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DIGESTIBILITY, DIGESTA FLOW, AND BEHAVIOR
ASSOCIATED WITH DIETS THAT VARY IN FIBER LEVEL AND FORM,
FED TO PONIES AT A MAINTENANCE LEVEL

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By

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ABSTRACT

DIGESTIBILITY, DIGESTA FLOW, AND BEHAVIOR ASSOCIATED WITH DIETS THAT VARY IN FIBER LEVEL AND FORM, FED TO PONIES AT A MAINTENANCE LEVEL

By

Michael J. Yoder

This study was designed to evaluate the ponies ability to utilize four dietary treatments: low-fiber (9% crude fiber) complete pellet (LF), LF plus 0.90 kg oat straw/d (LFS), high-fiber (17% crude fiber) complete pellet (HF), and HF plus 0.90 kg oat straw/d (HFS). Ponies were fed twice/d at a level to maintain body weight. Rate of digesta passage was determined for all treatments using chromium-mordanted fiber as a digesta marker. Behavior, including wood chewing, was observed and recorded. Digestibility of the dietary treatments was determined.

LF and HF were digested more completely than LFS and HFS. Rate of passage was faster for LFS and HFS, and for HF and HFS, when compared to LF and HF, and LF and LFS, respectively. No significant differences between behavioral scores or the amount of wood chewed were detected. The ponies efficiently utilized complete pelleted diets with 12.7% ADF.

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CHAPTER I

Feed Intake and Digestibility

Introduction

Complete pelleted diets have been fed to a wide variety of animal species, from pigs (Seerley et al., 1962) and horses (Argenzio et al., 1974; Haenlein et al., 1966; Shurg and Holtan, 1979; Ullrey and Dingerson, 1972) to zoo inhabitants such as the dik-dik (Baer, 1987). Earle (1950) suggested that pelleted rations are more convenient to feed, and decrease labor and feed wastage as well as transportation and storage costs. Lewis (1982) reported a 2 to 5% improvement in digestibility due to the processing of grains. Pelleted diets produce less dust when fed and, when properly processed, provide a more homogeneous ration.

Pelleted rations may also have several disadvantages. Excessive heat during the pelleting process may destroy vitamins and inhibit amino acid availability. Since nutritional quality is difficult to determine visually, poor quality feedstuffs may be incorporated in pelleted rations without detection prior to feeding (Lewis, 1982).

Current interest in feeding high-energy rations to performance horses has stimulated production and use of pelleted and extruded feeds. Energy density in a diet may be enhanced by: 1) feeding dietary fat; and (or) 2) decreasing dietary fiber in the diet, allowing for greater concentration of the nonstructural carbohydrates. Commercial feeds, such as Athlete™ (Ralston Purina, Inc., St. Louis, Missouri), achieve high-energy density through the addition of dietary fat. Bowman (1977), Rich (1981), and Scott (1987) successfully fed fat to horses and ponies without negative effects on digestion. Duren et al. (1987) indicated that fat may be efficiently utilized when fed at a rate of up to 20% of the total ration digestible energy. While such diets may be beneficial in efforts to increase or maintain body weight, the actual benefits of feeding fat to the performance horse have yet to be determined. Meyers et al. (1987) found that muscle glycogen concentrations increased significantly when a diet containing 10% fat was fed. This appears to agree with the suggestion by Hintz (1983) that endurance horses should benefit most from the sparing of muscle glycogen that results when high-fat rations are fed. On the other hand, Pagan (1987A) evaluated diets high in either carbohydrate, protein, or fat, concluding that the relative proportions of dietary fat and carbohydrate ideal for exercise of various intensities and durations in performance horses are still in question.

Formulation of a pelleted, energy-dense ration, without utilization of dietary fat, requires concentration of the nonstructural carbohydrates, most notably starch. Maximizing this concentration may be achieved by minimizing the percent dietary fiber in the ration. Heaton (1973) stated that dietary fiber provides three physiological barriers to energy intake: 1) bulky fiber displaces the more digestible nutrients from the diet; 2) consumption of fibrous diets is limiting since long fiber must be chewed (chewing stimulates salivation and secretion of gastric juices, which distend the stomach); and 3) fiber reduces absorption in the small intestine.

Hintz et al. (1978) defined an herbivore as "an animal (vertebrate or invertebrate) that can subsist on a diet consisting of fibrous plant material." As herbivores, horses and ponies have traditionally consumed large quantities of fibrous plant material through intermittent grazing. Janis (1976) noted that not only are horses highly successful herbivores, they also selectively consume diets higher in fiber and lower in protein than other nonruminant foragers.

Like many nonruminant herbivores, the horse is able to utilize fibrous feedstuffs through hindgut microbial fermentation. Hindgut fermenters, those animals in which microbial fermentation of digesta occurs in the enlarged cecum and large colon, are considered less efficient in digesting fiber than are ruminants. The horse digests the fiber of average quality grass hay with two-thirds the efficiency of the cow (Hintz, 1969). In addition to the limited efficiency of fiber digestion, energy intake by the horse may be limited due to the horses relatively small stomach. Church and Pond (1988) indicated that the equine stomach accounts for only 9% of the total gastrointestinal tract capacity. This becomes important when one considers the manner in which many domesticated horses are fed. Intermittent grazing allows wild or pastured horses to consume adequate amounts of energy through many, relatively small meals per day. However, those animals confined to stalls or small dry lots are commonly fed only twice per day. Thus, under common feeding regimens, horses performing high intensity work may have difficulty consuming adequate levels of energy.

Enhancing energy intake by the working horse may be achieved by: 1) increasing the number of feedings from two to three, or even four, per day (energy intake is thereby increased by increasing the total volume of feed consumed in a 24-hr period); and (or) 2) feeding energy-dense feeds, allowing greater energy intake per unit of feed consumed.

When compared to high-forage diets, high-concentrate (energy-rich) diets are utilized more efficiently. Feeding high-concentrate diets results in a greater amount of carbohydrate being digested in the small intestine and absorbed as glucose. When feeding high-roughage diets, more carbohydrate is converted to volatile fatty acids (VFA) in the hindgut. Blaxter (1967) suggested that the metabolizable energy (ME) of glucose is more efficiently utilized than VFA by ruminants, and Hintz et al. (1971) suggested that the same is probably true for horses. Thus, feeding high-concentrate rations provides greater energy intake per kg of feed consumed, and the end products of metabolism are utilized more efficiently than would those resulting from consumption of more fibrous diets.

Hintz and Loy (1966) found that pelleted diets were consumed faster and passed through the digestive tract more quickly, allowing them to be consumed in greater quantities than non-pelleted diets. Thus, energy intake may be dually enhanced through the consumption of greater volumes of energy-rich, pelleted diets.

A series of feeding trials was designed to evaluate the pony's ability to efficiently utilize energy-rich rations that varied in the composition and (or) form of dietary fiber. To evaluate the effects of fiber level in the diet, two complete pelleted, low-fiber (9% CF) and high-fiber (17% CF) diets (Table 1) were fed to evaluate the importance of fiber form, oat straw (Cullison, 1961) was provided to one pony on each of the two pelleted diets, during each period. Dry matter intakes and digestibility coefficients were compared to determine efficiency of diet utilization.

TABLE 1. Composition of the low- (LF) and high-fiber (HF) complete pelleted experimental diets.

Feed name	LF	HF
Corn cob product[A]	16.00	42.00
Corn grain	35.2	6.00
Soybean meal, 48% CP	5.05	8.25
Wheat middlings	30.00	30.00
Alfalfa meal, dehy	5.00	5.00
Cane molasses	5.00	5.00
Soybean oil	1.00	1.00
Sodium chloride	0.50	0.50
Trace mineral premix[B]	0.10	0.10
Vitamin premix[C]	0.10	0.10
Mold Chek[D]	0.15	0.15
Mono-dical phosphate, 18% C, 21% P	0.75	0.75
Calcium carbonate	1.15	1.15
Total	100.00	100.00
Total (DM)	89.59	90.93

[A] #4 cobs fraction, The Anderson's, Maumee, Ohio. Neutral detergent fiber 78.1%, acid detergent fiber 41.1% and lignin 5.4%.

[B] Provided per kg of diet: 50 mg iron, 0.8 mg iodine, 0.1 mg cobalt, 10 mg copper, 30 mg manganese, 0.2 mg selenium, and 75 mg zinc.

[C] Provided per kg of diet: 4 mg riboflavin, 20 ug vitamin B_{12}, 40 mg niacin, 300 mg choline, 10 mg Ca pantothenate, 5000 IU vitamin A, 100 IU alpha-tocopherol, 1000 IU vitamin D.

[D] Mold Chek[R], Flavor Corp. of American Division/Agrimerica, Inc., Northbrook, Illinois.

Materials and Methods

Four gelded, Shetland-cross ponies from four to ten years of age and weighing 178 to 248 kg were used in a 4 x 4 Latin Square experiment, beginning on April 20, and ending on July 14, 1988. Prior to the onset of Trial 1, each pony was vaccinated with Double-E™ FT (Pitman-Moore, Inc., Washington Crossing, New Jersey) for protection against tetanus, influenza, and Eastern and Western encephalomyelitis. In addition, each pony received 4 to 5 g of Eqvalen (MSD Agvet, Merck and Co., Inc. Rahway, New Jersey) for control of both internal and external parasites.

Ponies were housed in stalls (1.5 m x 3.0 m) located at the Michigan State University Horse Research and Teaching Center. Stall partitions consisted of metal gates which allowed interaction among ponies and enhanced ventilation. Sand was used as bedding to avoid use of fibrous bedding materials and to maximize comfort. Ponies received 1 hr free exercise in a dry lot each day, at which time stalls were cleaned and new sand added as necessary.

Ponies were fed and watered at 0800 and 1650 hr daily. Water, provided in 16 l buckets, was weighed prior to being placed in each stall and again before the next feeding to determine the amount of water consumed in each 24-hr period. Ambient temperature, humidity, and barometric pressure were recorded at each feeding and averaged to obtain one measurement for each day.

There were four experimental periods in which each pony received one of four dietary treatments: 1) low-fiber (LF) (9% crude fiber) complete pellet; 2) low-fiber pellet plus 0.90 kg oat straw/d (LFS); 3) high-fiber (HF) (17% crude fiber) complete pellet (HF); and 4) high-fiber pellet plus 0.90 kg oat straw/d (HFS). Oat straw was used, since it is considered less palatable than most hays commonly fed to horses, and would therefore, satisfy any need or desire for long fiber without interfering with consumption of the pelleted diets (Cullison, 1961). It should be noted that the diets used in this study were neither isocaloric or isonitrogenous. Ponies were weighed at the beginning of each trial and fed the pelleted diets at a rate equal to 1.5% of body weight. Each pony was weighed 7 d later, and feed was adjusted to maintain body weight.

Each experimental period consisted of a minimum of 10 d for diet adaptation followed by a 3-d collection period. On the first morning of each 72-hr collection period, each pony was fitted with a fecal collection bag (Figure 1). The collection bags, constructed of medium-weight canvas, were a modified version of those described by Carle (1975). The ponies in this trial were evidently smaller than those used by Carle so the collection bags used were 30% smaller. The harnesses used to hold the collection bags in place were constructed of 5 cm nylon webbing with 2.5 cm straps, which were attached to the bags (Carle, 1975).

