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EFFECT OF OAT AND SORGHUM GRAIN PROCESSING METHODS ON
UTILIZATION BY HORSES

THE UNIVERSITY OF ARIZONA

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**EFFECT OF OAT AND SORGHUM GRAIN PROCESSING
METHODS ON UTILIZATION BY HORSES**

by

Patricia Denise Kigin

**A Thesis Submitted to the Faculty of the
DEPARTMENT OF ANIMAL SCIENCES
In Partial Fulfillment of the Requirements
For the Degree of
MASTER OF SCIENCE
In the Graduate College
THE UNIVERSITY OF ARIZONA**

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ABSTRACT

Two separate studies were conducted for the investigation of cereal grain usage in the horse. The first study consisted of two trials evaluating the processing methods of oats for adult horses. The second study compared digestion, growth performance and water intake in yearling horses fed two modifications of milo grain. Mechanical processing methods of oats used in these studies does not appear to increase the feeding value of the total hay:grain diet when fed to mature horses. Digestibility coefficients were not statistically different between the two milo diets, but animals on the 40% steam processed and flaked and dry rolled milo diets showed an overall greater average daily gain for the growth trial. In this study milo was a more efficient grain for use in horse diets when compared to oats. Water intake was highly correlated with level of roughage in the diet and the management system incorporated.

CHAPTER 1

INTRODUCTION

Cereal grains are widely used in human diets and also used extensively in both horse and cattle rations. Livestock consumed more than 60% of the cereal grains produced in developed countries, but less than 10% of those consumed in underdeveloped countries in 1970. It has been estimated these proportions will increase to 67 and 15% respectively by the year 1990. The consumption of cereals by livestock is estimated to rise in twenty years by 194 million tons in the developed countries (52%) and by 112 million tons (221%) in the rest of the world (Greenhalgh, 1977).

Historically, the cattle industry has been the driving force behind feed experimentation. Only limited information is available on horse nutrition, and many recommended horse diets have been formulated based on existing ruminant nutrition data (Kern, et al., 1973). Horse feeding appears to emanate a certain "myth and magic which the scientist, perhaps in his own ignorance, has tended to ridicule" (Robinson and Slade, 1974).

Ideally, livestock should be fed rations which produce greater marketable gain for an affordable and/or profitable cost. For feed efficiency purposes, feed processing methodology has become of increasing importance in livestock production. Recent experimentation involving cattle fed processed diets deals primarily with different

forms of processing rather than comparing processing to the original product.

Some grains, such as milo, are inefficiently digested unless the harbored nutrients are made more accessible to the animal. Minimum necessary processing is preferable economically, therefore a uniform product of maximum acceptable size comprises what is labeled as an "optimum product" (Hansen and Stewart, 1965).

The objectives of these studies were: (1) to evaluate the acceptability and digestibility of oats fed to horses in either the whole, rolled, water-soaked whole or steam processed and flaked forms; (2) to investigate the potential of milo grain for immature horses when processed for improved digestibility and growth; (3) to evaluate water consumption patterns of immature horses under two management schemes and two feeding systems.

CHAPTER 2

LITERATURE REVIEW

Feed Processing: Modification of Cereal Grains

A major part of this review deals with processing of feedstuffs as it applies to ruminants due to limited information available on the effects of grain processing as it relates to utilization of grain by horses. There are at least eighteen different processing methods available for grain (Hale, 1973). Matsushima, as quoted by Tokheim (1966), indicates that grain processing can enhance feed efficiency in ruminants by increasing digestibility, palatability, and surface area. Thus, easier access is provided to the starches and other nutrients for the microorganisms and digestive enzymes. The process, if done correctly, can also increase the rumen production of propionic acid.

Utilization of grain protein as well as subsequent energy availability have been the main focus of grain processing studies (Potter, McNeill and Riggs, 1971). Hale (1973), indicates that processing methods could possibly have a marked effect on the disruption of the protein matrix, permitting easier access of bacterial or animal enzymes to the starch granules. This is in deference to the effect being entirely that of disruption of the starch granules due to processing, and is especially true for milo and corn.

Changes which occur within a grain during processing are generally referred to as gelatinization. The term gelatinization refers to the loss of the crystalline structure of starch granules by moisture,

heat, pressure, and in some cases mechanical shear (Smith, 1959; Williamson, 1967). Digestibilities of dry matter, energy, protein, and other organics in feed products may be influenced by the changes in the physical form of the feed (Schneider and Flatt, 1975).

The degree of gelatinization which occurs indicates the amount of alteration to the starch granules (Hinman and Johnson, 1974).

Changes which occur within the granule render the starch more available to the animal, and this change is interpreted as being responsible for improvements noted with fattening cattle (Hale, 1973).

One problem cited by B. P. Cardon at the 1968 Kansas Formula Feed Conference was that although some gelatinization occurs during steam processing and/or pressure processing, the amount appears to be variable. If the gelatinization process is allowed to progress too far, there is a trend toward lower weight gain in cattle for unknown reasons. In steam processing, as the steam pressure increases, the percentage gelatinization of the grain also increases (Anstaett and Pfof, 1969).

Processing and Utilization of Milo and Oat Grain by Livestock

In the Southwestern United States, it is evident that grain sorghum is the major grain source for feeding cattle and sheep (Buchanan-Smith, Totusek and Tillman, 1968). The milo berry is very resistant to water uptake, probably because it is coated with a waxy substance (Williamson, 1967). If whole milo is fed to horses there is a chance that a percentage of the kernels will escape chewing and pass on into the lower digestive tract. Therefore steaming and rolling of

grains, particularly milo, improves digestibility in a horse ration (Cardon, 1966).

To show profitable gains in production, the sorghum grain must be processed in some manner. Studies have been conducted, primarily using cattle, to compare digestibility coefficients for a number of processing methods including steam processed and flaked, dry rolled, reconstituted and micronized. The steam processing and flaking plus the dry rolled modifications will be the main concern.

Steam processing and flaking process was developed in an attempt to increase grain digestibility and subsequent animal performance. Certain steam pressure treatments can influence the efficiency of energy utilization of milo (Garrett, Lofgreen and Hull, 1971). Whereas steam rolled milo is steamed for 3-5 minutes, steam processed and flaked milo is steamed for 15-20 minutes. In addition, when the lesser steamed grain is rolled, it is not necessarily "flattened" per se. Steam rolling generally refers to a process in which the moisture content of the grain is increased only slightly, and the grain is exposed to steam heat for only a few minutes prior to rolling. From all appearances, the major advantage in this type of steam rolling is improved "elasticity" of the grain allowing rolling the grain without excessive shattering (Williamson, 1967).

