the horse. Correct management and proper levels of nutrition are required at this time in order that the young horse meet its inherent growth potential.

Energy

Energy is required by the growing horse for maintenance and growth. The maintenance requirement is that amount of energy for zero body weight change and normal

Development in the Light Horse

Table 1. Percent Mature Body Size at 18 Months

Author	Sex	Wither height	Body length	Height at hip	Knee to ground	Hock to ground	Body weight
Reed and Dunn 1977	M	94.76	92.13	97.17*	98.16	97.26	78
	F	95.43	92.94	98.53*	97.62	99.56	79
Cunningham and Fowler 1961	M	95.30	95.20	--	100.00	99.10	81
	F	95.40	91.10	--	100.00	100.00	77
Heird 1973	M	99.30	95.00	--	100.00	100.00	--
	F	98.30	85.00	--	100.00	100.00	--

M = Male

F = Female

* = only measured in this study

body activity of the idle horse. The growth requirement is more difficult to establish because of the unanswered question of what is the optimum growth rate for a young horse (NRC 1973).

The energy requirement for maintenance has been understood, but the amount of energy needed to meet that requirement has been an area of uncertainty for a long time. Breuer (1968) noted that when horses were fed at the NRC (1966) energy level a weight loss resulted, whereas feeding above the NRC (1966) level (150%) a weight gain was observed. Wooden et al. (1970) indicated that a positive energy retention was due to an excess of D.E. being supplied for maintenance. The energy requirement now used by NRC (1973) has been found to produce a zero weight change, while an increase in weight was found when the levels of D.E. were increased to 125 percent and 150 percent of the NRC level (Wolfram et al. 1976). Stillions and Nelson (1972) used a D.E. level which corresponds very closely to the NRC (1973) level, which produced a zero body weight change. Table 2 shows the various calculations for the D.E. requirements for maintenance.

The requirement of D.E. for maintenance increased as the body weight increased (Olsson 1969, Jordan 1970).

Energy requirements for growth are dependent on the stage of growth and the composition of the increase in weight. The requirement for energy will be greater if the animal is laying down fat and not muscle (Jordan 1970).

Data with growing horses has indicated a requirement of 8.1-8.4 Kcal of D.E. per gram of gain above maintenance. This was converted to 3.6 Mcal D.E. above maintenance per lb of gain (Breuer 1968). Rate of gain and optimal growth affect the energy requirements (Jordan 1970) as does type of horse and season of the year (Hintz 1968). At the present time NRC (1973) has formulated an equation which can be used to estimate the energy requirements for growth above maintenance:

$$Y = 3.8 + 12.3X - 6.6X^2$$

Y = D.E. Kcal/gram gain

X = fraction of adult weight

A deficiency in energy is characterised by a loss in weight and resulting poor condition. Young animals just do not grow and have an unthrifty appearance.

Energy requirements for growth present a similar problem as all other nutrients, in that the final product is very difficult to describe. A specific gain may be obtained but it is not known yet if that is synonymous with optimum gain. A specific growth rate could be in excess of what is required causing problems with overweight animals, or the animals may not receive enough nutrients causing stunted animals. When a range of optimum growth measurements is developed the specific nutrient requirements will be easier to determine.

Table 2. Digestible Energy Requirement for Maintenance

	kcal D.E./day
NRC 1966	$138.3 \times W^1$
Theracon 1967	1500 kcal D.E./100# B.W.
Breuer 1968	$162.6 \times W^1$
Wooden *et al.* 1970	$142.2 \times W^1$
NRC 1973	$155.0 \times W^1$

$W^1 = W^{.75}$

Protein

The quantity and quality of the protein fed to growing horses has received considerable attention and has been the subject of much controversy. Jordan and Meyers (1972) noted that the level of protein in the diet affects protein intake and lysine intake, and one or both of these may affect the rate of growth. Jordan and Meyers (1972) noted a linear increase in dietary intake of weanling ponies as the protein content of the diet increased from 11% to 15.8%. Pulse et al. (1973) found a similar increase in dietary intake with weanling horses as the protein of the diet increased from 10-19 percent. Ott and Feaster (1975) using diets ranging in protein content from 15-18 percent noted an increase in dietary intake as protein increased with eight month old foals. Jordan and Hackett (1977) found no effect of protein levels (14.4-17.5%) on feed intake of weanling pony foals. As the intake of the high protein diet increases so does the energy intake (Jordan and Meyers 1972).

With the increase in protein content, there were increases in daily gain, wither height, heart girth, and feed efficiency. This was observed by Jordan and Meyers (1972) using diets containing 11-15.8 percent protein. Pulse et al. (1973), using diets containing 10-19 percent and Ott and Feaster (1975) using diets containing 15-18 percent protein. Jordan and Hackett (1977) and Yoakam et al. (1975) found no effect on daily gain, wither height, heart girth, or feed efficiency of weanling ponies when the protein levels in the diet exceeded 14 percent.

As the animal matures the requirement for protein decreases. Jordan and Meyers (1972) and Ott and Feaster (1975) showed that after 12 months of age horses would consume enough feed to meet their protein requirement of 338 grams/day (expected mature weight 200 Kg) and 750 grams/day (expected mature weight 500 Kg) when the animals were consuming low protein diets. (Jordan and Meyers 1972 - 11.8% protein, Ott and Feaster - 15%). Jordan and Meyers (1972) showed that ponies fed the higher levels of protein at four months of age grew less after six months of age, and would indicate that the stage of growth affects the requirement for protein. Ott and Feaster (1975) recommended a grain mix containing 14.8 percent protein and .5 percent lysine (fed with 8.75% protein hay) was adequate for yearling horses. Jordan and Meyers (1972) used a 11.8 percent protein diet which provided adequate growth for yearling ponies. Yoakum et al. used a 14 percent protein diet from weaning to 14 months of age with good results.

Ponies on diets containing 14.4 percent protein consumed enough of the diet to have a daily protein intake equal to ponies on a 17.5 percent protein diet (Jordan and Hackett 1977).

Protein Quality

Jordan and Meyers (1972) indicated that the lower growth rate of young horses may be due to a lower lysine intake. Serum amino acid comparisons have shown that in low quality protein diets lysine is the first limiting amino acid (Breuer, Word and Kasten 1970). The use of supplemental lysine or proteins which contain large amounts of lysine has resulted in increases in growth and feed efficiency of young horses. Breuer and Word (1968) and Breuer, Word and Kasten (1970), showed that the addition of methionine and lysine to diets containing 11.5 percent protein increased the growth of young horses. Potter and Huchton (1975) added methionine and lysine to diets containing 11.5 percent and 15 percent protein, resulting in an increase in growth rate and feed efficiency with a greater increase noted for the 11.5 percent diet. When comparing horses fed soybean meal (SBM) or Brewers Dried Grain (BDG) diets, the SBM resulted in a larger increase in weight gain but not a change in body density, thus indicating a true response to protein quality. The addition of lysine and methionine to BDG gave a growth response similar to the SBM diets (Ott and Richardson 1977). The use of milk blend products has also shown promise as a protein source. Hintz et al. (1971) compared milk products and linseed meal, and showed a greater response to the milk products in gain and feed efficiency. When lysine and methionine were added to the linseed meal a response similar to the milk products was noted. The higher lysine content was felt to give greater response of the milk blend products. Barton, Anderson and Lyford (1973) noted a greater response to skim milk protein than soybean meal protein at both the 14 and 22 percent levels fed to weanling horses.