Total fecal collections were made at 6, 9, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 72 hr post dosage. Fecal samples were immediately weighed, mixed to insure homogeneity and frozen with all samples representing a given pony over the 72-hr collection period. Following the 72-hr collection, all samples

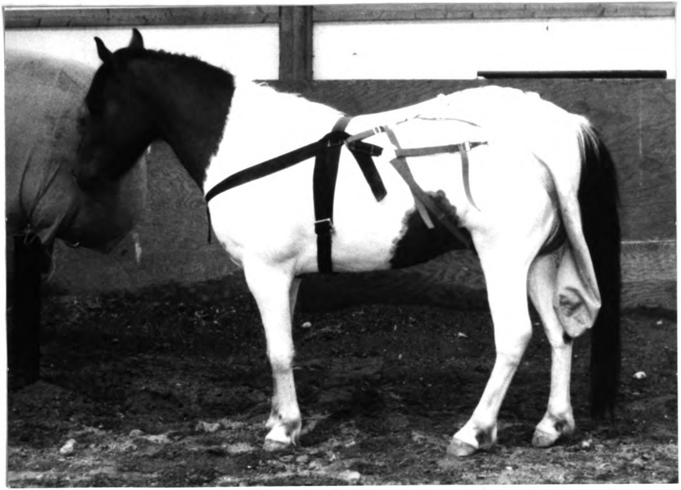

Figure 1: Pony 1 wearing collection bag and harness.

(representing a pony) were mixed and a 0.5 kg subsample was taken and frozen until analysis to determine digestibility of the experimental diets. Fecal samples were freeze dried (Model 25 SRC freeze dryer, The Vertis Co., Gardiner, New York) to minimize losses of volatile fatty acids during the drying process. Samples were then mixed (Commercial Blender, Model CB-5, Waring Products, Winsted, Connecticut) prior to analysis. Feed samples were ground in a Wiley mill to pass through a 2 mm screen. Feed and fecal samples were analyzed for crude protein (CP), dry matter (DM), gross energy (GE), neutral detergent fiber (NDF), acid detergent fiber (ADF), ash, and acid lignin (AL). CP was determined using a semi-automated micro-Kjeldahl method to analyze approximately 0.150 g of feed and fecal samples (AOAC, 1984). GE was determined by complete combustion in a Parr adiabatic bomb calorimeter (Parr Instrument Company, Moline, Illinois). Approximately 0.800 g of subsample was combusted with the resulting residue titrated with 0.725 N sodium carbonate to correct for the heat generated by nitric acid formation. Ash was determined by igniting approximately 0.800 g of subsample in a muffle furnace (600° C) for 4 hr. NDF and ADF were determined by the procedures of Goering and Van Soest (1970) as modified by Robertson (1978). Approximately 0.500 g and 1.000 g subsamples were used for the NDF and ADF, respectively. Alpha-amylase (Catalog #A1278, Sigma Chemical Co., St. Louis, Missouri) was used in the NDF analysis, as described by Robertson and Van Soest (1977). AL was determined on the ADF using 72% sulfuric acid (Goering and Van Soest, 1970). All analyses were performed in duplicate.

Results

Results from this study indicate that mean dry matter intake (Table 2) was higher ($P < 0.01$) when ponies were fed pellets plus oat straw (LFS and HFS) as compared to consumption of pellets only (LF and HF). Digestible energy (DE) (kcal/g DM) was greater when ponies were fed LF and HF as compared to LFS and HFS. Mean body weight (BW) and water consumption (H_2O) were similar across treatments.

TABLE 2. Mean body weight (BW), dry matter intake (DMI), digestible energy (DE) concentration of dietary dry matter (DM), and water intake (H_2O) of ponies fed four experimental diets: low-fiber complete pellet (LF), LF + 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), and HF + 0.90 kg oat straw/d (HFS) (N = 3).

	Treatment				
Factor	LF	LFS	HF	HFS	SEM
BW (kg)	210.3	211.2	212.3	210.9	1.83
DMI (kg/d)[1]	3.49	4.04	3.05	3.95	0.06
DMI (% of BW)[1]	1.66	1.93	1.69	1.92	0.03
DE (kcal/g DM)[1,2]	3.17	2.83	2.94	2.55	0.08
H_2O (l/d)	13.84	13.55	13.28	14.82	0.56

[1] Means for the complete pelleted diets (LF + HF) are significantly different from means for the pellet plus straw diets (LFS + HFS) ($P < 0.05$).

[2] Means for the low-fiber diets (LF + LFS) are significantly different from means for the high-fiber diets (HF + HFS) ($P < 0.05$).

CP and NDF (Table 3) were digested more efficiently ($P < 0.05$) when ponies were fed the complete pelleted diets (LF and HF) as compared to pellets plus straw (LFS and HFS). GE was digested more completely ($P < 0.01$) when LF and HF were fed when compared to LFS and HFS. Digestibility of GE was also greater ($P < 0.05$) for LFS when compared to HFS. There was no difference in GE digestion between LF and HF. ADF, AL, and ash digestibility were similar across all treatments. DE intake (kcal/g DM) increased linearly as dietary NDF and ADF decreased (Figure 3). Mean ambient temperature, relative humidity, barometric pressure and precipitation (Table 4) were confounded with period and, therefore, could not be separated for individual statistical analysis.

Discussion

Low-fiber, high-carbohydrate diets have traditionally been avoided in equine feeding programs since they have been thought to produce a greater incidence of gastrointestinal and metabolic disorders such as colic and laminitis. Pagan (1987B) noted that horses with increased muscle glycogen levels may have a greater tendency to develop exertional myopathy ("tying-up syndrome"). Schmitz (1984) reported that young Standardbred horses displayed fewer gastrointestinal problems when switched from pelleted to extruded feeds. While none of the experimental diets were consumed for an extended period, results from this study indicate that ponies may efficiently utilize complete pelleted, low-fiber, high-carbohydrate diets for relatively short periods of time, without evidence of gastrointestinal disturbance.

TABLE 3. Mean apparent digestibility (%) of constituents of four experimental diets: low-fiber complete pellet (LF), LF + 0.90 g oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 g oat straw/d (HFS) (N = 3).

	Treatment				
Factor	LF	LFS	HF	HFS	SEM
Dry matter[1]	90.1	87.6	88.4	85.8	0.57
Crude protein[1]	80.3	76.3	79.3	76.1	0.74
Gross energy[2,3]	73.6	65.1	68.1	57.1	1.27
Neutral detergent fiber[1]	56.4	49.0	51.7	40.1	2.27
Acid detergent fiber	21.6	22.7	37.4	29.0	7.35
Acid lignin	11.6	8.8	16.1	11.4	4.71
Ash	24.2	17.6	20.7	21.5	4.5

[1] Means for complete pelleted diets (LF + HF) are significantly different from means for the pellet plus straw diets (LFS + HFS) ($P < 0.05$).

[2] Means for complete pelleted diets (LF + HF) are significantly different from means for the pellet plus straw diets (LFS + HFS) ($P < 0.01$).

[3] Means for the pellet plus straw diets (LFS, HFS) are significantly different ($P < 0.05$).

TABLE 4. Mean ambient temperature, relative humidity, barometric pressure and precipitation (rain) for each of four experimental periods.

	Period			
Factor	I	II	III	IV
Temperature (°C)	11.1	18.3	22.0	25.7
Barometric pressure (Mb)	1010.9	1013.7	1013.6	1013.1
Relative humidity (%)	59.6	53.6	55.1	56.1
Precipitation (cm)	3.09	1.22	0.1	0.2

While not often considered a beast of burden, in the United States, the ultimate productive function of the horse is work. Whether that work is cutting a cow from the herd, racing 7 furlongs, or pulling a heavy load, the dietary factor most likely to change as a result of physical exertion is energy (Hintz, 1983). Energy consumption may be affected by feed availability, nutrient density and digestibility, dry matter intake, rate of digesta passage and fermentation, and the general health of the animal.

Dry matter intake, rate of digesta passage, and the rate of digesta fermentation are interrelated to the point where changes in any one of these factors will directly affect the other two (Colucci et al., 1982). Montgomery and Baumgardt (1965) and Ammann et al. (1973) reported that the level of dry matter intake by ruminants may be affected by rumen fill, and energy density of the available feeds, as the animal attempts to meet its physiological demand for energy. In this model (Figure 2), dry matter and energy intake increase with increasing energy density of the feed, until gut fill triggers satiety. At that point, energy intake may be maintained or enhanced by increasing the nutritive value of available feeds by processing roughages and increasing concentrate levels in the diet. In this manner, dry matter consumption is adequate to satisfy the animals physiological requirement for energy, and the level of feed intake is probably controlled by response to chemical or thermostatic mechanisms rather than gut fill (Montgomery and Baumgardt, 1965).

While dietary intake was controlled to maintain body weight, significantly greater levels of dry matter were consumed when the ponies in this project were fed the pelleted diets plus straw (LFS and HFS). Digestible energy consumed

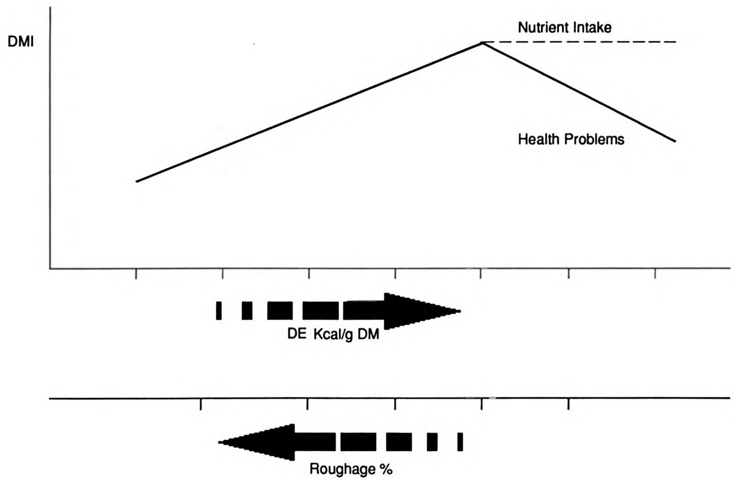

Figure 2: Proposed relationships involved in the regulation of food intake in ruminants (Montgomery and Baumgardt, 1965).

per unit of dry matter intake (Figure 3) was, however, greater for the complete pelleted diets (LF and HF). These results agree with those of Anderson et al. (1983), who found increasing levels of hay decreased dietary levels of digestible energy. It should be noted that the LFS and HF diets were virtually identical in concentrations of neutral detergent fiber, acid detergent fiber, and kcal of digestible energy per g of dry matter intake, yet LFS was consumed in significantly greater amounts than was HF. It is proposed that differing rates of digesta passage, due to the differing forms of fiber in these two diets, may account for the variation in dry matter intake. This will be examined in Chapter II of this thesis.

Ammann et al. (1973) suggested that white-tailed deer were able to regulate their energy intake at maintenance levels when the dietary concentration of digestible energy exceeded 2.17 kcal/g. Though dry matter intake increased as dietary energy density decreased over the four experimental diets in this study, feed intake was monitored and adjusted to maintain a constant body weight. Thus, the ponies were not allowed the opportunity to regulate their energy intake. Determination of the ponies ability to maintain their own body weight using the four experimental diets would require further studies in which each diet was offered ad libitum.