Longer processing times and higher steam pressures made sorghum flakes much less fragile (Anstaett and Pfoest, 1969). Improvement in utilization by the animal may be expected for sorghum as well as other grains that have been flaked following the steaming process (Hale, 1973). Flaking increases feed efficiency when compared to conventional

cracked or dry rolled grain treatments, and decreases feed intake (Matsushima, 1964). A specific description of the steam processing and flaking procedure is as follows:

Steam processed grain was prepared by subjecting the grain to low pressure, high moisture steam in an oversized tempering chamber for 20-25 minutes prior to rolling. The temperature of the grain reached 205-210° F, and the grain was flaked with no tolerance on the rollers. The moisture of the grain is raised to approximately 20%, with gelatinization following processing at 30-40%. Once the grain begins to flow by gravity through the roller mill, and the dry grain is introduced at the top of the chamber, the process becomes continuous. A large flat flake was produced having approximately half the weight per volume of the original grain. Weights per bushel of the milo flake on an air dry basis ranged from 22-27 pounds (Hale, et al., 1966; Hale, 1966 and 1967b).

Factors to consider in quality high moisture steam treatment followed by rolling are temperature, moisture, steaming time and flake thickness, with precise operation not only defined but repeatable (Hale as quoted by Newell, 1965; Anstaett and Pfoest, 1969). A poor flake would require 11% more feed as compared to feeding an excellent flake, and cost \$2.20 more per 100 pound gain. This information stresses the need for control in achieving a flat flake with steam treated grains (Hale, 1967a).

The amount of moisture in the grain prior to flaking varies with the type of grain and the starting moisture level of the original grain form. For example, barley or oat grains do not require as long a

cooking period as corn or milo, with 8-10 minutes appearing to be sufficient for flaking barley and oats (Matsushima, 1965). The flaking process is basically heat and pressure derived from the rollers on the moist, hot grain (Osman, et al., 1970). Additional moisture involvement over dry methods in the steam flaking and reconstitution processes appears important in the effects on nutrient availability and on digestion in the rumen (McNeill, Potter and Riggs, 1971). In addition to improving the physical qualities of sorghum grain, steam processing and flaking appears to also improve the nutritional value (Williamson, 1967).

Micronized and steam flaked sorghum showed the greatest degree of gelatinization, with small changes noted between the dry rolled and ground sorghum (Hinman and Johnson, 1974). Results of feeding properly heat processed sorghum grain in diets often show a lowered feed consumption accompanied by an increased feed efficiency (Garrett, et al., 1971; Hinman and Johnson, 1974). The depressed feed intake could be attributed to the subsequent increase of volatile fatty acid (VFA) blood levels (Garrett, et al., 1971). Data also indicate an increase in fermentation when the steam processed grain was fed as part of the diet.

When compared with dry rolled and steam rolled milo, steam processing and flaking tended to improve gain and feed efficiency (Hale, et al., 1966; Schuh, et al., 1969). If the milo has been processed by dry rolling, a larger amount of the grain will pass through the animal than when the grain has been steam flaked or pressure cooked (Williamson, 1967).

According to horsemen and tradition, grains such as milo are regarded with prejudice and suspicion, while oats are the most highly recommended grain for horse feed. In addition, a favorite feeding regime for horses utilizes rolled oats over other forms. However, in studies done with cattle and sheep, the benefits derived from rolling oats were insignificant, whole oats being well digested (Orskov, Fraser and McHattie, 1974; Kimberly, 1976; Toland, 1976; Morgan and Campling, 1978). Rolling grains prior to feeding showed better results in improved digestibility for sorghum, wheat and barley and the least with oats (Nordin and Campling, 1976). Relatively little information is available comparing the digestibility of oats when they are fed whole rather than in the processed form (Toland, 1976).

Oats have been used by cattle feeders to some extent when oats were considerably cheaper than other grains, or when the latter were in short supply. Compared with other cereal grains, oats differ somewhat in respect to the influence of roughage level. A possible explanation could relate to the higher fiber content than in other grains (Gartner and O'Rourke, 1975). In a trial with cattle fed hay and grain rations simultaneously, it was assumed that any associative effects on the digestibility of the hay and grain were not present. Furthermore, since the hay proportions were the same in all diets considered, any effect would not be a compounding factor (Kimberly, 1976).

Nutritive Availability and Use of Starch by Livestock

The major component of cereal grain is starch (Anstaett and Pfof, 1969), with relative values for milo and oats listed as 70-75% and 40% respectively (Totusek, Franks and Basler, 1967; Morgan and

Campling, 1978). For this reason, it appears that the digestibility of the starch portion of high concentrate rations may account for the differences observed in feed efficiency over high roughage rations (Hinman and Johnson, 1974). Processing plays a strategic role in the starch digestibility values of milo because of the hard kernel evident in the whole grain. Availability of barley and sorghum grain starch through in vitro enzymatic attack suggests that degree of flaking becomes a principal factor in processing methods studied. The flaking process may be the foremost step in the steam processing method, for when steamed grain was fed without flaking, starch degradation was depressed (Osman, et al., 1970).

During the heat and moisture treatments at the onset of processing, physical and chemical changes occur within the starchy portion of the grain. The high moisture levels tend to disrupt the crystalline structure of the grain matrix. The internal moisture of the sorghum grain gelatinizes as well as expands the starch granule. As the grain swells during the steaming process, the starch molecules comprising the starch chains are forced apart. Structural changes which occur within the grain become irreversible, gelatinized, at a temperature of 150° F. Rolling of the heated kernel further disrupts the starch granular structure (Williamson, 1967; Hinman and Johnson, 1974).

The proper interaction of factors such as heat, pressure and moisture appears to be involved in the susceptibility of starch to enzymatic attack. Whether this is attributed to disruption of the protein matrix surrounding the starch granule, to disruption of the

micellar network within the granule, or to inactivation of an amylase inhibitor is not known (Osman, et al., 1970).

Steers fed steam flaked or reconstituted milo showed significantly ($P < .05$) higher total starch digestion (McNeill, et al., 1971). Data accumulated from feeding studies illustrated that moist heat treated grain followed by flaking appeared to alter the starch of milo, making it more digestible by the rumen microorganisms and the animal (Husted, et al., 1968).

In a study done with beef cattle, approximately 250 grams more starch per day was digested when fed micronized and/or steam flaked forms of milo as compared to the dry rolled sorghum ration. Lower starch digestion of the dry rolled milo may be attributable to inaccessibility of starch molecules (Hinman and Johnson, 1974). Ruminants may be able to digest starch in steam processed milo because of the greater surface area. Less total starch passes out of the animal when gelatinization has been achieved within the grain matrix (Williamson, 1967). Rate of digestion and total digestibility of sorghum grain may be enhanced by steam processing and flaking (Osman, et al., 1970).