It appears that the young horse may require a specific amino acid balance in the diet. This is possibly affected by the intake of protein and levels of amino acids in the protein supplements. Establishing optimum levels of protein and the corresponding growth rate should be defined more clearly.

Minerals

The soundness of bone is of prime importance in the horse, because performance is the main function of the horse. Improper bone development can shorten the useful career in a promising young horse. A Purina Research Report (1971) noted nutrition as a major contributor to bone maturity. Inadequate bone maturity is a primary cause for many of the unsoundness problems seen in today's young horses (Anonymous 1971). Calcium (Ca) and Phosphorous (P) are the major minerals which have been looked at and will be the major area discussed herein.

Availability of minerals from feedstuffs is variable. NRC (1973) has indicated that P is about 60 percent available for growing animals, and only 50 percent available for mature animals. The P from wheat bran is only about one-half as available as the P from other supplements (Hintz et al. 1973). Calcium availability ranges between 45 and 50 percent in common feedstuffs. Anonymous (1967) reported that minerals in many feedstuffs were 40 percent available while supplements contained mineral elements which were 80 percent available.

Much of the work done to the present time has been in the area of the relationship between Ca and P as to levels in the feed, and the specific Ca:P ratio required.

The horse makes use of homeostatic mechanisms to control the level of Ca and P in the blood. The response to dietary changes in mineral content is towards maintenance of normal plasma levels of Ca and P. Work done by Schryver et al. (1970) showed ponies fed low Ca diets increased the fractional intestinal absorption, decreased renal excretion, and calcium removal rate from the bone increased to a rate which exceeded deposition. The reverse is true of a high Ca diet. Whitlock et al. (1970) also noted that there were no changes in Ca and P plasma concentrations on a high Ca diet, however, there was an increase in Ca retention. Hintz et al. (1973) using varying ratios of Ca:P, noted no effect on the mineral composition of the body, or Ca:P composition of the bone ash. No effect on growth rate was noted by Whitlock et al. (1970) or Hintz et al. (1973).

Studies by Stillions, Teeter and Nelson (1968) showed that an intake of 15 grams of Ca and P per day was required for a mature horse (455 kg) and a growing horse (200 kg) required 20-25 grams Ca and 18-24 grams P per day. Hintz et al. (1973) found that a growing animal (200 kg) required a larger amount of Ca (36 grams) and P (26 grams) per day. Olsson (1969) has indicated the fluctuating requirements for Ca and P for a growing horse up to 28 months of age (Table 3).

The effect of the ratio of Ca:P has also been investigated. Anonymous (1967) indicated that a ratio of 1.1:1 of Ca:P was satisfactory for growing animals. Recent work by Jordan et al. (1975) has shown that ratios as high as 6:1 Ca:P did not cause any bone abnormalities. NRC (1973) has indicated that ratios of 3:1 Ca:P are satisfactory for growing colts, when the P source was readily available. If the level of P should exceed Ca problems may occur. Ratios of 0.8.1 and 0.6:1 Ca:P can cause problems such as osteomalacia, osteoporesis, and nutritional secondary hyperparathyroidism (NRC 1973). This would indicate the relative importance of the correct amount of P as compared to the requirement of Ca. Whitlock et al. (1970) noted that with high levels of Ca and adequate levels of P no effect on epiphyseal closure or other bone developments were noted.

Salt is essential for body function. The requirement for salt depends on temperature, humidity and activity of the horse. Salt is used to make a ration more palatable (Cunha 1963) and in most instances can be fed free choice. The feeding of salt free choice will generally meet the daily requirement.

The requirements reported by NRC (1973) for the trace minerals required by the horse are very limited.

The recommended amount of magnesium has been

Table 3. Calcium and Phosphorous Allowances for Growing Foals (Olsson 1969)

	Grams per day	
Age	Calcium	Phosphorous
6 Months	30-40	18-24
12 Months	33-45	21-28
24-28 Months	30-40	20-27

estimated at 14 mg/kg of body weight. Five percent magnesium oxide added to the salt should prevent any deficiency.

When feeding a horse a diet which is 50 percent roughage (hay) the requirement of 0.6 percent of the diet for potassium should be met.

No known requirement for sulfure has yet been established for horses. If adequate sulfure containing amino acids are in the diet a level of .15% sulfure should be present in the diet and this appears adequate.

Iodine deficiency is relatively unknown in adult horses. The use of iodized salt for brood mares will prevent any problems in newborn foals.

At the present time there is no established level required for cobalt.

Growing horses require a level of 8.0 ppm copper per day and a level of 50 ppm iron per day in the diet.

At the present time there is no specific dietary level of manganese required by the horse. A suitable intake of manganese will result with a high forage diet, and the zinc requirement will also be met. Molybdenum has no specific dietary requirement.

A level of 50 ppm or less of flourine appears to be adequate, and the selenium intake should be around 0.5 ppm in the daily feed.

These are the best estimates available for the mineral requirements but no confirming experimental results are presently available.

Vitamins

There is a lack of knowledge and experimental data as to the vitamins required by the horse and the levels required for the various functions the horse may be required to perform. The recommendations used today result mainly from work conducted with other farm animals.

Seasonal fluctuations in liver, fat, and blood concentrations of vitamin A, and carotene have been found in the horse (Robinson and Slade 1974). The conversion of carotene to vitamin A has been found to be very inefficient in that large amounts of carotene in the feed are required to maintain plasma vitamin A levels. (Fonnesbeck and Symons 1967).

Vitamin A deficiency symptoms noted in the horse are similar to those found in other farm animals: i.e. night blindness, reproductive failure and bone disorders (Cunha 1963). Stowe (1968) found that the use of 9.5-10.0 I.U./kg body weight/day of vitamin A could effectively prevent any vitamin A deficiency. NRC (1973) recommends somewhat higher levels, 25 I.U./kg body weight for maintenance, 40 I.U. for growth and 50 I.U. for pregnancy and lactation.

The requirement for vitamin E is not known. Vitamin E has been used in combination with selenium and vitamin A for the treatment of various problems in the horse (Cunha 1963). Stowe (1967) has shown tentative evidence that a combination of vitamins A and E will improve the reproductive performance in mares. The use of alpha tocopherol and selenium for the treatment of muscle degeneration has not been successful (Robinson and Slade 1974). Recommendations have been made for foals, of 233 ug of oral alpha tocopherol and for breeding stock of 600-1000 I.U. of vitamin E per day during the breeding season (Cunha 1963).