Vander Noot and Trout (1971) reported that the digestibility of all forage decreased as dietary crude fiber increased. Results from this study indicate that neutral detergent fiber digestibility decreased with increasing dietary fiber levels. Acid detergent fiber and acid lignin digestibility, however, changed more in response to form rather than to level of dietary fiber. ADF and AL were utilized

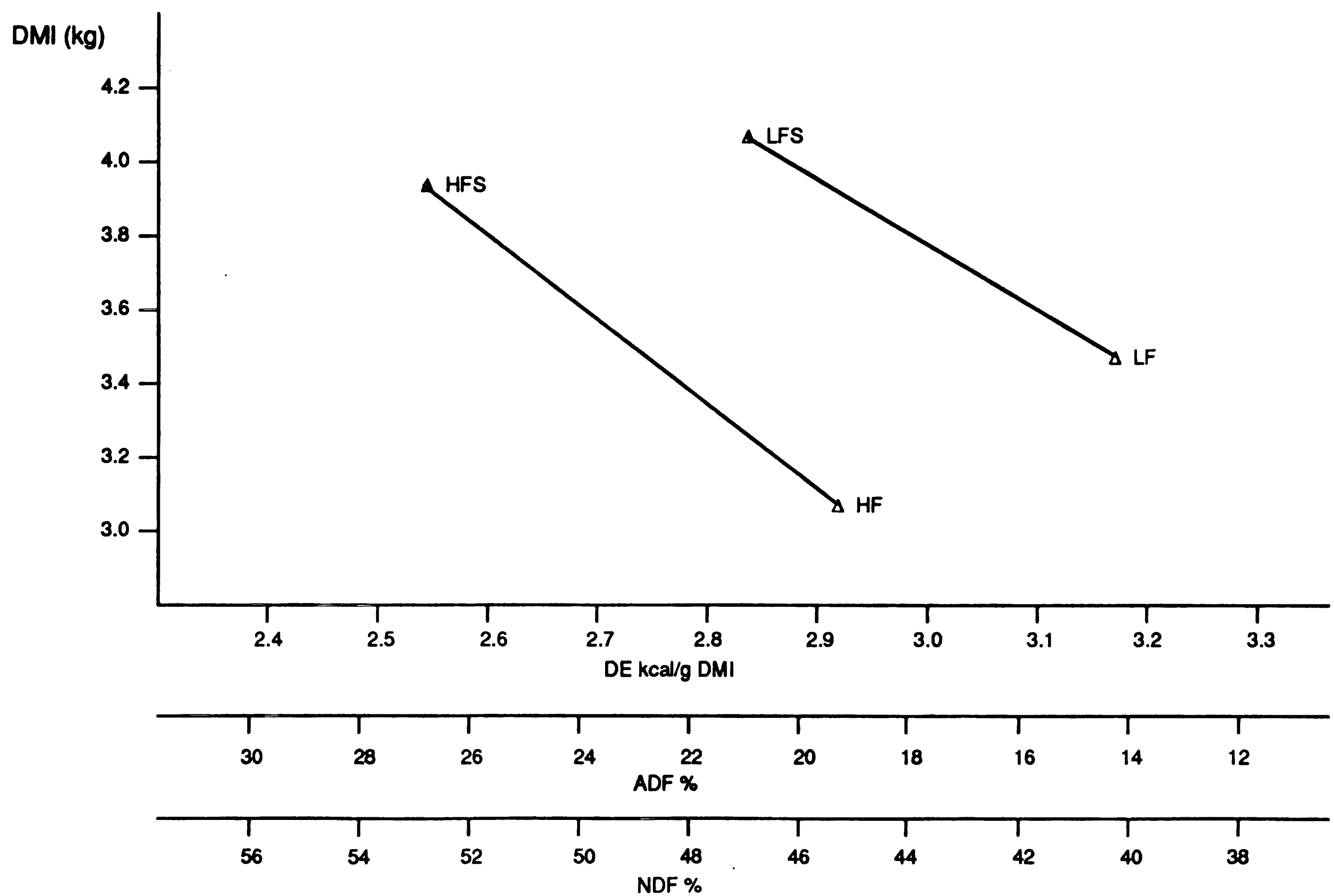

Figure 3: Relationship of dry matter intake (DMI) with dietary concentrations of digestible energy (DE), acid detergent fiber (ADF), and neutral detergent fiber (NDF).

more completely from the complete pelleted diets (Table 3). This response to form rather than to level of dietary fiber may indicate that the reduced particle size of the fiber in the complete pelleted diets was more easily digested due to increased surface area of the fiber involved.

Crude protein digestibility was significantly higher for the pelleted diets as compared to the pelleted plus straw diets. These findings are in agreement with Thompson et al. (1981), who reported that crude protein digestibility declined as the proportion of fiber in the diet increased. Results from this study indicate that fiber form was more important than fiber level in influencing protein digestibility.

Coenen and Meyer (1987) reported that horses fed hay consumed 32% more water than those fed concentrate, and Hintz and Loy (1966) reported that fresh feces from horses fed non-pelleted diets (concentrate plus roughage) were drier than the feces of horses fed complete pelleted diets. While there was a large variation between individual ponies in this study, water consumption (Table 2) was similar across all treatments. In addition, no differences were found in the percent dry matter in feces resulting from either the complete pelleted diets or the pelleted plus straw diets.

This study was designed as a 4 x 4 Latin square in an attempt to minimize the effects of period on feed intake and digestibility data. Following laboratory analysis, Pony 3 was determined to be an outlier, due to exceedingly negative digestibility coefficients for ADF, A lig, and ash, and was not included in statistical analyses of the data reported here. The high negative digestibility coefficients may have resulted from consumption of the sand that served as bedding throughout the trial. All feed intake and digestibility data were then analyzed using analysis of variance and least square means for a randomized complete block design, with N = 3.

In conclusion, the complete pelleted diets (LF and HF) utilized in this study were more readily digestible than these diets plus straw, with significant advantages in digestion of crude protein, dry matter, gross energy, and neutral detergent fiber. The addition of oat straw to the pelleted rations appeared to affect utilization of dry matter, acid detergent fiber and acid lignin, apparently decreasing digestibility of each of these factors. Since all dietary factors were virtually identical for diets LFS and HF, and the digestibility of LFS was lower for each factor, the possibility that long-stem fiber causes a more rapid rate of digesta passage, thereby limiting digestion, can not be ruled out. The presence of straw in the diets increased dry matter intake while decreasing energy density in those diets. As dry matter intake, and the dietary fiber components declined, digestible energy per unit of DMI increased in agreement with Montgomery and Baumgardt (1965). The results of this study appear to agree with Massey et al. (1985), who concluded that low-fiber, high-carbohydrate diets may be safely fed to ponies in two meals per day, when fed at maintenance levels.

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CHAPTER II

Rate of Passage

Introduction

Classified as herbivores, horses and ponies consume and utilize large quantities of the structural carbohydrates, cellulose and hemicellulose. Maximal digestion of these fibrous substances may occur only if the passage of food is subjected to delay at those sites where microbial digestion takes place (Blaxter, 1963). Since the horse is a hindgut fermenter, microbial fermentation, yielding volatile fatty acids, carbon dioxide, methane, and microbial cells, occurs in the enlarged cecum and colon of the equine digestive tract. Haenlein et al. (1966A), Hintz (1969), and Vander Noot and Galbraith (1970) reported that ruminants utilized, more fully, the fibrous portions of feeds, than did horses. This was thought to occur due to a faster rate of digesta passage in the horse allowing less exposure of the fiber to microbial fermentation. Alexander (1963) suggested that when fiber is exposed to microbes of the rumen and cecum for equal lengths of time, the horse actually digests fiber more efficiently. Using an in vitro technique to compare cecal and rumen inocula, Koller et al. (1978) found that dry matter and the cell wall fraction of forages were more efficiently digested by ruminal bacteria than by cecal bacteria, even when time of exposure was equal.

Efficient utilization of various feedstuffs, by the horse, is determined by three factors: 1) the rate at which feed moves through the digestive tract; 2) the rate of digesta fermentation; and 3) the amount of dry matter consumed (Colucci et al., 1982). Changes in any one of these three will affect the other two.

Rate of digesta passage may be influenced by various factors, such as feed intake level, ration composition and preparation, rate of digestion, digestive tract anatomy and size, and the age and health of the animal (Balch, 1961; Balch and Campling, 1965; Church, 1969). Martens (1973) studied sheep and cattle and concluded that body weight showed the highest correlation (negative) with rate of digesta passage. Seerley et al. (1962) and Heitman (1966) reported that pelleted diets passed through the digestive tract of pigs faster than did the same diets in meal form. Hintz and Loy (1966) found that the rate of digesta passage in ponies was apparently faster for pelleted versus non-pelleted diets. Seerley (1962) and Castle and Castle (1957) reported that higher feed intakes resulted in faster rates of digesta passage for pellets and meal fed to pigs, and Colucci (1982), working with Holstein dairy cows, reported decreased digestibilities due to increased rates of digesta passage that resulted from increased feed intakes. Robinson and Slade (1974), in a summary of studies by Pulse et al. (1973), stated that digesta passage rate was affected by the physical form, but not the composition, of the diet.

Digesta passage for both nonruminant and ruminant animals has been studied extensively using many different markers. Hintz and Loy (1966) used yellow, styrofoam particles with ponies. Vander Noot et al. (1967) and Hintz et al. (1985) utilized chromic oxide (Cr_2O_3) in studies with ponies and beef cows. Weber (1983) evaluated lignin, ytterbium, lanthanum, and chromium EDTA in digestibility and passage rate studies with Holstein steers. Uden et al. (1980), Colucci et al. (1982), and Quiroz et al. (1988) used chromium-mordanted fiber to study rates of digesta passage for dairy cattle and goats. Selection of a marker to study rates of digesta passage should be done with care since absorption or migration of markers will yield skewed results. Weber (1983), in review of Kobt and Luckey (1972), suggested that markers ideally possess the following properties:

1. Indigestible
2. Nonabsorbable and nonmigratory
3. Flow with the total digesta in a steady state
4. Nontoxic to tissues or microbes of the digestive tract
5. Noninterposing with respect to digestibility of dietary components
6. Analytically quantifiable by specific and sensitive means
7. Noninterposing with the analysis of other dietary components

Terminology used in the measurement of digesta passage rates includes transit time, the time required for the initial appearance of a given meal to pass through the digestive tract, and total mean retention time (TMRT), the weighted average time for the appearance of marker in the feces (Faichney, 1975). Peak time, time to maximal fecal marker concentration, was also of interest in this study.

The rate of digesta passage in equids has been shown to change as a result of changes in the physical form of a ration. Hintz and Loy (1966) found that the rate of passage was faster for a pelleted vs. a conventional diet containing hay. Seerley et al. (1962) found that pelleted diets had a faster rate of passage than did meal-form diets when fed to pigs.

The objective of this study was to measure and compare the digesta passage rates of the four experimental diets previously described. In particular, comparisons were made of the two complete pelleted (HF vs. LF) diets, as well as evaluating the effects (on passage rate) of adding oat straw to each of the pelleted diets.

Materials and Methods

This series of digesta passage rate trials utilized the same ponies, under the same conditions, as described in the previous chapter. The marker chosen to evaluate the rates of digesta passage was chromium-mordanted fiber (Uden et al., 1980). The fiber used was second cutting alfalfa hay, determined by visual appraisal to be of excellent quality. This was prepared by grinding in a Wiley mill to pass through a 2 mm screen. The ground sample was then treated by boiling 1 hr in a neutral detergent solution, after which it was thoroughly rinsed. Because a relatively large amount of neutral detergent fiber was needed, rinsing was most efficiently accomplished by sewing the sample in a cloth bag and putting it through the rinse cycle of an automatic washer. The fiber was then oven-dried (100° C) and a 14% sodium dichromate solution added. This mixture was then baked for 24 hr in a 100° C oven. The fiber was then thoroughly rinsed, suspended in tap water, and ascorbic acid (Catalog #4640, Eastman Kodak Co., Rochester, New York), equal to one-half the weight of the fiber, was added. After soaking at least 1 hr, the fiber was thoroughly rinsed and dried at 65°C.