The Use of Inert Markers for Digestibility Calculations

Ratio techniques for digestibility calculations are dependent on assumptions that the inert substances are evenly distributed and their passage through the digestive tract is similar to digesta patterns (Kane, Jacobson and Moore, 1952). Recovery of the chromic oxide in the ratio technique is of primary importance. The term "absolute recovery" refers to the actual weight of the marker recovered in total fecal

collections, expressed as a percentage of the weight of the marker given. "Relative recovery" is the concentration of the marker in a given sample of feces, represented as a percentage of the daily mean concentration in the feces (Curran, Leaver and Weston, 1967).

The actual rate of recovery, especially based on small numbers of animals, is influenced more by the individual horse than the ration fed (Vander Noot, et al., 1967). Using cattle as an indication, there were significantly different ($P < .01$) excretion levels of chromic oxide, crude protein and gross energy for steers (Phar, et al., 1970). However, according to Lambourne (1956), feed quality is the most important factor in determining the rate of passage of markers and feed residues through the gastrointestinal tract of sheep.

Variation in absolute recovery may be a result of many factors, including errors in feces collection, sampling and analysis, as well as a result of differences between animals in the pattern of chromic oxide excretion (Wilkinson and Prescott, 1970). Possible reasons for low recovery of chromic oxide resulting in low or negative digestibilities are regurgitation, absorption at varying rates, losses in grinding samples, and analytical losses (Bloom, et al., 1957; Curran, et al., 1967).

Accuracy appears to be limited greatly by the sampling error, which may result when the methodology includes "grab" sampling of feces. Errors encountered when such samples are taken are attributed to large intra-day variations which occur in the fecal excretion pattern of the indicator(s) (Elam, Putnam and Davis, 1959). Other shortcomings which have been cited for the chromium indicator method include diurnal

variation, incomplete recovery, or selective retention and diffusion (Haenlein, Smith and Yoon, 1966; Knapka, et al., 1967; Schneider and Flatt, 1975; Sutton, Bowland and McCarthy, 1977).

Other aspects to be taken into account are sampling time and the number of samples taken. A period needs to be identified at which the concentration of the marker in the feces is most near its mean level. Variations are noted with various feeds consumed and their rate of passage through the gastrointestinal tract (Kane, Jacobson and Moore, 1950; Rosiere, Galyean and Wallace, 1980).

Comparative Anatomy of Ruminants and Non-Ruminants

Nutrient availability between individual horses may vary with level of feed intake (Ott, 1981), and digestibility differences of a particular feed by horses can be large (Olsson, Kohlen and Cagell, 1949). Since a majority of the developed horse diets have been derived from ruminant nutrition data, a brief comparison between horse and ruminant structural anatomy follows.

In the ruminant animal, the primary site of bacterial activity is located in the anterior portion of the digestive tract, consisting of a multi-compartmented stomach. Non-ruminant herbivores, of which horses are a part, possess an enlarged cecum and colon, which are posterior to the small intestine. These compartments have clearly defined dorsal and ventral regions in the horse (Robinson and Slade, 1974).

Differing from ruminants, non-ruminants practice no rumination or eructation, salivary secretion occurs only during mastication, and the rate of passage of food from the stomach to the large intestine is more rapid than in ruminants because of a smaller stomach capacity

(Dougherty, 1968; Robinson and Slade, 1974; Pearce, 1975). In comparison with various species, the overall rate of passage in the equine animal is intermediate between ruminants and monogastrics such as pigs and poultry. Starches, sugars, fats and proteins are energy sources for the horse. They are broken down by digestive enzymes in a similar fashion to non-ruminant mammals (Pearce, 1975). Consequently, from overall appearances, horses fed high grain diets seem to adopt a metabolic pattern similar to monogastric animals (Robinson and Slade, 1974).

A small amount of fermentation may occur in the equine stomach, but most soluble parts are hydrolyzed in the small intestine, large intestine, and cecum, with cellulose decomposition occurring through bacterial enzymatic digestion (Dougherty, 1968). Cellulose fermentation, located primarily in the large intestine, provides an important function in the energetic economy of the equine (Robinson and Slade, 1974). The large intestine has been cited as the main site of nutrient digestion and absorption in the horse (Kolb and Wujang, 1958). In relation to protozoa activity in the equine, none of the protozoa species found in ponies was in steers. Oats added to forage diets increased the bacterial numbers in ponies' cecal ingesta but not in the steers' ruminal digesta (Kern, et al., 1973).

The assumption has been made that the equine utilizes soluble carbohydrates, proteins and fats via absorption in the small intestine, with the presence of VFA resulting from crude fiber fermentation via absorption in the large intestine (Robinson and Slade, 1974). The sites for dietary protein digestion are in the stomach and small intestine,

with some protein being subjected to microbial attack in the large intestine (Pearce, 1975).

Major sites for carbohydrate and protein digestion are prececal, with neutral detergent fiber digestion primarily occurring in the colon and cecum regardless of the hay:grain ration. When feeding typical grains and forages, associative effects on digestibility appear to be of little concern. Changing the site of end products of digestion seems to be the most significant effect of varying the forage:grain ratios in horses (Hintz, Argenzio and Schryver, 1971b). Digestion in the lower gut of the horse increases in importance as the levels of forage in the diet are increased (Hintz, et al., 1971a).

The large intestine of the horse functions as four separate compartments comprised of the cecum and the ventral, dorsal, and small colon. Retrograde flow, like that between the rumen and reticulum of ruminants, is not observed within the lower digestive tract of the horse (Wootton and Argenzio, 1975). Retention time is prolonged in the ventral and dorsal colon as compared to the stomach, small intestine and cecum (Argenzio, et al., 1974; Wootton and Argenzio, 1975). This prolonged period of particles and fluid in the large colon is important for microbial digestion. This retention appears to be greater than when compared to the ruminant forestomach (Argenzio, et al., 1974).

CHAPTER 3

MATERIALS AND METHODS

Two separate studies were conducted for the investigation of cereal grain usage in the horse. The first study consisted of two trials evaluating processing methods of oats for adult horses. The second study compared digestion, growth performance and water intake in yearling horses fed two modifications of milo grain.