Vitamin D has been shown to be essential for the absorption of calcium and phosphorous in the horse (Hintz et al. 1973). Generally exposing horses to sunlight is an effective means of supplying the vitamin D requirement (Cunha 1963). With horses that receive minimal amounts of sunlight NRC (1973) recommends 6.6 I.U. per kg body weight per day.

Vitamin K is produced in suitable amounts in the intestinal tract of the horse so that no nutritional requirement has been established. Also vitamin C has no established nutritional requirement (NRC 1973).

It has been assumed that sufficient amounts of the B complex vitamins are synthesized by the microflora of the gut to meet the daily requirements of the horse. At the present time it is not clear as to how great an effect this production has on the horses need for supplemental B vitamins (Cunha 1963).

Thiamine has been found to be produced in the cecum of the horse with about 25 percent being utilized by the horse. A level of 3 mg per kg of feed is felt to be adequate in meeting the horse's daily requirement (NRC 1973).

Riboflavin has been indicated as a possible form of therapy for periodic moon blindness. A level of 2.2 mg/kg of feed is recommended to meet the daily requirement for the horse (NRC 1973).

Pantothenic acid has no known specific requirement but a level of 2 mg/kg of feed appears to be adequate (NRC 1973).

Work done to the present time has indicated no dietary requirement for niacin. Intestinal synthesis appears to be adequate to meet the horse's needs (NRC 1973).

Vitamin B_{12} has been utilized by race horse people as a body builder but at the present time this has not been confirmed experimentaly. The use of vitamin B_{12} as a cure for anemia has been documented but the exact dietary requirement has not been established (NRC 1973).

Further research on vitamin requirements for horses is required during periods of stress before the recommendation for vitamins can be confirmed.

Water

An ample supply of clean fresh water should be made available at all times. Feed intake can be adversely affected if water intake is reduced.

Water intake is affected by many factors such as type of ration. It has been found that horses on an all roughage diet consume more water than horses being fed both hay and grain. Dry matter intake, ration digestibility and mineral content all have an effect on water intake

(Fonnesbeck 1968).

Water consumption by horses under various conditions of stress has been reported by Caljuk (1961), (Table 4).

Table 4. Water Consumption of Light Horses
Caljuk 1961

Activity	kg/day
Fattening	27
Pregnancy and Lactation	40-57
Work (varies with temp.)	79

Robinson and Slade 1974

MATERIALS AND METHODS

Part I

Effect of Energy Level and Form of Diet on the Growth of Yearling Horses

Dawson *et al.* (1945) noted that good growth was seen in young horses up to 18 months of age as long as an adequate level of nutrition was provided. When the plane of nutrition was reduced after 18 months, growth was reduced so that the horses did not attain their expected mature size. This study was initiated to examine the effect of decreasing the energy level, and physical form of the diet on growing colts (12-18 months of age).

Experimental Animals

Twelve Quarter horses were randomly selected from a group of sixteen animals loaned to the Department of Animal Science by Mr. Harold McLeod and Mr. Connor Doak of Brookdale, Manitoba for use in a feeding trial. There were nine fillies and three colts with an average age of 13 months and an average weight of 285 kilograms. The animals were housed individually in pens 3 x 12 meters. A three week period prior to the start of the 100 day feeding trial was used for halter breaking, deworming, vaccinations and adaptation to the diets.

Experimental Design

The twelve animals were weighed and body measurements obtained prior to the start of the feeding period.

Based on body weight the horses were allotted to one of three weight groups: light, medium and heavy and then randomly assigned to one of the four diets and fed for 100 days. The data was analysed using a randomized block design (Snedecor and Cochran 1967). Means of individual weight groups and for the diets were tested using the Student Newmann Keul test for means (Snedecor and Cochran 1967). Analysis of variance for daily gain, wither height increase, heart girth increase, feed conversion and dry matter consumption is presented in Appendix Table 2.

Experimental Diets

The four diets used contained two energy levels and two physical forms of the diet per energy level. Composition of the diets is indicated in Table 5 and the analysis of the rations both calculated and analysed are shown in Table 6.

Energy level I was formulated to meet the NRC (1973) requirement for Digestible Energy (D.E.) of 2.75 Mcal/kg feed and 12.5 percent protein. This was fed in two forms: Diet I was fed as a pelleted grain mix at 0.92 kg/100 kg body weight and long hay was fed at 1.33 kg/100 kg body weight. Diet II was fed as a complete pellet at 2.25 kg/100 kg body weight.

Energy level II was formulated to supply 85 percent NRC (1973) requirement for D.E. (2.33 Mcal/kg feed) and 12.5 percent protein, and fed in two physical forms. Diet III was fed as a pelleted grain and straw mix at 1.60 kg/100 kg body weight with long hay fed at 0.66 kg/100 kg body weight. Diet IV was fed as a complete pellet at

Table 5. Diet formulation for the four diets used during the 100 day feeding trial, and the digestibility trial.

	% Composition			
	Energy Level I		Energy Level II	
Ingredient	Diet 1[a]	Diet 2[a]	Diet 3[a]	Diet 4[a]
Oats	29.0	29.0	17.8	17.8
Barley	7.50	7.50	--	--
Soybean Meal	3.0	3.0	8.1	8.1
Molasses	1.0	1.0	3.70	3.70
Alfalfa-Brome Hay Long	59.50	--	29.7	--
Alfalfa-Brome Hay Ground	--	59.50	--	29.7
Barley Straw Ground	--	--	40.7	40.7

[a]All treatment groups were provided with mineral free choice in a 2:1 mineral block.

Table 6. Calculated and analysed feed compositions for the four diets fed to yearling horses for the 100 day feeding trial, and the digestibility trial.

Calculated Analysis	Diet 1	Diet 2	Diet 3	Diet 4
Digestible Energy Mcal/kg	2.75	2.75	2.33	2.33
Crude Protein %	12.5	12.5	12.5	12.5

Laboratory Analysis				
Digestible Energy Mcal/kg	2.92	2.66	2.03	2.15
Crude Protein %	14.0	13.85	12.05	12.0

2.25 kg/100 kg of body weight.

All diets were calculated to meet the requirement for a 272 kg yearling horse. Daily feed offerings were adjusted as the horses grew, appetites changed and the horses were fed to appetite as they adapted to the individual diets.

The straw was ground and added to the grain mix pellet in Diet III to insure consumption and reduce any possible digestive upsets.

A mineral block (2:1) (Table 7) and water were offered *ad libitum* during the feeding period.

Sampling Procedures

Measurements for body weight (kg), wither height (cm), heart girth (cm) were taken initially and bi-weekly for the entire period with the horse in a normal standing position (Fig. 1 and 2). The animals were weighed in a livestock scale after an overnight fast.