On the first morning of each fecal collection period, each pony was weighed to determine the amount of marker to be administered. Each pony then received an amount of chromium-mordanted fiber equal to 0.013% of body weight (Baer, 1987). The marker was administered via stomach tube, after being mixed with approximately 2.5 l of tap water. Each pony received it's normal ration immediately following administration of the marker. Since the ponies began to consume feed immediately, feed marker administration appeared not to be overly stressful.

Total fecal collections were made at 6, 9, 12, 18, 24, 30, 36, 42, 48, 54, 60, 66, and 72 hr post dosage. Each sample was immediately weighed, mixed by hand, and a 500 g subsample removed and frozen until analyzed. Prior to analysis, each sample was placed in a Waring blender (Model #CB-5, Waring Products, Co., Winstead, Connecticut) and ground using approximately 250 ml of liquid nitrogen. Liquid nitrogen maintained the sample in a frozen state, enhancing the effects of grinding, and then evaporated during the grinding process. Approximately 1.2 g of sample was then placed in a 250 ml erlenmeyer flask. Ten ml of nitric acid and 4 ml of 70% perchloric acid (Fenton and Fenton, 1979) were added to the sample which was then placed on a hot plate until fully digested. Following digestion, samples were diluted with distilled deionized water. Standards ranging from 1 to 5 ppm of chromium were prepared from a 1000 ug Cr/ml (at 20° C) solution of chromium (Alfa Products, Danvers, Massachusetts). An atomic absorption/emission spectrophotometer (Model IL951, Instrumentation Laboratory, Inc., Wilmington, Massachusetts) was used with emission wavelength set at 425.4 nm. All analyses were performed in duplicate.

Statistical analyses were performed using the Statistical Analysis Systems (SAS) analysis of variance of repeated measures by general linear models and least square means procedures. Comparison of treatments within each period were performed using the Bonferroni t-test (Gill, 1986). Missing cells in the data set were replaced using the method for replacing missing cells in a Latin square as specified by Gill (1978).

Results

There were no significant differences in transit time since chromium was detected in rather small amounts at the 6 hr collection for all ponies. Peak time, ranging from 24 - 54 hr, was also similar across all treatments, with large variations between ponies.

Significant differences were detected in total mean retention time (TMRT) across all treatments. The high-fiber complete pelleted diet (HF) and HF plus 0.90 kg oat straw (HFS) passed more quickly ($P < 0.01$) than did the low-fiber complete pelleted diet (LF) and LF + 0.90 kg oat straw (LFS). LFS and HFS had a TMRT significantly ($P < 0.001$) lower than that for the complete pelleted diets (Table 5). LF was retained in the digestive tract longer than HF ($P < 0.05$).

TABLE 5. Mean retention time and peak time for rates of digesta passage associated with four experimental diets: low-fiber complete pellet (LF), LF+ 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS) (N = 4).

	Treatment				
Factor	LF	LFS	HF	HFS	SEM
Retention time (hr)[1,2,3]	57.0	33.9	42.8	23.9	3.22
Peak time (hr)	42.0	33.0	33.0	27.0	3.24

[1] Means for the complete pellet diets (LF, HF) are significantly different ($P < 0.05$).

[2] Means for the high-fiber diets (HF + HFS) are significantly different from the low-fiber diets (LF + LFS) ($P < 0.01$).

[3] Means for the pellet plus straw diets (LFS + HFS) are significantly different from means for the complete pellet diets (LF + HF) ($P < 0.001$).

Table 6 indicates that the greatest differences in rate of digesta passage were from 42 - 72 hr, during which time chromium concentrations in the LFS and HFS samples declined rapidly.

Discussion

Many factors have been recognized as potential effectors of digesta passage in herbivores and omnivores alike. Moir (1968) reported that ruminants retain digesta longer than nonruminants, indicating the importance of gut anatomy and capacity. Diet preparation, intake level, rate of digestion, age, and general health of the animal also have been noted to affect digesta passage (Balch, 1961; Balch and Campling, 1965; Church, 1969). Robinson and Slade (1974) reported that dietary form, not composition, affected digesta passage

TABLE 6. Concentration (ppm) of chromium (Cr) in fecal dry matter of ponies fed four experimental diets: low-fiber complete pellet (LF), LF + 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS) (N = 4).

Time after dosing (hr)	Treatment				
	LF	LFS	HF	HFS	SEM
6	144.8	112.2	131.2	90.5	5.99
12	162.8	124.5	159.0	105.5	8.87
18	256.2	275.0	306.8	369.8	33.63
24[2]	600.0	841.0	640.2	1104.5	85.74
30	916.8	1102.0	793.8	955.0	107.17
36	1024.0	918.5	813.8	576.0	112.99
42[1,2]	966.2	596.0	712.2	278.8	69.84
48[2]	840.5	390.2	664.8	189.8	59.44
54[2]	846.8	371.8	599.2	167.8	87.62
60[2]	624.5	201.0	446.8	108.2	102.56
66[2]	571.2	157.8	333.8	80.2	77.32
72[2]	445.0	147.8	285.8	111.8	68.30

[1] Means for complete pellet diets (LF, HF) are significantly different ($P < 0.05$).

[2] Means for complete pellet diets (LF + HF) are significantly different from means for pellet plus straw diets (LFS + HFS) ($P < 0.01$).

rates in horses. This agrees with Johnson (1964) and Heitman (1966) feeding steers and swine, respectively.

Hintz and Loy (1966) in studies with horses, Weir (1959) with steers, and Seerley et al. (1962) with swine reported that pelleted diets passed through the gastrointestinal tract more quickly than did conventional hay, chopped hay, and meal-form diets. In this study, mean retention time (Table 5) was significantly greater for both the low- and high-fiber complete pelleted diets, when compared to these diets plus oat straw. These results appear to indicate that at low levels of dietary fiber, the form of fiber may play an important role in diet utilization. While these results appear to be in conflict with those previously reported, the relationship between rate of digesta passage, dry matter intake, and rate of digestion should be reviewed.

Blaxter (1956), Thornton and Minson (1973), and Colucci et al. (1982) found in studies with sheep and cattle, that increased rates of digesta passage resulted from increased levels of feed intake; their results agree with those of Seerley et al. (1962) in studies with swine. As reported in Chapter I of this thesis, dry matter intake of the diets containing straw was significantly greater than that of the complete pelleted diets alone. Thus, perhaps the most obvious explanation for the difference in rates of passage noted in this study is the difference in dry matter consumption for each experimental diet. In this manner, changing dietary form through the addition of long-stem fiber, increases the rate of digesta passage, apparently as a result of increased dry matter intake. The decrease in digestibility of dietary components, generally associated with increased rates of passage, were observed and reported in Chapter I.

It should be pointed out that Hintz and Loy (1966) and Weir (1959), in reporting higher rates of passage for pelleted diets, fed hay as their source of long-stem fiber rather than oat straw, as was used in this study. Oat straw is reported to be higher in percent cell walls, acid detergent fiber, cellulose and lignin than is alfalfa hay (NRC 1978). Analysis of the oat straw utilized in this study indicates it was higher in acid detergent fiber and cellulose than reported by the NRC. It was considerably lower (8.4% vs. 13%) in acid lignin, and digestibility of this fiber component was less than noted for the complete pelleted diets (Table 3). Lower digestibility of the fiber fraction of a diet may account for the increased rate of passage exhibited by those diets containing straw. Higher digestibility of the fiber component of the hays fed by Hintz and Loy (1966) and Weir (1959) may explain the increased retention of those diets when compared to the pelleted diets used in their studies.

Robinson and Slade (1974), in a review of work by Haenlein et al. (1966), reported that diet composition apparently does not affect the rate of digesta passage. Colucci et al. (1982), however, found a reduction in retention time of both forage and concentrate components of a high-forage diet when compared to a low-forage diet. In this study, a highly significant reduction in total mean retention time was found when the high-fiber pellets, with and without oat straw, were fed. Table 7 shows the composition of the four experimental diets utilized in this trial. The high-fiber diets (HF and HFS) had higher levels of neutral detergent fiber, acid detergent fiber, and acid lignin. These results appear to indicate that at low levels of dietary fiber, minor increases in the composition of the dietary fiber components effectively increase rate of digesta passage.

Recovery of dietary markers in studies with equine subjects has varied with type of marker and diet. Alexander (1946), using colored particles, and Haenlein et al. (1966), using chromic oxide (Cr_2O_3), recovered 100% of their respective markers by 48 hr. Vander Noot et al. (1967) reported maximal recovery of Cr_2O_3 at 36 - 48 hr, and recovery was virtually complete by 72 hr.

TABLE 7. Analyzed composition of four experimental diets: low-fiber complete pellet (LF), LF + 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS)

	Experimental diet			
Factor	LF	LFS	HF	HFS
Dry matter (%)	90.1	90.2	91.4	91.2
Digestible energy (kcal/g)	3.17	2.83	2.94	2.55
Crude protein (%)	12.7	11.3	13.7	12.2
Neutral detergent fiber (%)	39.3	46.5	46.2	52.4
Acid detergent fiber (%)	12.7	19.9	20.9	26.6
Acid lignin (%)	2.7	3.8	3.8	4.7
Ash (%)	7.3	7.0	7.6	7.3

Hintz and Loy (1966) used yellow styrofoam particles to monitor complete pelleted and non-pelleted hay-grain diets, with 99% recovered in 63 hr. Cr_2O_3 was used by Hintz et al. (1985) to compare passage rates for pelleted and extruded feeds, with only 76% accumulative recovery at 72 hr and complete recovery by 120 hr. While 72 hr appeared to be adequate time to evaluate passage rates for the pellet plus straw diets in this study, an additional 24 - 48 hr were needed to accurately plot passage rates for the two complete pelleted diets (see Appendix B).

All things in research are relative, and while methods, equipment, and environment may not be perfect, if all factors are equal for all subjects and procedures, valid comparisons can be made. Collection of fecal samples, as discussed in Chapter I of this thesis, while potentially inconvenient for the ponies, worked very well. For future reference, one modification to the collection bags may aid in providing slightly more accurate data. The collection bags, constructed of medium weight canvas (Carle, 1975) had a tendency to absorb moisture from the feces. How much and to what extent this absorption affected fecal dry matter data was not determined. Lining the canvas bags with a water-resistant material may be of some value in studies where fecal dry matter is important.

In conclusion, the results from these trials appear to indicate that both composition and form of the experimental diets effectively altered rates of digesta passage. Whether passage rate increased directly in response to the addition of long-stem fiber, or indirectly, due to an increased rate of digestion could not be determined. Further evaluation of the data indicates that while 72 hr appeared to be adequate to measure passage rates for the diets containing straw, an additional 24 - 48 hr would have improved passage rate data for the complete pelleted diets. It is recommended that a minimum of 4 d be used for fecal collections when evaluating rates of digesta passage.

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CHAPTER III

Behavioral Evaluation

Introduction

Under modern management programs, many domesticated equids rely heavily upon man for adequate feed, shelter, and exercise. Commonly fed two meals per day, confined horses may spend 2-5 hr in feeding activity while free ranging horses often spend 10-12 hr (Feist and McCullough, 1976; Tyler, 1972). The 5-10 hr of what would otherwise be feeding time, often becomes spare time. It has been suggested that spare time may lead to boredom, often demonstrated through such vices as wood chewing, cribbing, and coprophagy (Hart, 1985). Many of the so called vices exhibited by the stabled horse may in fact be reactions to an abnormal environment and as such, should be called displacement behaviors or acts of self-entertainment, rather than vices (Houpt, 1986).