Experiment 1: Oat Grain Digestibility

In phase one, six mature mares (450 kg) were randomly assigned to a double 3 x 3 Latin Square design experiment. The three diets compared consisted of 40% grain plus 60% alfalfa hay cubes and were fed at twelve hour intervals. The grain treatments investigated were whole oats (WO), rolled oats (RO), and water-soaked whole oats (WSWO). The chemical composition of the experimental diets are shown in Table 1.

Initial and final body weights for each mare were recorded according to dietary treatment at the beginning and end of the experiment. Water was available ad libitum and animals were housed in box stalls with adjoining runs. All horses were exercised daily for thirty minutes on a mechanical hot walker.

Prior to the initiation of the fecal collection period, there was a ten day adaptation period followed by a six day fecal grab sampling regime daily from each horse such that each two hour interval after the 7 am feeding was represented. Samples were composited over

Table 1. Chemical Composition of the Various Prepared Oat Diets (Experiment 1)

<u>Composition</u> ^b	Dietary Treatments ^a				
	WO + Hay	RO + Hay	WSWO + Hay	SPFO + Hay	Hay
Dry Matter, % ^c	92.2	92.2	92.0	92.1	92.1
Organic Matter, %	91.0	91.4	91.3	92.7	90.0
Gross Energy, Mcal/kg	4.4	4.5	4.5	4.6	4.5
Crude Protein, %	17.6	17.9	17.4	17.3	19.8
Acid Detergent Fiber, %	26.1	25.5	27.1	26.0	35.0
Lignin, %	5.0	5.0	4.8	5.0	6.7
Neutral Detergent Fiber, %	37.0	36.1	37.9	38.0	46.1
Starch, %	47.6	47.3	46.8	47.8	29.3
Ash, %	9.0	8.6	8.7	7.3	10.0

a. Diets: Whole oats + alfalfa (WO), rolled oats + alfalfa (RO), water-soaked whole oats + alfalfa (WSWO), and steam processed-flaked oats + alfalfa (SPFO).

b. Composition calculated on lab dry matter basis.

c. Moisture levels: WO = 7.0%, RO = 8.4%, WSWO = 34.0%, SPFO = 13.0%, Hay = 7.0%.

time within horses. Feed and fecal samples were dried in a forced air oven at 50° C for 48 hours and ground in a Wiley mill through a 1 mm screen. Dry matter (DM) and crude protein (CP) of the feed and feces were determined by A.O.A.C. (1970) methods. Gross energy in the feed and feces was determined by oxygen bomb calorimetry. Acid detergent fiber (ADF), permanganate lignin (PL), and neutral detergent fiber (NDF) in feed and feces were determined by the modified micro-procedure of Waldern (1971). Starch was determined by enzymatic procedure (Keppler and Decker, 1974). Chromic oxide in the feed and feces was analyzed by perchloric acid oxidation as well as an Atomic Absorption technique (Refer to Appendix 1).

Digestion coefficients were determined by changes in feed to fecal nutrient:chromium or lignin ratios. Digestion coefficients for alfalfa hay were obtained from a previous study done with the same horses at the Arizona station. Oat grain digestibility was calculated by difference.

In the second phase, three mares were randomly assigned from phase one and were fed a diet of 40% steam processed and flaked oats (SPFO) plus 60% alfalfa hay cubes. All animals were adapted to the experimental diet for ten days followed by a three day digestion trial. Fecal grab samples were taken at 7 am and 7 pm daily. Animals, time of feeding, exercise, housing, availability of water and chemical analysis were the same as described for phase one. Results of this study were compared with those of phase one. All data where possible were subjected to analysis of variance (Steel and Torrie, 1960).

Experiment 2: Milo Grain Digestibility

Nine yearlings were assigned to a randomized complete block design. The three treatments considered were 100% chopped alfalfa hay, 60% chopped alfalfa hay plus 40% dry rolled milo, and 60% chopped alfalfa hay plus 40% steam processed and flaked milo. All diets included the addition of monobasic sodium phosphate to provide an adequate amount of phosphorus for growing horses. Digestion coefficients were determined using the total fecal collection technique.

Both the dry rolled milo and steam processed and flaked milo were processed at the Arizona Feedlot Station and subsequently mixed on a percentage basis with the chopped alfalfa. The steam treated grain was mixed with the alfalfa prior to drying, with adjustments made in grain levels to give an amount of milo equal to that of the dry rolled milo diet (Husted, et al., 1968). Enough feed was mixed at one time to carry through the end of the digestion trial. Chemical composition of the diets is shown in Table 2.

Prior to placement on the experimental diets, animals were fed a uniform diet of alfalfa hay cubes for two weeks. This was to derive an estimation for actual feed intake per animal on an average daily basis. For this period, the average intake for the nine yearlings was approximately 2.83% of their body weight, or 7.5 kg of feed. All animals were wormed with Equizole A at this time.

Animals were then placed on the respective experimental diets, and intake was adjusted weekly based on the lowest level of intake. Individual animal body weights were monitored weekly throughout the

Table 2. Chemical Composition for Yearling Milo Grain Diets
(Experiment 2)

<u>Composition</u>	<u>Dietary Treatments^a</u>		
	<u>1</u>	<u>2</u>	<u>3</u>
Dry Matter, %	90.9	89.2	88.9
Organic Matter, %	90.0	93.4	93.4
Gross Energy, Mcal/kg	4.5	4.4	4.4
Crude Protein, %	17.4	14.7	14.7
Acid Detergent Fiber, %	36.9	24.7	24.7
Lignin, %	8.3	5.9	5.9
Neutral Detergent Fiber, %	44.3	32.1	32.1
Starch, % ^b	35.4	47.1	47.1
Ash, %	10.0	6.6	6.6

- a. 1 = 100% alfalfa
 2 = 60% alfalfa + 40% dry rolled milo
 3 = 60% alfalfa + 40% steam processed-flaked milo

- b. Value for milo grain obtained from Masters thesis of Francis Delfino, University of Arizona, 1982.

digestion trial in order to obtain an accurate estimate of intake on a metabolic weight basis ($\text{kg}^{.75}$).

During this four week diet adaptation period, all yearlings were handled at least three times per week and exercised on a lounge line for approximately 15 minutes in a round pen. Along with these halter lessons was an introduction to the metabolism unit and stalls. Yearlings were individually walked through the unit and tied in one of the stalls to enable them to become accustomed to the surroundings. All yearlings were taught to lounge and tie prior to the diet adaptation period.