Feed consumption was recorded and sampled daily throughout the feeding period. The feed samples were composited every two weeks. The samples were dried at 60°C in a forced air dryer for 48 hours, ground to pass a 1 mm screen in a Wiley mill and analysed for protein using the Kjeldahl Crude Protein Determination, gross energy using the Adiabatic Bomb Calorimeter, fiber using the Acid Detergent Technique (AOAC, 1960) and dry matter.

Table 7. Analysis of mineral block used during the 100 day feeding trial and the digestibility trial.

Calcium (Act.)[1]	19.0%
Phosphorous (Act.)	9.0%
NaCl (Act.)	25.0%
Iron (Act.)	0.5%
Iodine (Act.)	0.004%
Manganese (Act.)	0.08%
Copper (Act.)	0.036%
Zinc (Act.)	0.14%
Fluorine (Max.)	0.30%
Magnesium (Act.)	0.23%
Cobalt (Act.)	0.002%

[1]Act. - Actual

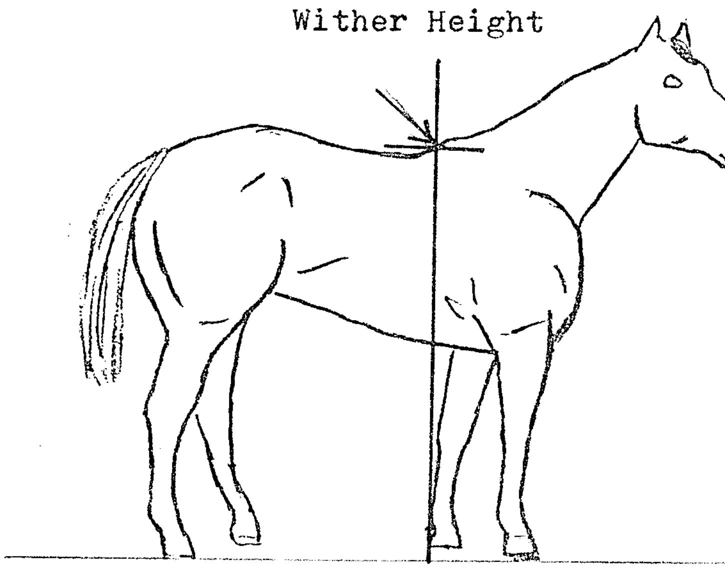

Figure 1 Wither Height

Measurement taken in a normal standing position.

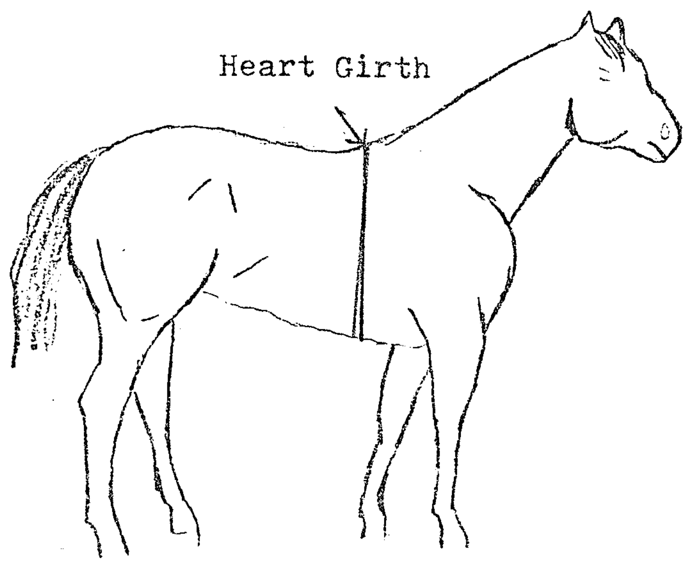

Figure 2 Heart Girth

Measurement taken in a normal standing position.

RESULTS

Feeding Trial

Daily gains (kg), wither height increases (cm), heart girth increase (cm), feed conversion (kg feed/kg gain), and dry matter consumption (kg/day) are presented in Table 8. Values presented are the means of three animals per diet over the 100 day feeding period. Daily gain (kg/day) ($P<0.01$) was greater for the horses fed diet I (.75) and diet II (.88) than for those horses fed diet III (.63) and diet IV (.58). The differences noted due to physical form of the diet within an energy level were not significant ($P>0.05$). The wither height increase (cm) ($P<0.01$) was also greater for the horses fed the high energy diets, diet I (7.50), diet II (5.80) compared to the animals fed the low energy diets: diet III (5.10) and diet IV (3.85). The differences due to physical form of the diets were not significantly different ($P>0.05$). Heart girth increases were significantly greater ($P<0.01$) for horses fed diets at energy level I than for the horses fed the energy level II diets. The differences between the physical form of the diets (pelleted vs. non-pelleted) within the energy levels were not significantly different ($P>0.05$).

Animals fed diets containing high energy (level I) had a better feed conversion ($P<0.05$) than the horses fed the diets containing low energy (level II). The difference between diet I (10.59) and diet II (8.08) in the high energy diet (level I) and the difference between diet III (13.81) and diet IV (12.69) in the low energy diets (level II) were not significant ($P>0.05$).

Animals fed diets at energy level II (III 7.72 kg, and IV 6.44 kg) consumed significantly ($P<0.05$) more dry matter than the horses fed diets at energy level I (I 6.36 kg and II 6.35 kg). There was a significant ($P<0.05$) difference between the two diets fed at energy level II and this was due to the increased consumption of the animals on diet III.

The horses readily consumed the diets offered and were in good condition at the conclusion of the feeding trial.

Table 8. Daily gain (kg), wither height increase (cm), heart girth increase (cm), dry matter consumption (kg) and feed conversion for horses fed two energy levels during a 100 day feeding trial.

	Energy Level I		Energy Level II		
	Diet I	Diet II	Diet III	Diet IV	$S\bar{x}$
Average Daily Gain[1] (kg)	.76	.88	.63	.58	±.098
Wither Height Increase (cm)[1]	7.5	5.8	5.1	3.9	±.22
Heart Girth Increase (cm)[1]	10.4	15.4	6.9	7.9	±.78
Dry Matter Consumption (kg/day)[2]	6.36	6.35	7.72	6.44	±1.0
Feed Conversion[3] (feed/gain) kg feed/kg gain	10.59	8.08	13.81	12.69	±1.0

All numbers are the average of 3 animals/ration.

[1]Mean for energy level I is significantly ($P<0.01$) greater than the mean for energy level II.

[2]Mean for energy level II is significantly ($P<0.05$) greater than the mean for energy level I.

[3]Mean for energy level I is significantly ($P<0.05$) greater than the mean for energy level II.