Displacement behavior is not limited to the horse. Duncan (1987), working with caged chickens, reported that hens displayed a back and forward pacing in response to frustration resulting from the inability to perform normal functions, i.e., feed, nest, incubate eggs, and brood chicks. It was further noted that the initial back and forward movements appeared to be attempts to escape from the frustrating situation, but once established, even tranquilization would not inhibit the movement, possibly indicating that the urge to perform the behavior became addictive.

The value of the horse to man is dependent upon its trainability and submission to human authority (Haag, 1980). With the exception of a few horses still used for work (draft animals used for logging, or by the Amish for farming, and a small number of ranch horses), ponies and horses are used exclusively for recreation and sport. In this capacity, temperament, trainability, stability, and a competitive spirit become important. Any physical, psychological or environmental factor that places undue stress on an individual (equine or human) may directly or indirectly inhibit performance.

Stott (1981) noted that livestock (cattle, sheep and swine) management is the manipulation of the animal environment to maximize efficient production of meat, milk, and wool. Manipulation of the equine environment is an attempt to minimize the combined effects of environmental stresses to which the horse is subjected, in an effort to achieve optimal performance. Stress may be either external, due to extreme climate, or internal, such as parasitism, nutritional deficiencies and toxicities or disease (Hafez, 1968). Confinement without physical exercise may impose psychological as well as physical stress on an animal. As Houpt (1986) suggested, displacement behaviors may well be exhibited in response to stress, experienced when equids are subjected to modern management regimens.

Wood chewing is one of the most costly displacement behaviors displayed by the horse. Many theories concerning the causes of wood chewing have been suggested, including boredom and frustration (Ensminger, 1969;

Ralston et al., 1979), a reduced level of dietary fiber (Haenlein, 1969; Hintz and Loy, 1966), complete pelleted diets (Shurg et al., 1977; Willard et al., 1977), and wet-cold weather or weather related anxiety (Feist, 1971; Jackson et al., 1985). Shurg et al. (1977), Willard et al. (1977), and Hintz (1983) reported that horses and ponies receiving pelleted rations displayed an increased incidence of wood chewing and general nervousness, when compared to those receiving nonpelleted rations, suggesting behavior could be altered as a result of diet.

The objectives of this study were:

1. Develop a method for numerical classification of behavior that would allow statistical analysis of behavior in equine research.

    This was attempted by developing a behavioral classification table to which daily behavior was compared. In this way a numerical value could be placed on a given set of behavioral factors and comparisons made statistically.

2. Evaluate the effects of dietary form on behavior in general, and wood chewing in particular.

    This was accomplished by measuring and comparing the amount of wood chewed as well as observed behavioral characteristics associated with consumption of each experimental diet.

3. Determine whether ponies need (physically) or simply desire long-stem fiber in their diet.

    This was accomplished by comparing the observed behavior of each pony with the digestibility and rate of digesta passage data recorded.

Materials and Methods

The experimental subjects, diets, and husbandry practices for this study were the same as described in Chapters I and II of this thesis. To monitor the behavioral tendencies displayed by the four subjects in this study, each pony was observed for 15 min twice each day. Observation was initiated 5 min prior to each feeding and lasted 10 min into the feeding period. Eagerness to be fed, exhibited by verbalization, pacing, and (or) aggression toward other subjects was recorded using a record sheet designed for this study (Figure 4).

Acceptance of and preference for each diet was determined by observing how quickly and quietly each individual ate and what component (pellet or straw) was consumed first. Refusal to eat, attempts to reach the straw fed a neighboring pony, and any aggression exhibited toward the individual feeding the ponies was recorded. So that statistical analysis of the behavior exhibited could be performed, behavior displayed by each pony was compared to a behavioral classification table (Table 8) and, thereby, assigned a number from 1 to 4, 1 being the most desirable. The two scores assigned each day (1 per observation) were averaged so that one score was recorded to represent each day of the period. While behavioral tendencies were recorded daily, the actual classification of behavior was not performed until all four experimental periods were complete. Behavioral class was then determined using only the daily records, in an attempt to minimize subjectivity in the classification process. Wood chewing was measured by placing a white pine board, 5.1 cm x 20.3 cm x 1.5 m in each ponies stall. Each board was weighed prior to being placed in

SUBJECT	DATE	TIME	EATING			Dr	CW	S	LD	St	C	LEB	BT	T	HR	R	WEIGHT	COMMENTS
			V	Q	P													
		7:00																
		5:00																
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C - coprophagy
CW - chewing wood
Dr - drinking
Bt - bared teeth
HR - heart rate
LEB - layed ears back
LD - lying down
P - picking at feed
R - respiration
S - searching
St - standing
T - temperature
Q - quietly eating
V - vigorously eating

Figure 4. Daily behavioral record.

TABLE 8. Behavioral/Attitudinal classifications

1. **CONTENTED**	stands and lies quietly; eats, drinks, and interacts with other ponies in a quiet manner.
2. **MODERATELY CONTENTED**	appears nervous (paces in stall) or anxious; handles easily; and interacts peaceably with other ponies.
3. **MODERATELY IRRITATED**	lays ears back when confronting other ponies; pushes feed or water buckets around rather than eating and drinking quietly; does not want to be handled but handles easily once caught; chews wood.
4. **IRRITATED**	is aggressive toward other ponies and (or) handlers (lays ears back, kicks stall walls); paces in stall; nervous and obnoxious when eating (excess aggression at the feed bunk); chews wood excessively.

the stall and again at the end of the feeding period (Jackson et al., 1985). The difference was determined to be the amount of wood chewed.

Statistical analyses were performed using the Statistical Analysis Systems (SAS) analysis of variance and least square means for a Latin square.

Results

Due to the confounding of ambient temperature, relatively humidity, barometric pressure and precipitation within period, the individual components could not be analyzed separately. Therefore, even though significant period effects were indicated following statistical analysis, it was not possible to determine which, if any, of these factors affected the level of wood chewing.

When fed the complete pelleted diets, LF and HF, both the behavioral score and the amount of wood chewed appeared to increase when compared to feeding LFS and HFS, though the differences were not significant (Table 9). While means for the four treatments appear to be different, it is thought that a large variation between the ponies may account for a lack of significance. No differences were found between the complete pelleted feeds.

TABLE 9. Relationships between mean behavioral score, amount of wood chewed and four experimental dietary treatments; low-fiber complete pellet (LF), LF + 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS).

	Treatment				
Factor	LF	LFS	HF	HFS	SEM
Behavioral score	2.03	1.29	1.80	1.37	0.22
Wood chewed (g/d)	38.0	29.5	38.8	21.3	5.18

Discussion

Hintz (1983), reported that adding hay to a pelleted diet reduced wood chewing, by confined ponies, by 80%. Willard et al. (1977) found that ponies fed pelleted diets consumed their ration faster and spent more time in chewing wood, coprophagy and searching (presumably for food), than did ponies fed loose hay. There were no significant differences between behavioral scores or the amount of wood chewed. However, the ponies consistently chewed more wood when fed the complete pelleted diets (Table 9), as compared to being fed the pellet plus straw diets. The inference, then, is that wood chewing and other displacement behavior increases as the amount of spare time (resulting in boredom) increases (Hart, 1985). Thus, diet form may indirectly, rather than directly, affect equine behavior.

Jackson et al. (1985) reported that horses chewed more wood in wet-cold weather, which would appear to agree with results from this study. Because the individual environmental components, temperature, humidity, barometric pressure, and precipitation were completely confounded within period, individual analysis was not possible. There was, however, a linear relationship between wood chewing and precipitation (Figure 5) and an inverse relationship between wood chewing and ambient temperature (Figure 6). Thus, as temperature decreased and precipitation increased, more wood was chewed. Feist (1971) reported that wild horses chewed more wood in the winter months. Whether this was in response to wet-cold weather, lack of a more desirable forage, or some other factor, is not known.

Pagan (1987) reported that, "subjectively," behavior of horses appeared to change as a result of diet, and Haenlein (1966) reported that horses fed pellets desired to continue chewing, even after their appetites were satisfied. Subjective observations are often of value to the farm manager but are difficult to evaluate statistically. Willard et al. (1973, 1977) and Ralston et al. (1979) were able to quantify equine behavior by monitoring the amount of time spent in each normal daily activity (i.e., feeding, lying down, standing) while

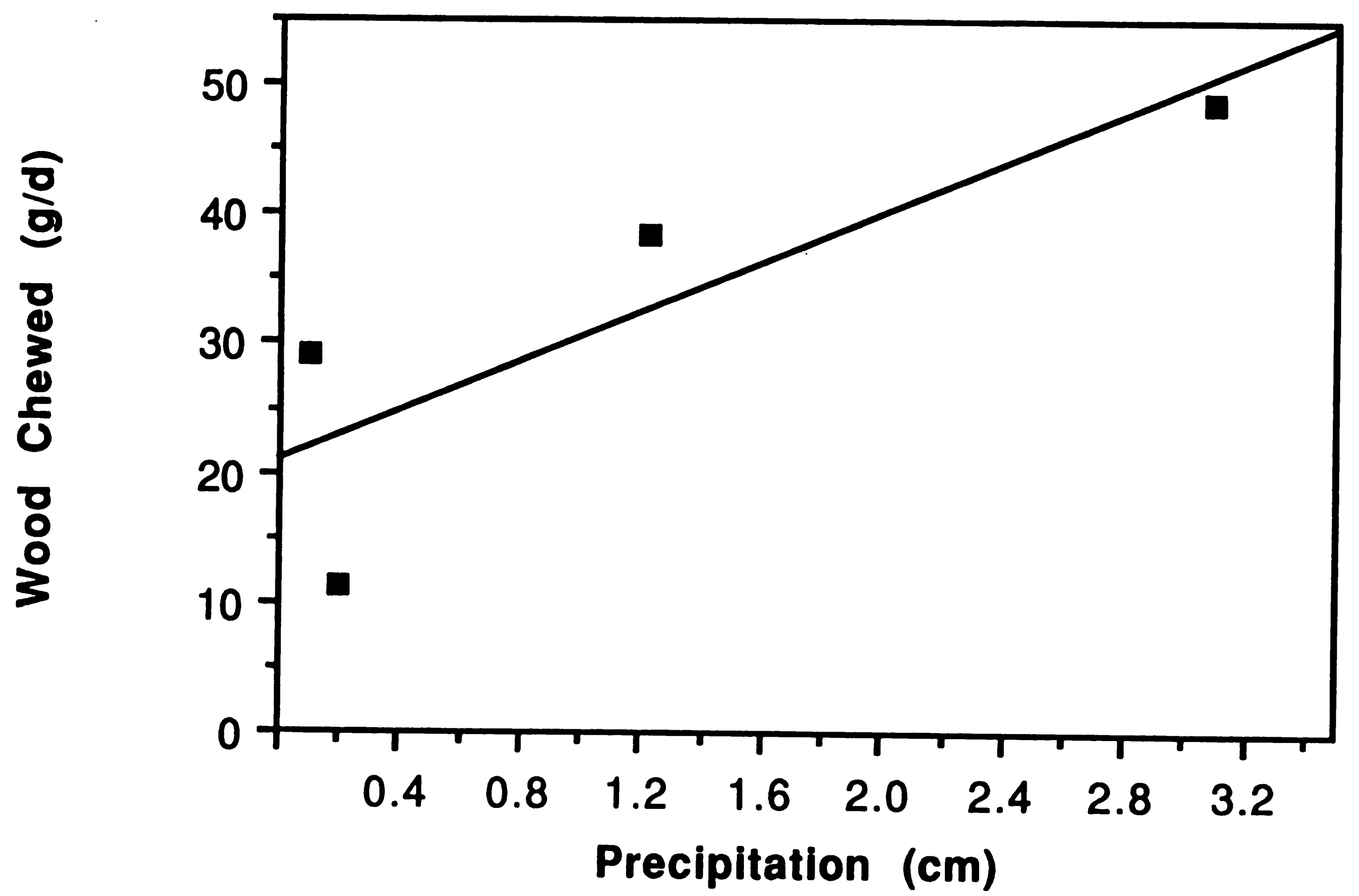

Figure 5: Relationship for wood chewing and precipitation.