Horses were fed twice a day at 7 am and 7 pm respectively. Water intake was also recorded daily via calibrated buckets. Horses were watered three times daily until thirst was abated. Following the dietary adaptation periods, animals were placed in the metabolism unit after a final exercise period. Conditions were such that they were required to stand on a concrete floor, supplied with individual Fortex rubber feeders and water buckets to decrease chance of injury and wood chewing. Horses were held in the units by two stout chains attached to the metal pole sidings of the stall by panic snaps in case of an accident. Stalls were equipped with wire mesh panels up near the head to reduce fighting, and panels were removeable in case of animal entrapment.

Horses were allowed a four day adaptation period to adjust to the stresses and surroundings. Water was available ad libitum for the first day, and then monitored again on a three time per day basis. Animals were not removed from the stanchions throughout the four day

adjustment and five day total collection period. Yearlings were weighed immediately following the last collection day, prior to being placed on an ad libitum feeding and watering routine.

Following daily total collections, samples were weighed and mixed according to day, and a 500 gram allotment was taken and dried in a forced air oven at 50° C for 48 hours. Treatments of the samples and experimental procedures coincide with those identified for Experiment 1. The only variation was in the crude protein (CP) analysis. Analysis using an Auto Analytical technique was employed, which gave comparable results to macro-Kjeldahls when a check was run. For a complete outline on the digestion procedures, refer to Appendix 1.

Experiment 2: Yearling Growth Study

Following the completion of the digestion trial for milo grain, a growth study was initiated to evaluate growth responses to three dietary treatments. The 100% alfalfa diet was supplemented with 40% oats to ensure energy equivalency to the 40% milo diets. Horses were slowly worked up to a monitored ad libitum intake regime, adjusting from the restricted metabolic intake of the digestion trial. Yearlings were weighed initially and at 28 and 56 day intervals. Water was available ad libitum and horses were housed in separate 4 x 8 meter pens with individual feeders. Animals were allowed a free choice exercise regime.

Ascarids were noted in one yearling half way through the second 28 day period, and feed intake had been depressed for three days. All yearlings were treated the next day, with noticeable clearing of the parasites. Appetites subsequently increased and condition improved.

CHAPTER 4

RESULTS AND DISCUSSION

Experiments 1 and 2: Comparative Dietary Intake for Oats and Milo

Daily nutrient intake of digestible energy (DE) in Mcals and crude protein (CP) in grams is listed in Table 3 for horses fed the oat or milo diets in Experiments 1 and 2, respectively. The experimental diets when fed at 2.5% of the body weight provided in excess of NRC, 1978, requirements for mature horses at rest and growing yearling horses. Feed levels listed for the yearling digestion trial were estimated on a metabolic weight basis ($\text{kg}^{.75}$).

Experiment 1: Feed Intake and Digestibility Calculations for Oat Diets

Results of daily intake and body weight of Experiment 1 are shown in Table 4. All animals consumed 7.6 kg of the various prepared oat diets with no differences in feed acceptance or preference indicated. Animals maintained body weight with average initial body weights of 477.6 kg and final body weights of 477.7 kg.

Apparent digestibility coefficients, calculated by the chromic oxide marker technique provided lower digestion coefficients among all the nutrient fractions measured, and values for fiber digestibility were substantially lower than those calculated via lignin ratios. Many workers have observed misleading and often times lowered chromium determined digestibility coefficients as compared to other techniques

Table 3. Daily Nutrient Intake (Experiments 1 and 2)

	Mature Horse (500 kg)			Growing Foal (Mature Weight, 500 kg)		
	Recommended		Oat Experimental	Recommended	Milo Experimental	
	Maintenance	Light Work	Diet	12 mos.(325 kg)	2.5% BW	BW ^{.75}
DE(Mcal)	16.39	21.39	22.04	16.81	25.20	17.81
CP(grams)	597	803	1338	750	1197	690

Table 4. Mean Daily Intake, Initial and Final Body Weight for Mature Horses Fed Processed Oat Diets (Experiment 1)

	Dietary Treatments ^a			
	WO + Hay	RO + Hay	WSWO + Hay	SPFO + Hay
<u>Parameters</u>				
Mean Daily Intake, kg	7.6	7.6	7.6	7.6
Initial Body Weight, kg	476.3	478.6	478.1	---
Final Body Weight, kg	479.3	477.7	477.4	---

- a. WO = 40% whole oats + 60% alfalfa hay cubes
 RO = 40% rolled oats + 60% alfalfa hay cubes
 WSWO = 40% water-soaked whole oats + 60% alfalfa hay cubes
 SPFO = 40% steam-processed and flaked oats + 60% alfalfa hay cubes

(Stevenson, 1962; Haenlein, et al., 1966; Knapka, et al., 1967; Drennan, Holmes and Garrett, 1970; Phar, et al., 1970).

When the chromium:feces ratio was used to calculate digestibility values, negative results were noted for the fiber fractions. Consequently, a method for determining chromium concentration by Atomic Absorption (Hinman and Johnson, 1974), was employed to compare values obtained by perchloric acid digest. (See Appendix 1 for Atomic Absorption methodology). One major problem encountered in chromium determination lies in dissolving the chromic oxide. Sample digestions using perchloric and sulphuric acids, with the temperature held at 180-190° C, resulted in incomplete oxidation to dichromate. The oxidizing power of the solution is lost as the temperature is increased, and reduction to the trivalent state takes place (Christian and Coup, 1954).

Results were also negative for fiber digestibility values calculated with the chromium ratios determined by Atomic Absorption. A comparison of the values determined for the accumulated fecal and feed samples using the two methods is listed in Table 5. It would appear that under the conditions of these studies, chromic oxide used as an indicator method administered in the powdered form was not an accurate measure of determining nutrient digestibility. These findings are in agreement with the work of others (Drennan, et al., 1970).

The diurnal variation of the rations' nutrients measured in the oat trial is presented in Figures 1 through 5. Crude protein (CP), fiber (ADF and lignin), energy, and chromic oxide excretion in the feces are represented according to dietary treatment for Experiment 1. There

Table 5. Comparison Between Perchloric and Atomic Absorption Techniques for Chromic Oxide (Cr_2O_3) Determination (Experiment 1)

	% Cr_2O_3 in Feed				Cr_2O_3 in Accumulated Feces				Acid Detergent Fiber Digestibility			
	WO	RO	WSWO	SPFO	WO	RO	WSWO	SPFO	WO	RO	WSWO	SPFO
Perchloric	.226	.217	.243	.223	.414	.412	.440	.412	-15.75	-16.46	-11.95	-15.23
Atomic Absorption	.228	.213	.203	.207	.432	.444	.502	.417	-11.94	-6.08	+14.80	-5.65