MATERIALS AND METHODS

Part II

Effect of Energy Level and Form of the Diet on the Digestion and Nitrogen Balance of Growing Horses

Experimental Animals

Four male Quarter horses selected from the previously mentioned 16 in Part I with an average weight of 382 kg were used in a digestibility study. A two week adjustment period prior to the digestibility study was used to acclimitize the horses to the collection crates. The horses received the same pretreatment as the twelve in Part I.

Experimental Design

All four diets were fed at the same time, with each diet making up a digestibility period. This was done to reduce problems encountered when the horses could see other horses being fed the hay portion of specific diets (diet I, and III). The order in which the diets were fed were randomly selected (see Appendix, page 74).

The collection period was made up of a ten day adaptation to the diet followed by a four day total collection. At the start and finish of the four day collection period the horses were weighed. During the collection period the horses were kept in metabolism crates (Fig. 3), designed following patterns described by Vandernoot et al. (1965), and Stillions and Nelson (1968).

A one-way analysis of the means was used to analyse differences in energy digestibility, dry matter digestibility, fiber digestion and nitrogen balance (Snedecor and Cochran 1967). A Student Newmann Keul test was used to test significance of means within energy levels (i.e. diet I vs. diet II) (Snedecor and Cochran 1967). Analysis of variance tables for these are noted in Appendix Table 3.

Experimental Diets

The four diets used were those previously discussed in Part I. Daily feed was recorded and the horses had the same mineral and water free choice as the animals in Part I.

Sampling Procedures

Urine was collected using a collection funnel described by Howell (1930) and a collection harness described by Grandier (1960), into a two gallon plastic collection jug containing 6N HCL. Urine was collected and sampled twice daily, refrigerated until the four day collection was completed, and then combined, an aliquot obtained and frozen for future analysis.

Urine was analysed for N using the Kjeldahl Crude Protein Determination (AOAC 1960).

Feces were collected from the area directly behind the horses by using the constant surveillance technique described by Hintz (1971). The feces were collected and stored in plastic containers, daily collections were weighed, mixed and sampled. The samples were refrigerated and at the end of the four days, mixed, sampled, then frozen for future analysis. After all four collection periods were completed the feces were dried at 60°C in a forced air dryer for 48 hours, ground to pass a 1 mm screen in a Wiley mill, and analysed for protein using Kjeldahl Crude Protein Determination, Gross Energy using the Adiabatic Bomb Calorimeter, fiber using Acid Detergent Fiber Technique (AOAC 1960) and dry matter.

Feed samples were taken twice daily, composited at the end of each four day period, dried in a forced air dryer at 60°C for 48 hours, ground to pass a 1 mm screen in a Wiley mill. Feed was analysed for protein using Kjeldahl Crude Protein Determination, Gross Energy using the Adiabatic Bomb Calorimeter, fiber using the Acid Detergent Fiber Technique (AOAC 1960) and dry matter. Apparent digestibilities were calculated for each horse on each diet for energy, dry matter and fiber as well as N balance.

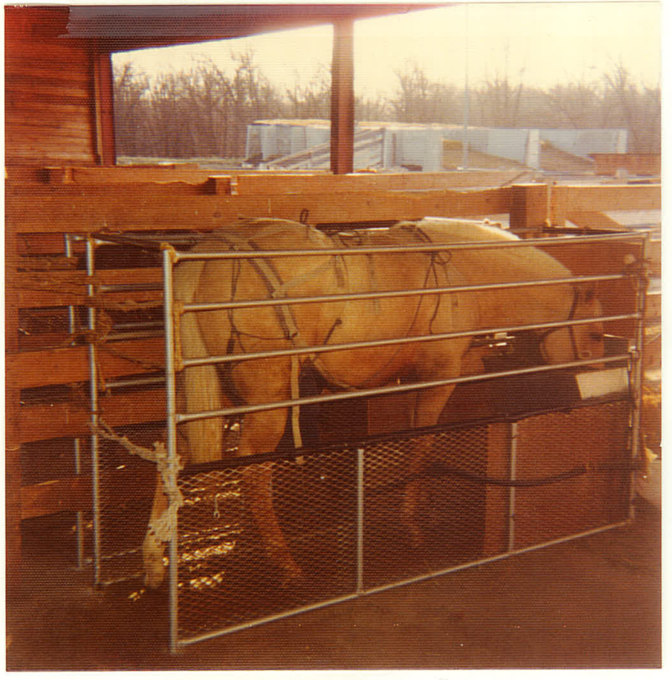

Fig. 3 Metabolism Crate

RESULTS

Digestibility Trial

Dry matter digestibility (%), energy digestibility (%), A.D.F. digestibility (%) and nitrogen balance (g/day), results are presented in Table 9. The values presented are means of four animals for the four collection periods. During the adaption period for diet I, one horse was injured and had to be removed prior to the start of the collection period.

Dry matter digestibility ($P < 0.01$) was greater for horses fed diet I (64.97) and diet II (59.40) than for horses fed diet III (49.50) and diet IV (46.80). The differences between horses fed diets I and II within the high energy diets (level I) and the horses fed diets III and IV within the low energy diets (Level II) were not significant ($P > 0.05$).

Energy digestibility ($P < 0.01$) was greater for the horses fed the high energy diets (level I) than for the horses fed the low energy diets (level II). The difference between diets I (67.66) and II (58.54) within energy level I, and the difference between diets III (48.17) and IV (50.10) in energy level II were not significant ($P > 0.05$).

Differences among horses for all diets for A.D.F. digestibility were extremely variable and were not significantly different ($P>0.05$).

The horses fed diet I (13.25), diet II (15.06) and diet III (14.87) had nitrogen balances which were within the expected range. The animals fed diet IV (-2.25) had a nitrogen balance which was extremely variable due to individual horse variation and was statistically significant ($P<0.05$) from horses fed the other three diets.

At the termination of the digestibility trial all the horses were in good condition. No difficulties due to feed refusal had been encountered.

Table 9. Energy digestion (%), dry matter digestibility (%), ADF digestibility (%), and N-balance (gm/day) for the digestion trial using 4 day total collection.

	Energy Level I		Energy Level II	
	Diet I*	Diet 2**	Diet 3**	Diet 4**
Energy Digestion %[1]	67.66	58.54	48.17	50.10
N Balance grams/day	13.25	15.06	14.88	-2.25[2]
Dry Matter %[1]	64.97	59.40	49.50	46.80
Fiber Digestion (ADF %)	34.0	25.03	27.89	21.52

*Average of 3 horses due to illness in one animal.

**Average of 4 horses.

[1]Mean for energy level I is significantly ($P<0.01$) greater than mean for energy level II.

[2]Significantly ($P<0.05$) greater than the other three diets regardless of energy level.