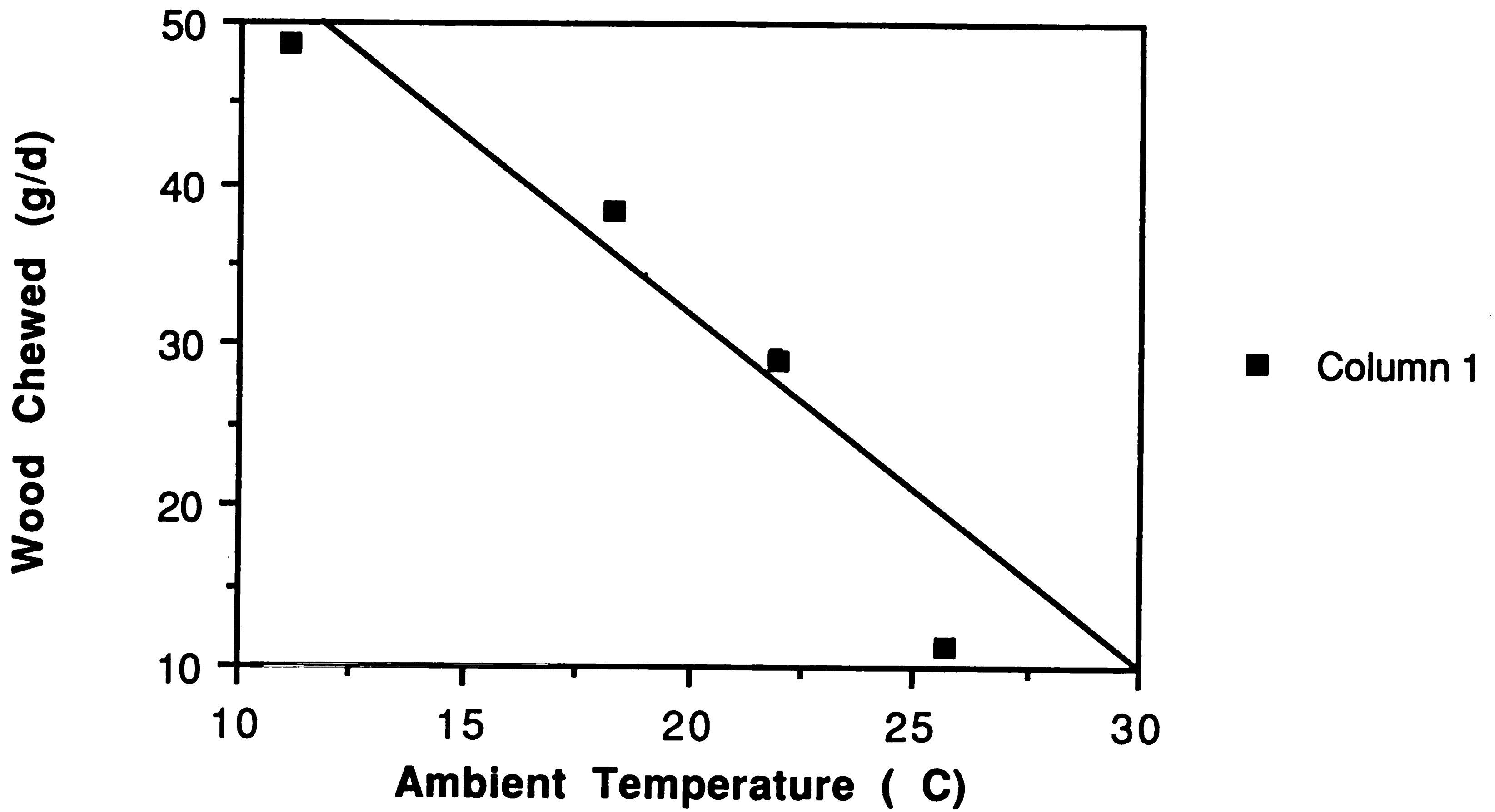

Figure 6: Relationship of wood chewing and ambient temperature.

Jackson et al. (1985) effectively monitored wood chewing and meal duration in response to different diet forms. The results from this study appear to indicate that behavior may be classified and effectively evaluated using statistical analysis. Care must be taken to minimize subjectivity in the observations. This may be accomplished best by limiting the number of observers. Allowing one person to make all observations (when possible) and another to classify the observed behavior may also help in this matter.

Houpt (1986) suggested that wood chewing was caused by a lack of roughage in the diet, but whether roughage was needed, or simply desired was not addressed. Results from this study appear to indicate that the ponies at least desired the roughage (oat straw). Behavioral scores (Table 9) were slightly lower when ponies received LFS or HFS, apparently indicating greater contentment when receiving straw. Results from Chapters I and II of this thesis indicate that the ponies were able to utilize, without incidence of gastrointestinal disturbance, the low- and high-fiber complete pelleted diets. These combined results appear to indicate that while the ponies in this trial desired roughage, they did not have a physiological need for it. Further work would need to be done to determine the long range effects of feeding the low-fiber, complete pelleted diets.

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CHAPTER IV

Summary and Conclusions

Pelleting low-fiber diets that are high in soluble carbohydrate is one means of increasing energy intake by the horse. These energy-rich diets may be consumed in greater quantities and are utilized more efficiently. While others have reported digestive and metabolic disorders associated with feeding complete pelleted diets, the ponies in this study efficiently utilized complete pelleted diets with as little as 12.7% acid detergent fiber, with no evidence of gastrointestinal disturbance.

Increased levels of dry matter intake, when ponies were fed the pelleted plus straw diets, were associated with increased rates of digesta passage and decreased digestibility of gross energy, crude protein, and neutral detergent fiber. The relationship between dry matter intake, rate of digesta passage, and digestion, displayed here appears to indicate that diet form may affect the efficiency of diet utilization. The low-fiber complete pelleted diet was retained in the digestive tract longer than the high-fiber complete pelleted diet, indicating that diet composition may also affect digesta passage rate.

While there were no significant differences in behavioral scores and the amount of wood chewed (Table 9) in association with dietary treatment, the data do indicate that when the ponies received straw they chewed less wood and were, thus, more contented. Large variation between a small number of subjects may be responsible for a lack of statistical significance.

In conclusion, the ponies in this study efficiently utilized the complete pelleted, low-fiber, high-carbohydrate diets without evidence of gastrointestinal disturbance. Digestibility, rate of digesta passage, and behavioral data appear to indicate that, while the ponies desired long-stem fiber in their diet, their physiological well-being did not rely upon its presence.

APPENDIX A

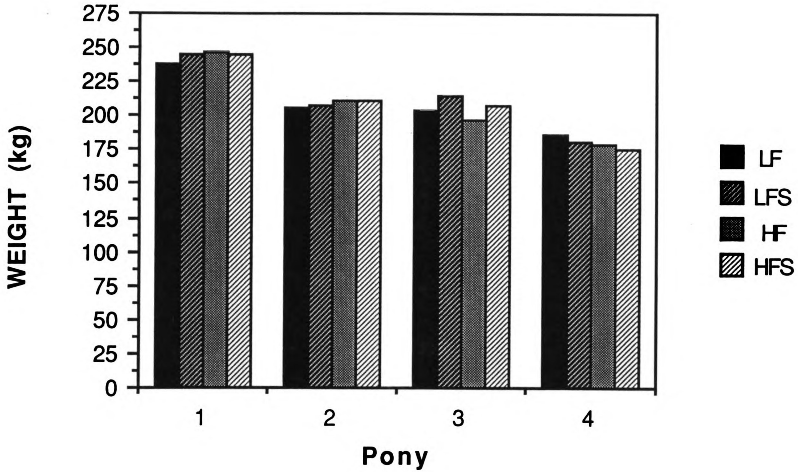

Figure 7: Average pony weights.
Low-fiber complete pellet (LF), LF+ 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS) (N = 4).

APPENDIX B

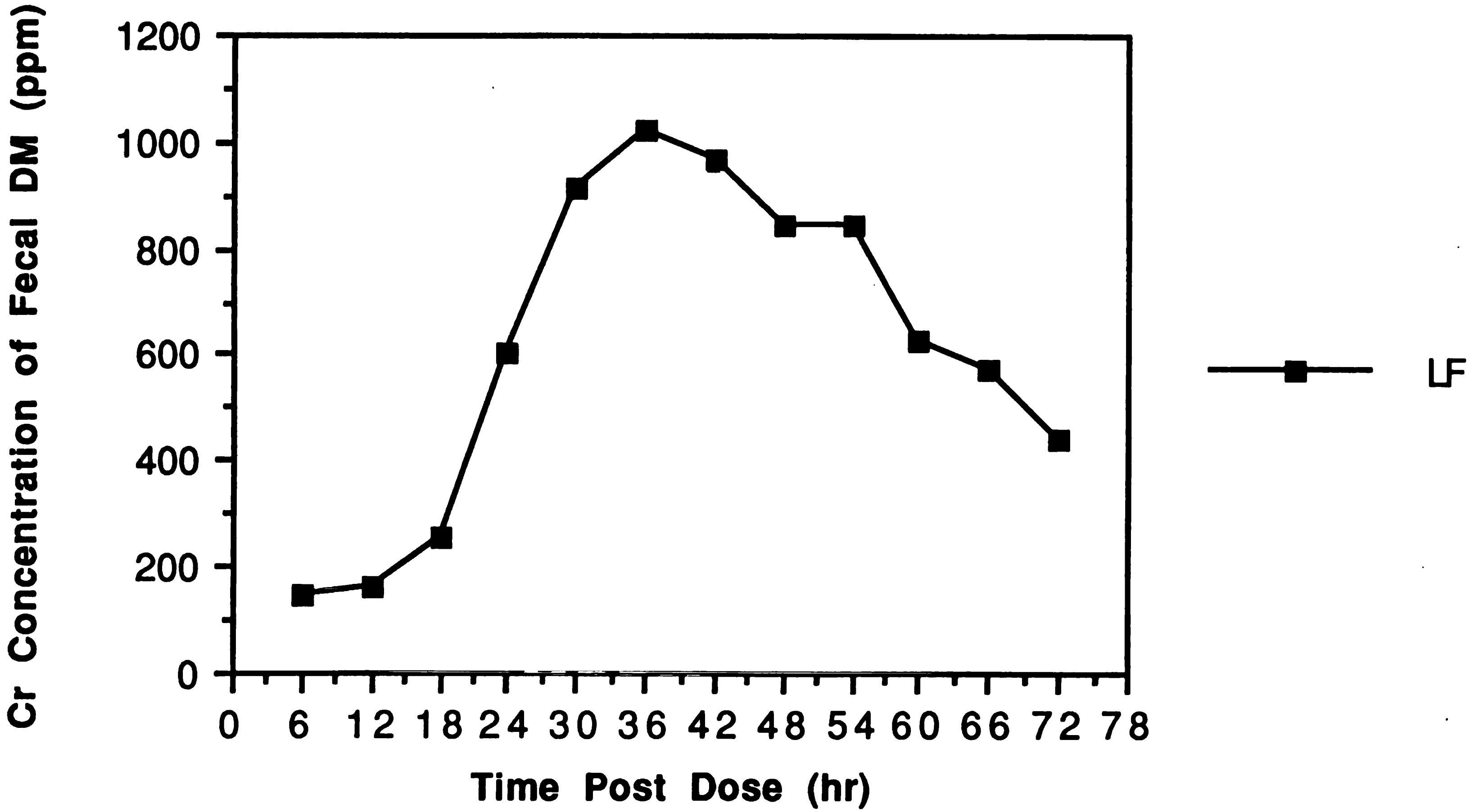

Figure 8: Chromium excretion curve.
Diet: LF (mean, N = 4).