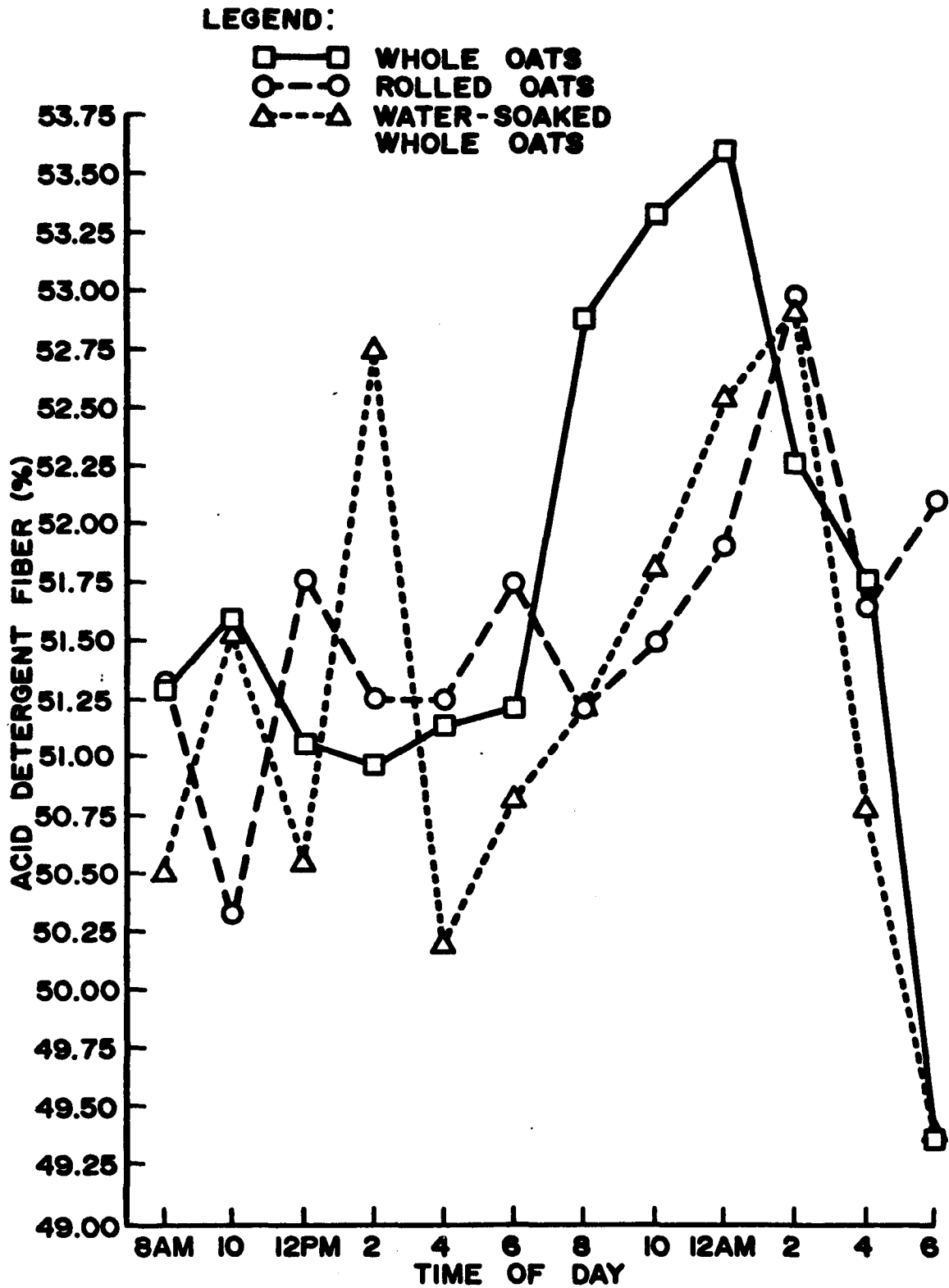


Figure 1. Acid Detergent Fiber Fecal Excretion Hourly Variations (Experiment 1)