Discussion Feeding Trial

The reductions in daily weight gain of horses fed diet III (0.63 kg) and diet IV (0.58 kg) were significantly different ($P<0.01$) in comparison to diets I (0.76 kg) and II (0.88 kg), and were associated with a reduction in the DE content of the diet. Similar results feeding yearling horses have been observed. Potter and Huchton (1975) fed horses diets containing soybean meal (SBM) or cottonseed meal (CSM) as the protein supplement, the diets formulated to contain 15% protein resulted in gains of 0.43 and 0.57 kg/day. Aber and Potter (1975) fed horses 14.5% protein diets comprised of sorghum or oats and noted gains in yearling horses of 0.50 kg and 0.58 kg/day. Using brewers dried grains (BDG) or SBM to supplement 15% protein diets Ott and Richardson (1977) reported Quarter Horse, and Thoroughbred yearlings gained 0.48, and 0.55 kg/day. Yearling fillies on pasture or fed in drylot have been recorded to gain 0.49 and 0.52 kg/day (Heusner and Albert 1977). Householder _et al_. (1977) fed sorghum, or oat diets containing 2.82 Mcal DE/kg of feed and 14% protein to yearling Quarter Horses and obtained gains of 0.64 and 0.69 kg/day. NRC (1973) indicates that 0.55 kg/day is an adequate rate of gain for yearling horses with an expected mature weight of 500 kg.

The horses fed the diets containing the NRC recommended level of DE (2.83 Mcal DE/kg feed) resulted in a greater increase ($P<0.01$) in wither height than the horses fed the diets containing 85% of the NRC level of DE (2.33 Mcal DE/kg feed). The horses fed the diets at energy level I (NRC recommended level of DE) had wither height increases of 7.5 cm (diet I) and 5.83 cm (diet II) while the horses fed diets at energy level II attained wither height increases of 5.10 cm (diet III) and 3.85 cm (diet IV). Potter and Huchton (1975) using protein supplements of either soybean meal or cottonseed meal in 15% protein diets found wither height increases of 6.10 cm and 8.63 cm which are similar to those reported from this study. Aber and Potter (1975) using sorghum and oat diets had wither height increases of 5.84 cm - 7.25 cm which again are comparable to those reported in this study. Householder _et al_. (1977) using sorghum and oat diets with 2.82 Mcal DE/kg feed and 14% protein reported wither height increases of 8.33 cm - 9.65 cm which exceeded those reported by Potter and Huchton (1975) and Aber and Potter (1975). Yearling thoroughbreds and Quarter Horses fed a 15% protein diet had wither height increases of 8.46 - 10.41 cm which were comparable to those by Householder _et al_. (1977) (Ott and Richardson 1977).

The increases for heart girth noted with the horses fed energy level I diets were significantly ($P<0.05$) greater than the heart girth measurements recorded for the horses fed energy level II diets. Work done by Aber and Potter (1975) using diets containing 15% protein and Potter and Huchton (1975) using 14.5% protein reported heart girth increases of 5.33 cm to 11.18 cm and 8.12 cm to 9.40 cm respectively. These values compare to those reported in this study. Ott and Richardson (1977) using 15% protein diets, and Householder et al. (1977) using a 14% diet reported heart girth increases of 16.27 cm - 17.79 cm and 12.83 cm - 14.0 cm respectively. These values were much higher than those reported in this study.

The growth made by the horses in this study regardless of diet fed was comparable in most cases to the work previously reported by other authors (Appendix Table 4). The horses fed diets I and II did however achieve a better daily gain than data previously reported, while the diets III and IV formulated for a lower DE content maintained growth rates similar to those previously reported. Heusner and Albert (1977) reported that post weaning treatment was positively correlated to the rate of growth of yearling fillies, and they observed that the weanling fillies which grew at an accelerated rate did not grow as fast during their yearling summer. Jordan and Meyers (1972) observed that weanling ponies grew rapidly from four to six months of age but did not maintain this rapid growth after six months of age.

If the horse were to attain a specific percentage of its mature size by the age of 18 months, the age at which this growth occurred may not be particularly important. The horses used in this study may have been showing the opposite effect to post weaning treatment, that was reported by Heusner and Albert (1977) and Jordan and Meyers (1972), in that their growth rate was accelerated rather than decreased during the yearling stage.

The horses used in this study had previously been group fed on low quality forage diets while overwintering outside. This type of pre-treatment could reduce the portion of the diet the horses had available for growth by increasing the percentage of the intake required for maintenance. The stresses of group feeding outside could effectively reduce the potential growth rate of the horses at that stage of development.

Individual feeding could reduce many of the former stresses encountered by the colts. The horses would then be able to use a larger percentage of the daily feed for growth and the possibility of compensatory growth could be a factor, in that growth rate would be improved and growth potential expressed as stress was reduced and feed consumption and nutrient intake increased.

The horses which were fed the diets at energy level II would be growing at a lower rate than the horses fed the diets at energy level I, but both groups would be growing at a faster rate due to compensatory growth. This would result in greater gains than those previously reported by other workers.

The effect of changing the physical form of the diet from that of a grain mix and long hay to that of a complete pellet was looked at, to see what the resulting growth rate, feed consumption and feed conversion would be.

No significant differences ($P<0.05$) were noted for growth due to physical form of the diet. Hintz and Loy (1966) observed no effect on the growth of horses 5-19 months of age when the diet was fed either as a pellet or in a nonpelleted form, when consumption was held equal for each physical form.

In this study there was a significantly ($P<0.05$) greater consumption for one specific treatment group. The horses on diet IV consumed more dry matter than the horses on the other three diets. This increase in consumption did however result in a slightly greater daily gain, wither height increase but these were not significant ($P>0.05$) differences. For the horses on diets I and II (energy level I) the daily consumptions were not significantly ($P>0.05$) different. From this and from visual observations it would seem probable that the increased consumption was due to the individual animals rather than physical form of the diet.

Nutritive value of the diet is not increased by changing the physical form of the diet, when equal quantities are being fed. Haenlein *et al*. (1966) and Hintz and Loy (1966) found a preference for pelleted feeds over non-pelleted feeds when diets were fed *ad libitum*.

Feed conversions of yearling horses have been recently reported by Potter and Huchton (1975) and Aber and Potter (1975) who observed a range of feed conversions (feed/gain) of 11.89-16.30; and 12.96-15.61 with yearling horses fed 15 and 14.5% protein diets based on oat or sorghum grain. Heusner and Albert (1977) using fillies on either drylot or pasture observed feed conversions of 13.01 and 13.10 respectively. Horses fed high energy diets (I - 10.59 and II - 8.08) had significantly ($P<0.05$) better feed conversions than did the horses fed the lower energy diets (III - 13.8 and IV - 12.69). The increased gains made by the horses on all four diets resulted in better feed conversions than those indicated by other workers (Appendix Table 4). The physical form of the diet did not significantly affect the feed conversion of the horses on either energy level. This is in agreement with Hintz and Loy (1966) where no difference in feed conversion due to form of the diet was noted.