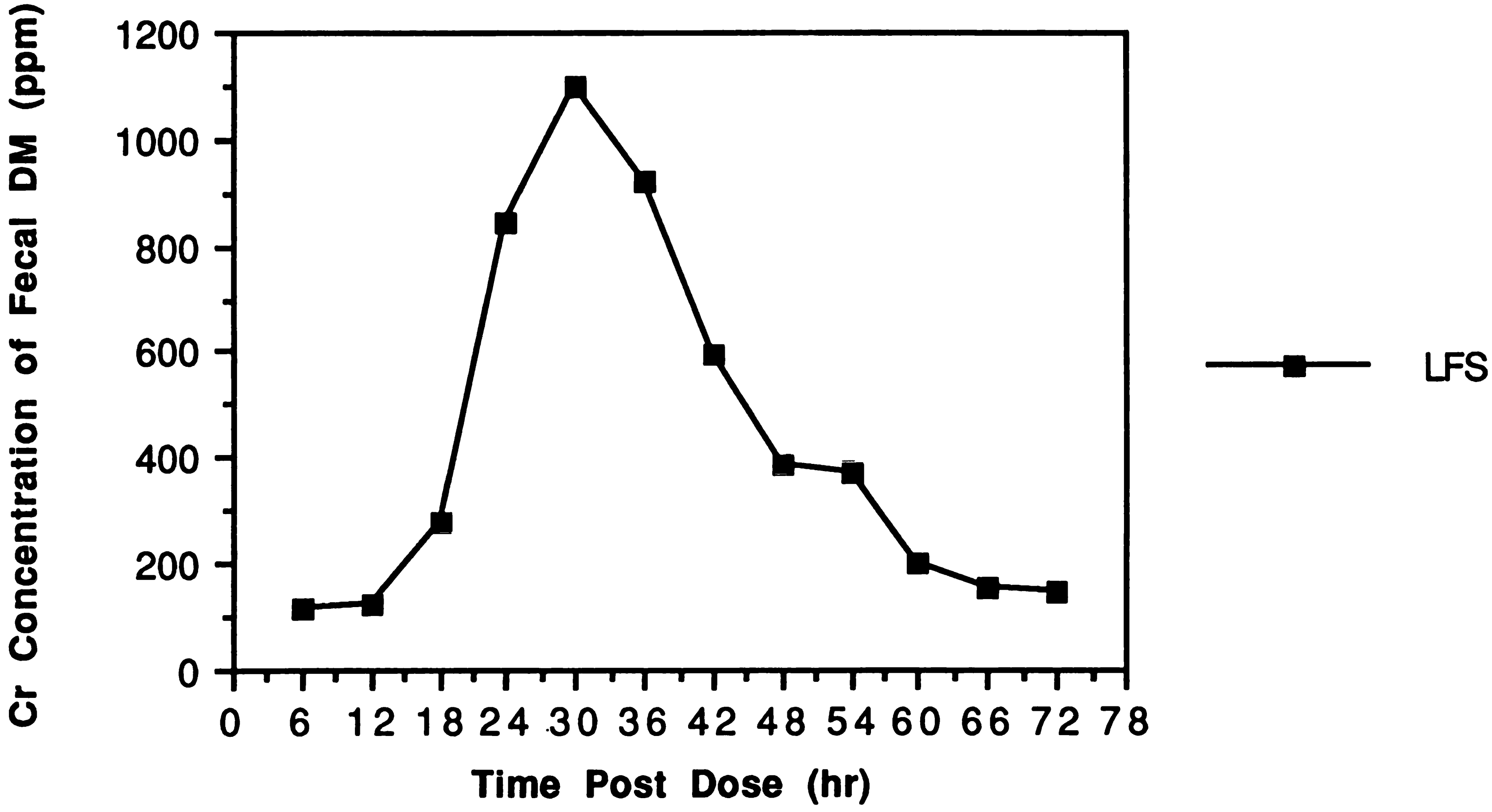

Figure 9: Chromium excretion curve
Diet: LFS (mean, N = 4).

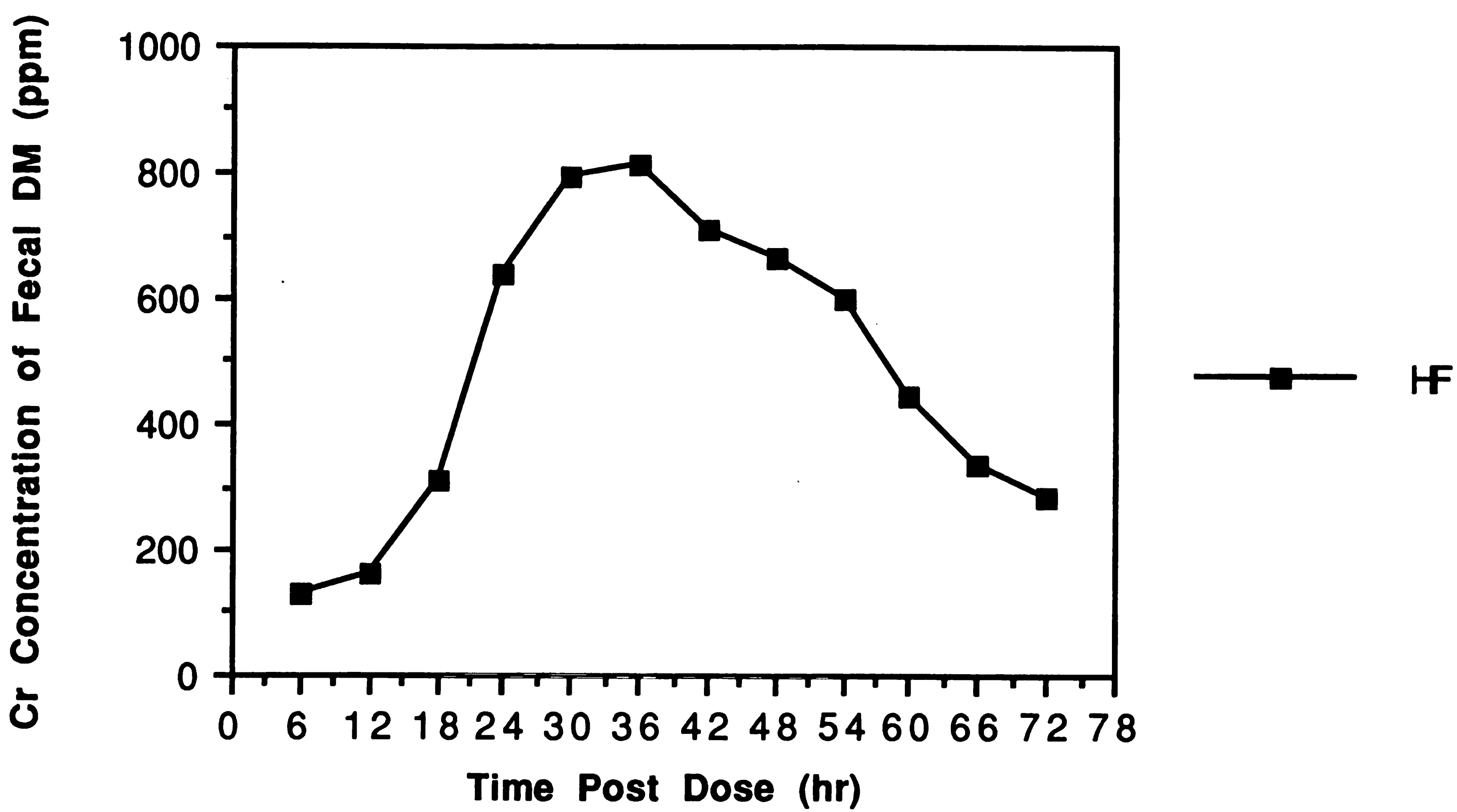

Figure 10: Chromium excretion curve.
Diet: HF (mean, N = 4).

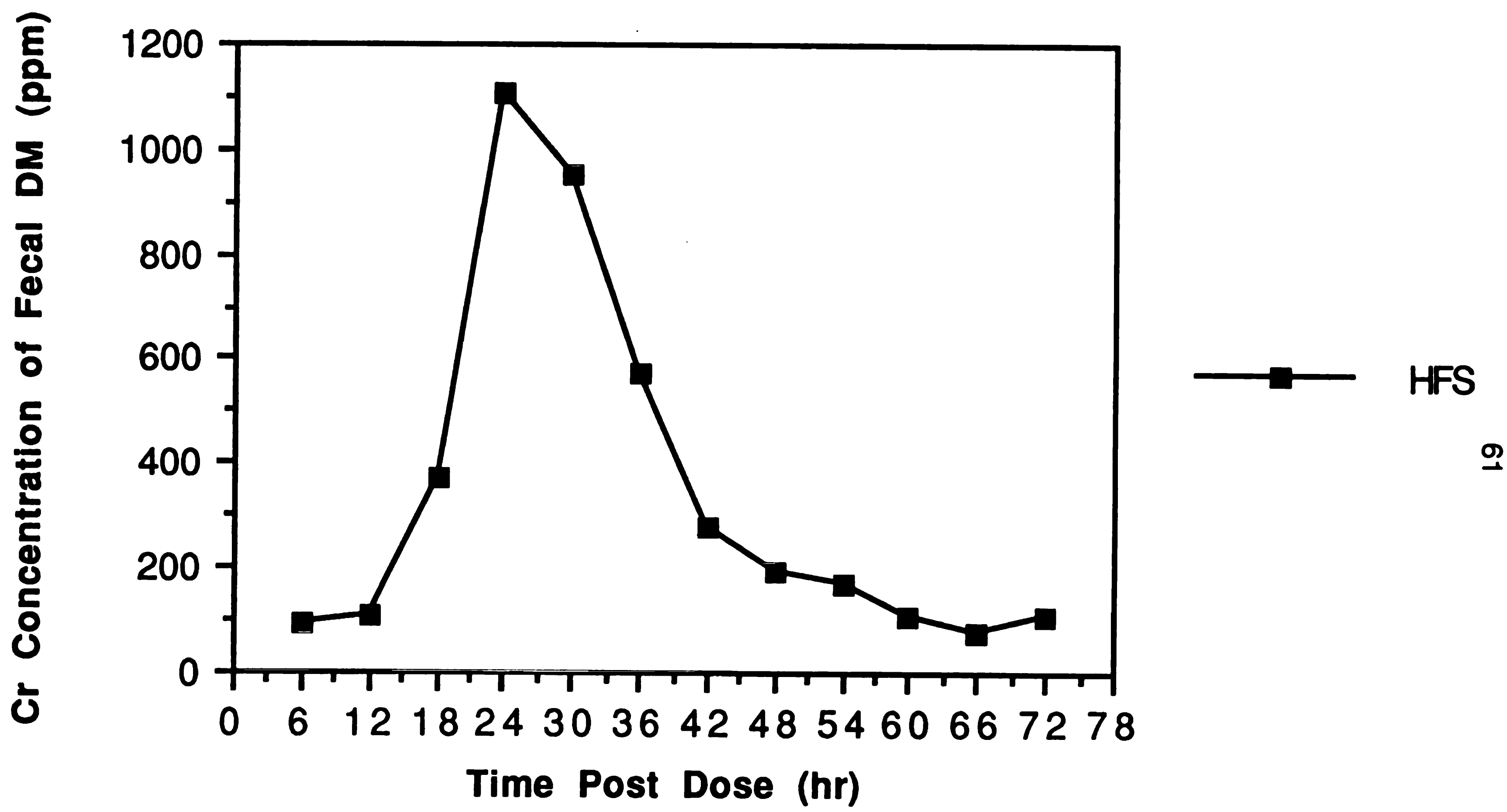

Figure 11: Chromium excretion curve.
Diet: HFS (mean, N = 4).