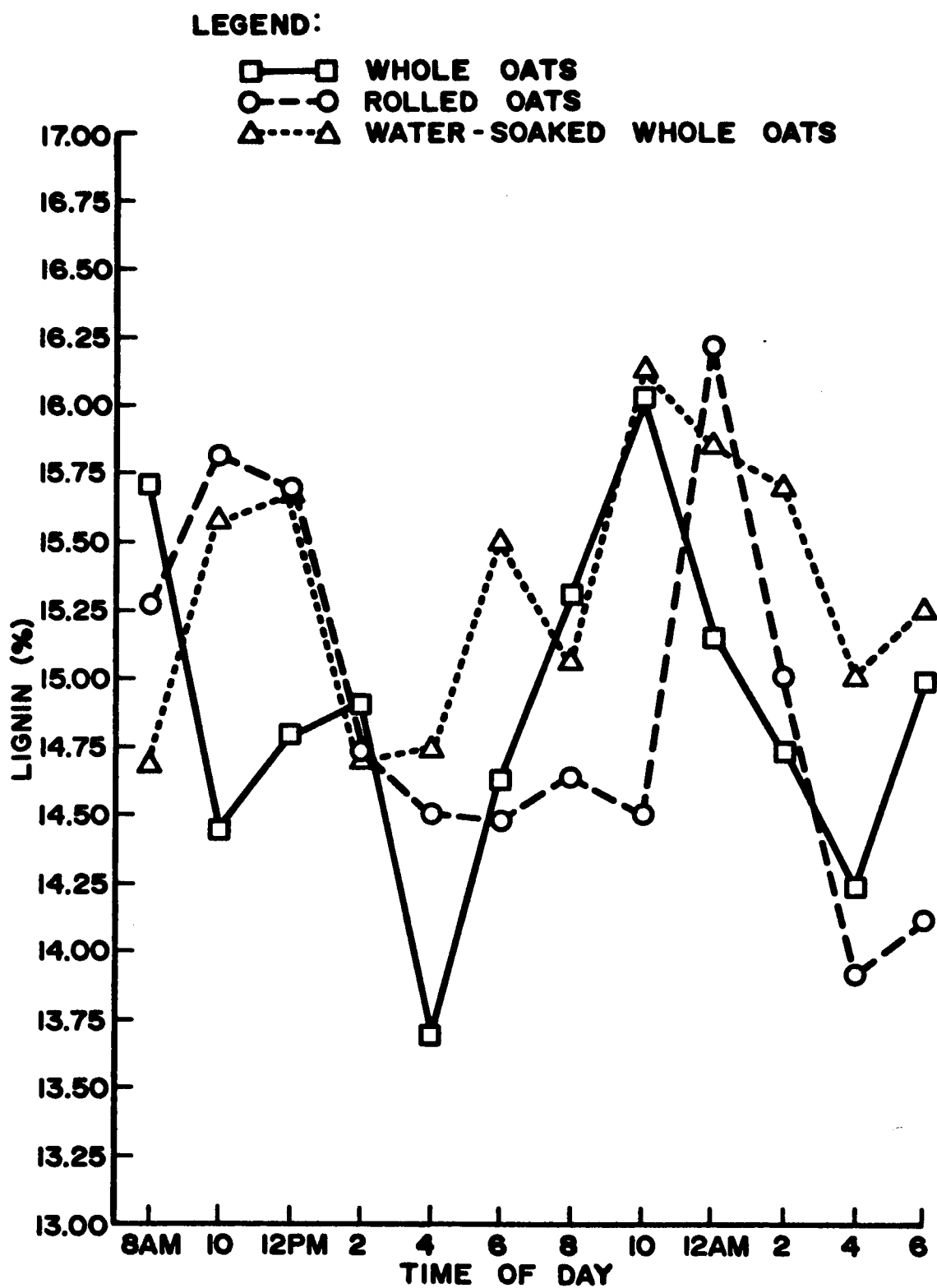


Figure 2. Lignin Fecal Excretion Hourly Variations (Experiment 1)

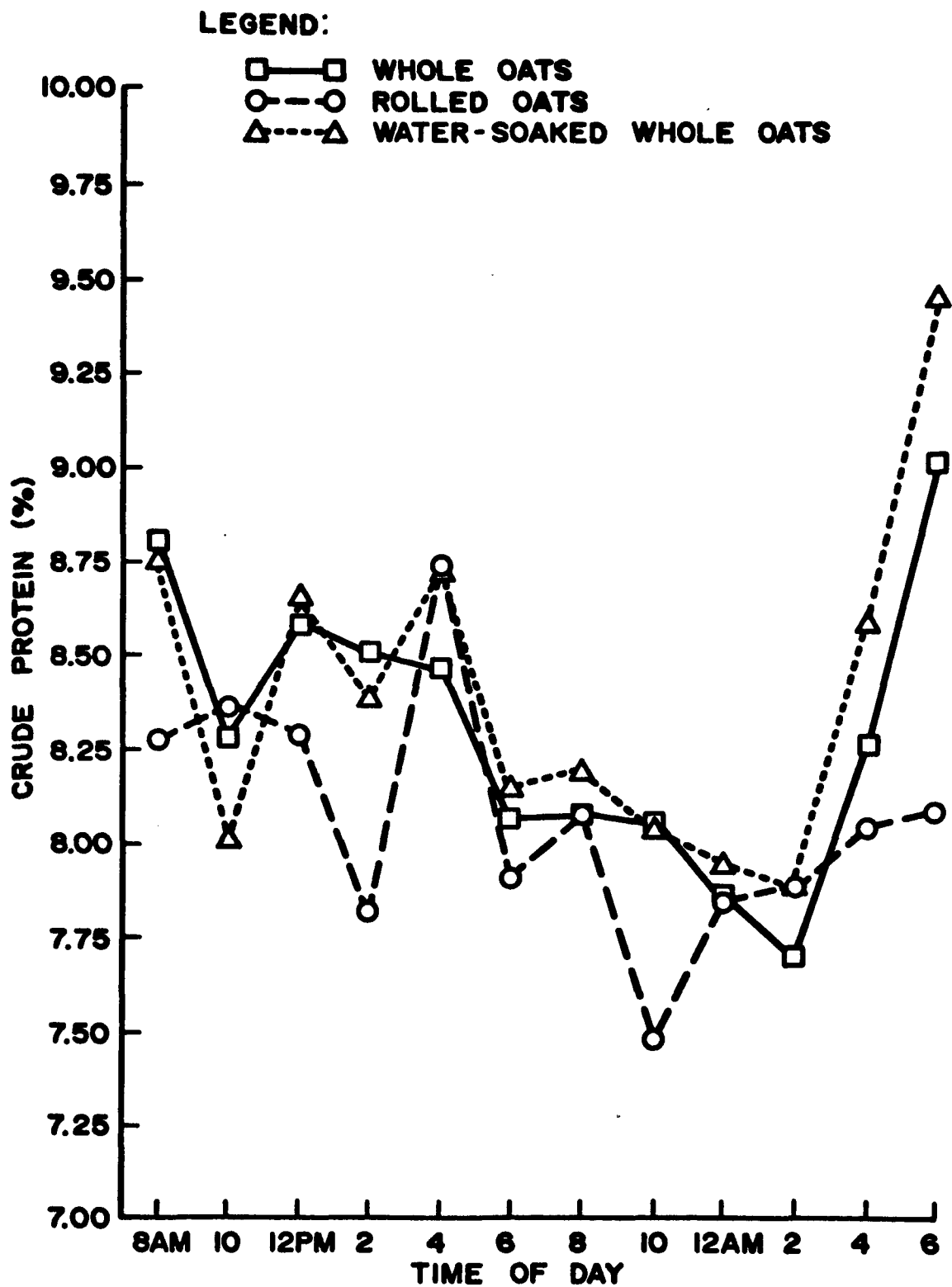


Figure 3. Crude Protein Fecal Excretion Hourly Variations (Experiment 1)