The horses were blocked according to weight. In all the parameters for growth, i.e. daily gain, wither height increase, and heart girth increase the variations between blocks were significant ($P<0.05$). The variations were not consistent throughout the entire feeding period, that is the light group did not always outperform the other two groups. This seems to indicate the variations in growth patterns of the individual horses.

Summary Feeding Trial

A feeding trial was conducted to observe the effect of the D.E. content, and physical form of the diet fed to growing yearling horses. Daily gain, and wither height increase were significantly greater ($P<0.01$) for the horses fed the NRC recommended level of D.E. (2.75 Mcal/kg feed) than for the horses fed the diets containing 85% NRC recommended level of D.E. (2.33 Mcal/kg feed). The differences due to the physical form of the diet within energy level for daily gain and wither height increase were not significant. Heart girth increases were significantly ($P<0.05$) greater for the horses fed diets at energy level I (NRC level of D.E.) than for the horses fed diets at energy level II (85% NRC level of D.E.). Differences noted within an energy level due to physical form of the diet were not significant ($P>0.05$) for either energy level I or II. The horses fed the NRC level of D.E. consumed less dry matter/day ($P<0.05$) than the horses fed the 85% NRC level of D.E. The differences noted between diet I and diet II for dry matter consumption were not significant, while the differences between diet III and diet IV were statistically significant ($P<0.05$). Feed conversion ($P<0.05$) was improved for the horses fed diets I and II than for the horses fed diets III and IV. The differences noted within energy level I and II due to physical form of the diet were not significant ($P>0.05$).

Discussion Digestibility Trial

The percent digestible dry matter was significantly ($P<0.01$) greater for the diets at energy level I (62.19%) than for the diets at energy level II (48.15%). The differences could be attributed to the composition of the diet at the two energy levels as the diets formulated at energy level I had a lower fiber content than did the diets at energy level II. Olson (1969) indicated that as the fiber content of a diet increases, the digestibility of the other nutrient components of the diet decrease. Householder et al. (1977) observed similar digestible dry matters (62.16%) with yearling and two year old horses fed oat-sorghum based diets formulated to contain 2.82 Mcal D.E./kg; as were noted with the yearling horses fed at energy level I. Wooden et al. (1970) using mature horses fed rations formulated to meet NRC requirements for maintenance observed similar digestible dry matter values (66.0%). Aber and Potter (1975) using yearling horses fed sorghum based diets observed digestible dry matter values in excess of the values found on diets at energy level I in this study (75.45% vs 62.19%). Schurg et al. (1977) maintained mature horses on whole corn plant pellets supplemented with soybean meal and noted digestible dry matter values similar to those reported by Aber and Potter (1975). The differences in digestible dry matter values observed between diets within an energy level due to form of the diet were not significant. Hintz and Roy (1966) also indicated that pelleting of a diet did not influence the apparent digestibility of the dry matter portion of the diet when compared to the unpelleted form of that diet.

Energy digestibility was significantly greater (P<0.01) for the diets at energy level I than for the diets at energy level II (63.0% vs 49.0%). Householder et al. (1977) using both yearling and two year old horses noted digestible energy values of 65.0% and 60.5% respectively. These values are in close agreement with those noted for diets at energy level I. The horses used by Householder et al. (1977) were fed diets formulated to meet energy levels of 2.82 Mcal/kg. Aber and Potter (1975) fed yearling horses sorghum based diets, and noted digestible energy values greater than those noted in this study (79.0% vs 63.0%). Workers using mature horses have noted a wide range of apparent energy digestibilities. Wooden et al. (1970) noted a value of 63.0% for horses fed at NRC maintenance levels, while Schurg et al. (1977) observed energy digestibilities similar to that of Aber and Potter (1975), while feeding horses a whole corn plant pellet diet. Differences noted between diets within an energy level due to form of the diet were not found to be significant. Hintz and Loy (1966) also observed no effect on energy digestibility due to pelleting of the diet.

There was no significant difference in nitrogen balance values (grams per day) among diets I, II, III (13.25, 15.0, and 14.85 respectively), with protein values of the diet formulated to approximately 12.5% regardless of the energy level. These values are in close agreement with those obtained by Reitnour and Treece (1971) of 10-70 grams per day, for ponies fed a diet using soybean meal as its major source of protein. Hintz et al. (1969) noted a lower nitrogen retention of 3.39 grams/day, also using soybean meal as a major protein source. The value of -2.25 grams per day noted for diet IV was a result of extreme variability. This value was significantly ($P<0.05$) different from the values noted for diets I (13.25), II (15.0 and III (14.85).

The acid detergent fiber (ADF) technique was used to determine the fiber content of the feed. It was felt that this would give a clearer picture of the effect of lignin on digestibility. The ADF portion of the feed contains the lignin and cellulose, and is generally higher than crude fiber because of the loss of crude fiber during the alkaline extraction process during the crude fiber determination. ADF does not, however, clearly show the distinctions in total fiber content between feedstuffs (Fonnesbeck 1968). The differences in ADF disappearance between diets at energy level I (28.7%) and energy level II (24.0%) were not significant. A wide range was noted both within an energy level and between energy levels. A larger difference would have been expected because of the larger lignin content of the straw used in formulating diets III and IV for energy level II. Schurg et al. (1977) noted an ADF digestibility of 47.5% with mature horses being fed whole corn plant pellet diets. Wooden et al. (1970) using a maintenance diet fed to mature geldings observed an ADF digestibility of 36.8%. These two values are much greater than those reported in this experiment. The results obtained were extremely variable, possibly due to the age of animal, and length of adaptation allowed for each diet. Jordan (1970) indicated that the number of bacteria and their activity would have a large effect on lower gut digestion in the horse. It may be possible that the young horses used in this study may not have had a suitable population of bacteria to effectively utilize the type of fiber in the diets.

Summary   Digestibility Trial

A digestion trial was conducted using four male horses to observe the effect of a reduced D.E. content and physical form of diet on digestion, and nitrogen balance of growing horses. Dry matter digestibility and energy digestibility were significantly greater ($P<0.01$) for the diets (I and II) containing the NRC recommended level of D.E. (2.75 Mcal/kg feed), than for the diets (III and IV) containing 85% of the NRC recommended level of D.E. (2.33 Mcal/kg feed). Differences between diets within energy levels were not significant. ADF digestibility was extremely variable between horses, and the differences between diets were not significant. Nitrogen balance was variable between horses and the differences between diets were not significant.

Conclusion

The inclusion of a low quality roughage such as straw in a feeding program causes a reduction in the digestible energy (D.E.) content of the diet. The reduced D.E. content of diets fed to growing colts resulted in significantly ($P<0.01$) reduced growth rates. The reduction in growth was noted in average daily gain, wither height increase and heart girth increase.