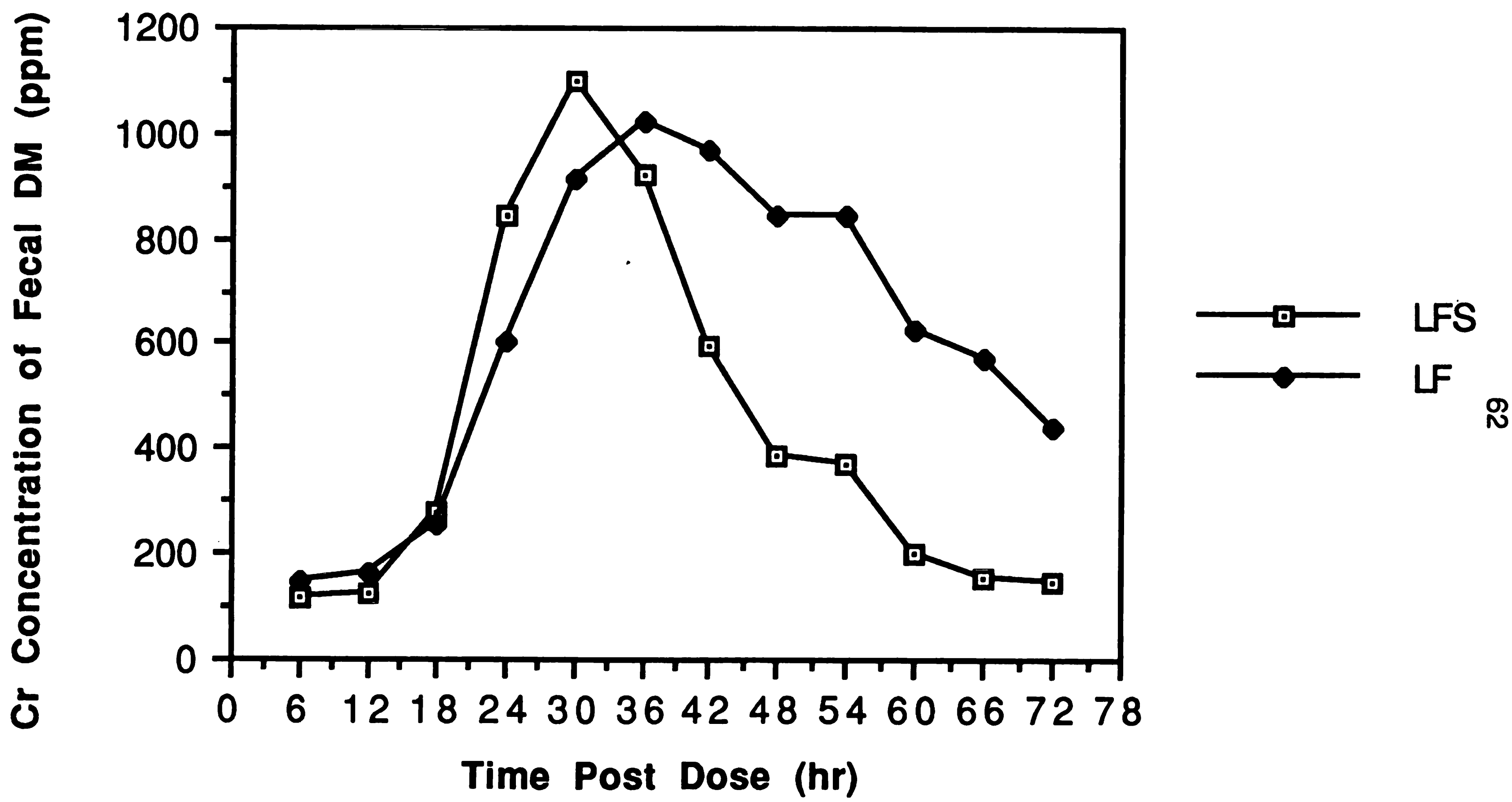

Figure 12: Mean Chromium Excretion Curves (LF/LFS) (N = 4).

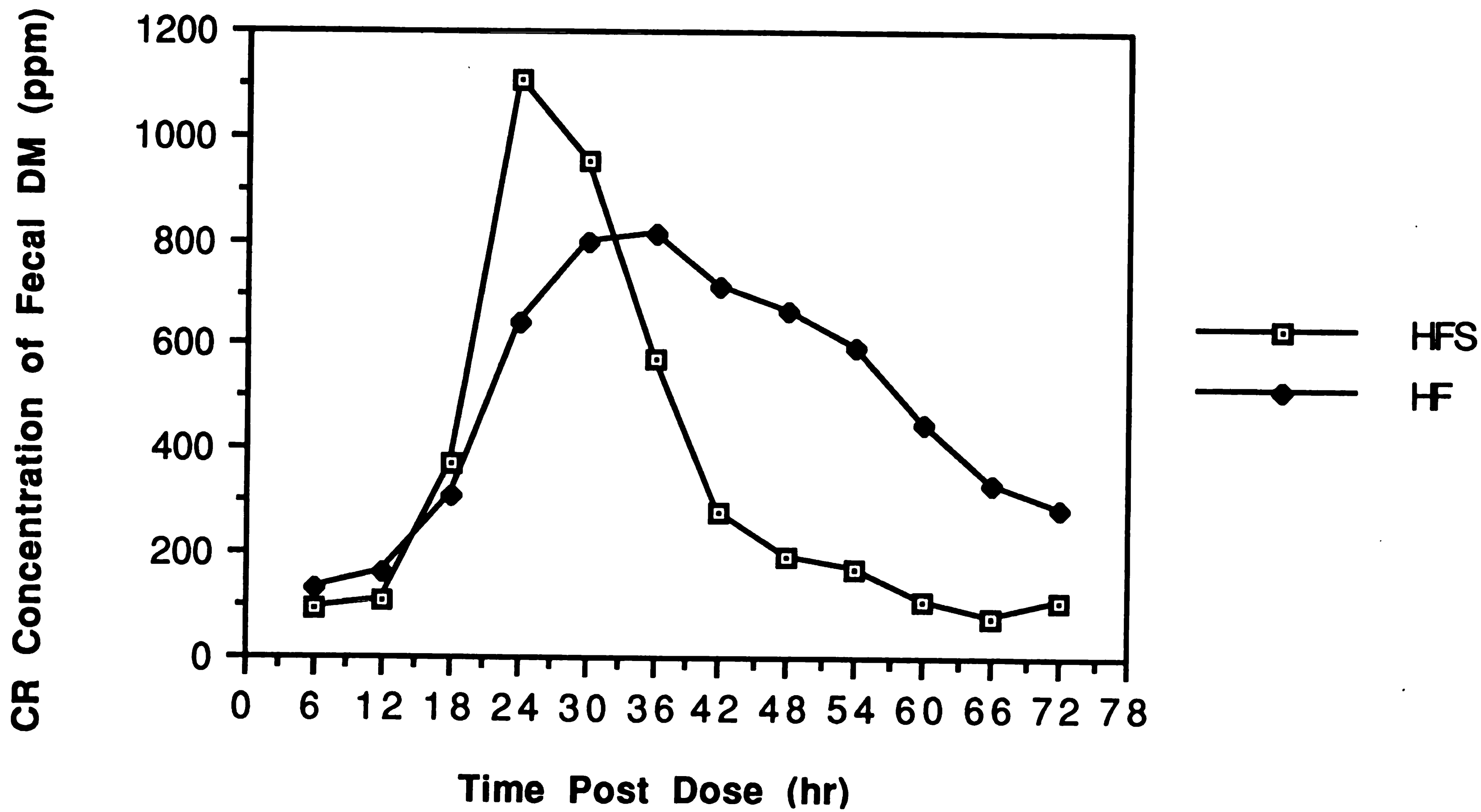

Figure 13: Mean Chromium Excretion Curves (HF/HFS) (N = 4).

APPENDIX C

Ileal-Cannulation of Ponies for Determination of Partial Tract Digestion and Digesta Flow

Initially, this study was designed to measure partial and total tract digestibilities and passage rates of the four experimental diets. So that pre-cecal and post-ileal digestibilities and rates of digesta passage could be determined, ileal cannulas were inserted approximately 15 cm anterior to the ileo-cecal valve (Tanksley, 1981). The cannulas used were simple t-type, constructed of silastic medical grade tubing (Lowe et al., 1970; Weber, 1983), 16 mm ID and 22 mm OD.

Three ponies were fitted with cannulae, which two of the subjects removed within 48 hr by biting and pulling. This was possible since the silastic tubing was soft and pliable, allowing the t-end to be drawn through the fistula. Taping the cannula in place and using a neck cradle to discourage removal resulted in the ponies rubbing until the cannula was removed. If found within several hours, the cannula could be maneuvered back into position. If not found within 6 - 8 hr (as could happen at night), the fistula would close enough so that even a finger could not penetrate it. One pony, after having the cannula reinserted surgically, reached back, grasped the cannula in its mouth and removed it, while still partially sedated. At this point, due to time and monetary constraints, it was decided to forego cannulation and study only total tract utilization of the diets.

The extreme effort by the ponies to remove the cannulae, apparently indicated considerable discomfort. Consultation with the surgical team led to the conclusion that the location of the cannula, in the lower portion of the flank, was most likely the problem. In this region the body wall was approximately 5.1 cm thick, due to abdominal musculature, in particular, the transverse abdominal and internal oblique abdominal muscles. Since the incision was made with the pony in a prone position and in a relaxed state, the muscular shift, due to contraction around the cannula, following recovery was thought to cause the discomfort. Placement of the cannula high on the flank, where the body wall is considerably thinner, may help avoid the problems observed here.

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APPENDIX D

TABLE 10: Feces dry matter (%) from four ponies fed four dietary treatments: low-fiber complete pellet (LF), LF+ 0.90 kg oat straw/d (LFS), high-fiber complete pellet (HF), HF + 0.90 kg oat straw/d (HFS) (N = 4).

	Treatment				
Pony	LF	LFS	HF	HFS	$\bar{X}$
1	30.4	30.9	29.8	28.7	29.9
2	31.7	29.9	30.2	31.3	30.8
3	32.8	30.3	31.5	30.8	31.4
4	30.8	29.1	31.2	31.2	30.6
$\bar{X}$	31.4	30.1	30.7	30.5	