The reduction in growth due to the reduced D.E. content was associated with the lower total intake of energy which subsequently would result in a reduced amount of energy available for growth over the maintenance requirements. Hintz (1968) noted that the fiber composition greatly affected the digestibility of the diet. The end products of digestion and their subsequent utilization would affect the efficiency of the specific diets. The more highly digestible diet would be more efficient in meeting maintenance and growth requirements.

(1) Adequate growth rates can be achieved with diets formulated to meet NRC nutrient levels for yearling horses. The colts fed diets I and II had extremely good growth rates and exceeded the expected NRC (1973) daily gains.

(2) The colts fed diets III and IV (formulated to meet 85% of the NRC level of D.E.) also had satisfactory daily gains. The gains made by these horses while

they also exceeded the expected NRC daily gain were significantly lower than the gains noted with diet I and II. This indicates that a high rate of gain can not be achieved with this type of ration.

(3) Compensatory growth was a factor throughout the feeding period. The change from a herd situation to an individual feeding situation resulted in daily gains far in excess of what has been recorded by other workers.

(4) The practicality of incorporating a roughage such as straw into the diet in the manner used in this study is very low. The use of this type of roughage in a practical situation could be from the standpoint where it does not make up a large portion of the daily intake. Some processing would be required, i.e. chopping and this chopped roughage offered free choice. The use of large amounts of poor quality roughage could result in poor growth of young horses when fed in a herd situation.

(5) Problems of feed refusal and possible health problems such as compaction and colic could result with straw making up a large portion of the daily ration.

(6) The extra work required in utilizing straw and the extra management of young horses (watch consumption and general health) when straw is a major portion of the daily ration is too great and offsets any economic advantage of using this cheaper roughage.

The use of high quality feedstuffs for rations of growing horses is far more economical in that a better growth rate can be obtained and the problems in handling such a feeding program are greatly reduced. If excessive gains are being made on a high quality diet, the control of daily intake is a far better way to modify growth than by making excessive use of a low quality roughage.

Until such time as we have more detailed information on growth rates for horses we should endeavor to maintain NRC nutrient levels in our feeding programs and keep the colts growing.

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Appendix Table 1

Results - 100 day feeding trial

ADG (kg/day)
Wither height increase (cm)
Heart girth increase (cm)

Feed conversion kg feed/kg gain
Dry matter consumed (kg/day)

Horse	Ration	ADG kg/day	Wither height increase (cm)	Heart girth increase (cm)	Feed conversion kg feed/kg gain	Dry matter consumed kg/day
Suzie	1	.95	7.5	18.75	3.3	6.36
Imp	2	1.025	7.5	20.00	3.08	6.34
Fawn	3	.73	4.38	10.00	4.30	6.42
Bette	4	.77	5.0	10.00	5.26	8.2
Dakota	1	.90	5.63	8.75	3.52	6.4
George	2	.88	3.75	13.75	3.59	6.35
Shrimp	3	.61	3.44	3.75	5.21	6.44
Socks	4	.65	4.0	5.0	6.24	8.20
Peggy	1	.41	9.38	3.75	7.75	6.29
Chief	2	.73	6.25	12.5	4.3	6.35
Sandy	3	.4	3.75	10.0	7.75	6.44
Lady	4	.45	6.25	5.63	7.30	6.77

Appendix Table 2

Analysis of variance for daily gain (kg/day), wither height increase (cm), heart girth increase (cm) dry matter consumed (kg/100 day), and feed conversion (kg feed/kg gain) for the 100 day feeding trial.

Source	df	Mean squares				
		Daily gain kg/day	Wither height increase (cm)	Heart girth increase (cm)	Feed conversion feed/gain	Dry matter consumed kg/100 day
Block	2	.6996**	.8958*	9.6458	40.0232**	9,029
Treatment	3	.2614*	1.1128*	6.7500	19.1735*	65,202*
Energy	1	.6533**	2.2968**	14.083**	46.1776*	76,320*
Form	1	.0261	1.0208*	2.083	9.9008	60,066*
Energy x Form	1	.1045	.0209	4.084	1.4421	59,220*
Error	6	.0259	.1505	1.8125	3.51	7,787
Total	11					

* Indicates significance at the 0.05 level.

** Indicates significance at the 0.01 level.

Appendix Table 3

Analysis of variance for dry matter digestibility (%), energy digestibility (%), fiber digestibility (%), and nitrogen balance (grams/day).

Source	df	Mean square			
		Dry matter digestibility	Energy digestibility	Fiber digestibility	Nigrogen balance
Between rations	3	254.347**	221.29*	21.67	.0068
Within rations	11	17.060	47.07	69.272	.0023
Total	14				

* Indicates significance at the 0.05 level.

** Indicates significance at the 0.01 level.

Appendix Table 4

Growth of yearling horses

Researcher	Daily gain kg/day	Wither height cm	Heart girth cm	Feed conversion feed/gain
NRC, 1973	.55			
Potter and Huchton, 1975	.43-.57	6.10-8.63	5.33-11.18	11.89-16.30
Aber and Potter, 1975	.50-.58	5.84-7.24	8.12- 9.40	12.96-15.61
Ott and Richardson, 1977	.48-.55	.039-.048	.075-.082	
Heusner and Albert, 1977	.49-.52			13.01-13.10
Householder _et al._, 1977	.64-.69	8.33-9.65	12.83-14.00	
This Study Energy Level I	.818	6.65	12.9	9.33
This Study Energy Level II	.604	4.48	7.44	13.25

Appendix Table 5

Results Digestibility Trial

Energy Digestibility (%) (E-D)
Dry Matter Digestibility (%) (DM-D)
Nitrogen Balance (gram/day) (N-B)
Acid Detergent Fiber Digestibility (%) (ADF-D)

Horse	Ration	E-D	DM-D	N-B	ADF-D
A	I	61.0	63.6	1.25	29.8
B					
C		76.0	63.1	11.5	30.8
D		66.0	68.2	27.0	41.5
A	II	61.4	63.0	33.5	30.6
B		52.5	52.6	4.75	11.5
C		60.4	60.7	1.75	28.8
D		59.7	61.2	20.25	29.2
A	III	58.0	47.5	13.50	21.2
B		44.2	43.1	18.75	15.6
C		46.0	45.2	15.50	20.8
D		52.0	51.2	11.75	28.4
A	IV	52.4	53.1	-24.75	31.4
B		49.0	50.7	0	29.5
C		50.4	51.7	-1.0	32.4
D		40.4	42.4	14.50	18.1

Appendix

During the adaptation period prior to the digestibility trial it was found that complications caused by upsetting the horses when some received hay and pellets (diets I and III) while others (diet II and IV) received only pellets; could be reduced by feeding the same diet to all horses at one time. The complications were caused by too much movement in the crates resulting in contamination of feces and spillage of urine. Had the construction of the crates been different, more solid, these problems would have been reduced and the Latin square design could have been used.