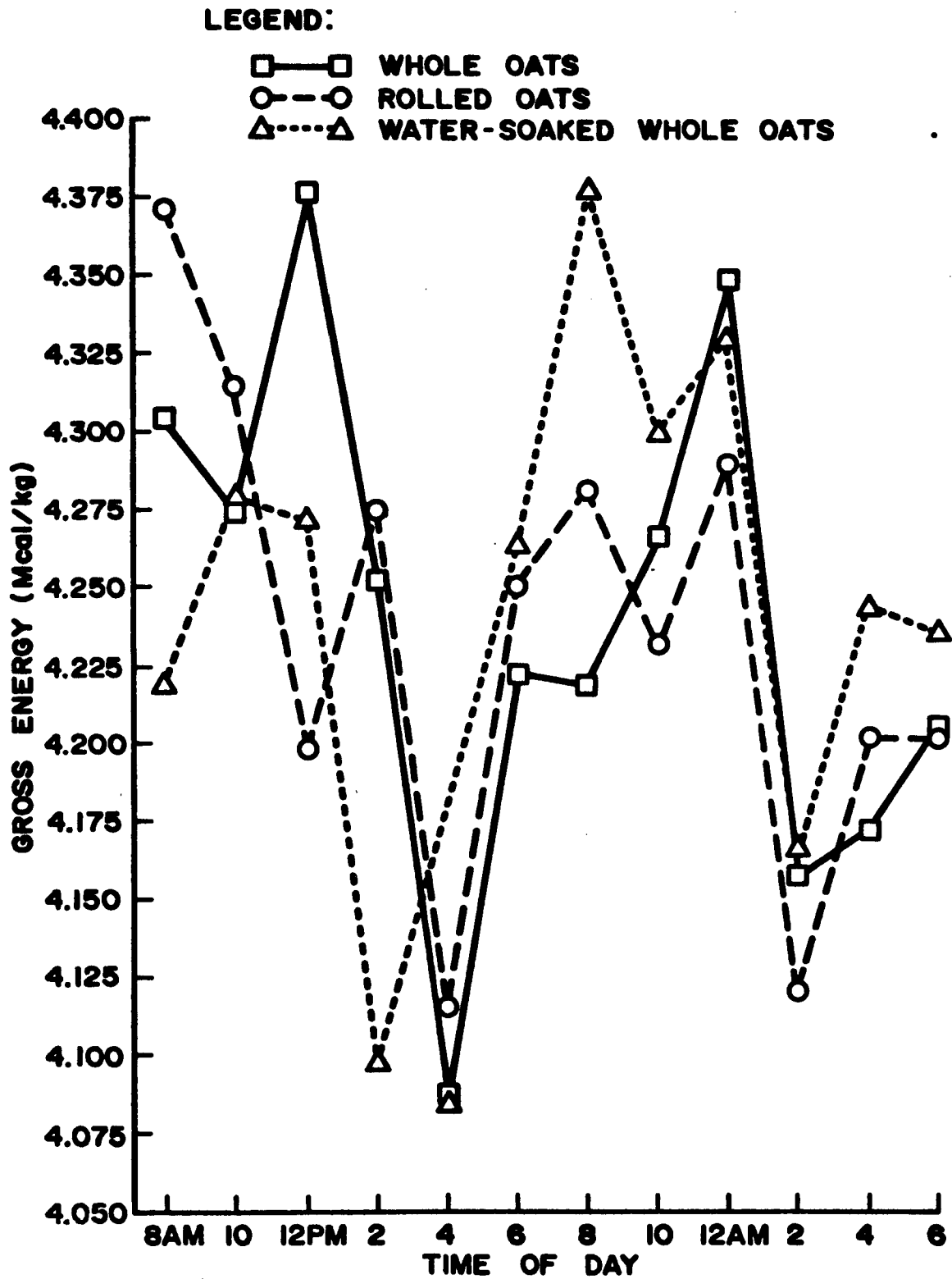


Figure 4. Gross Energy Fecal Excretion Hourly Variations (Experiment 1)

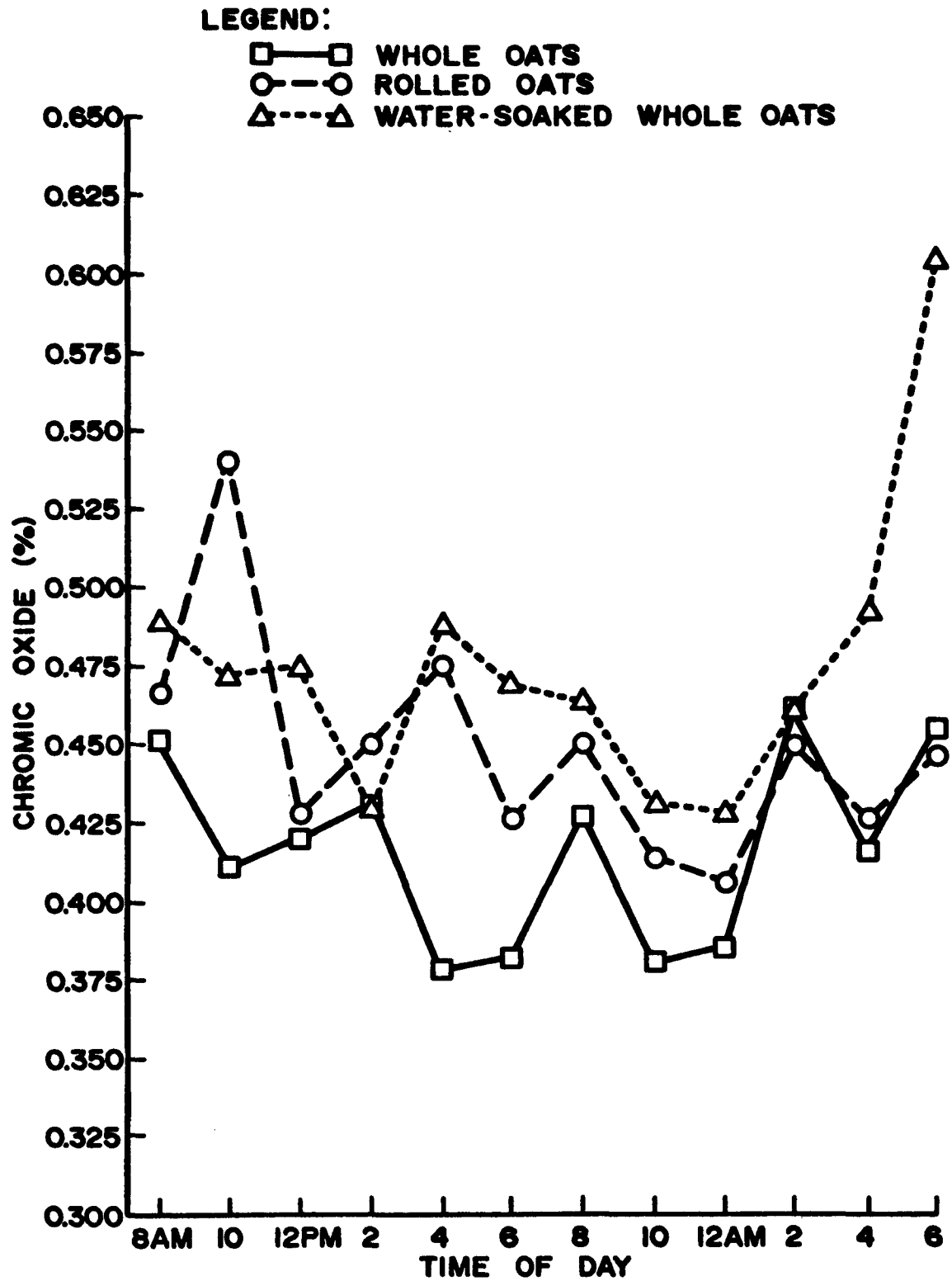


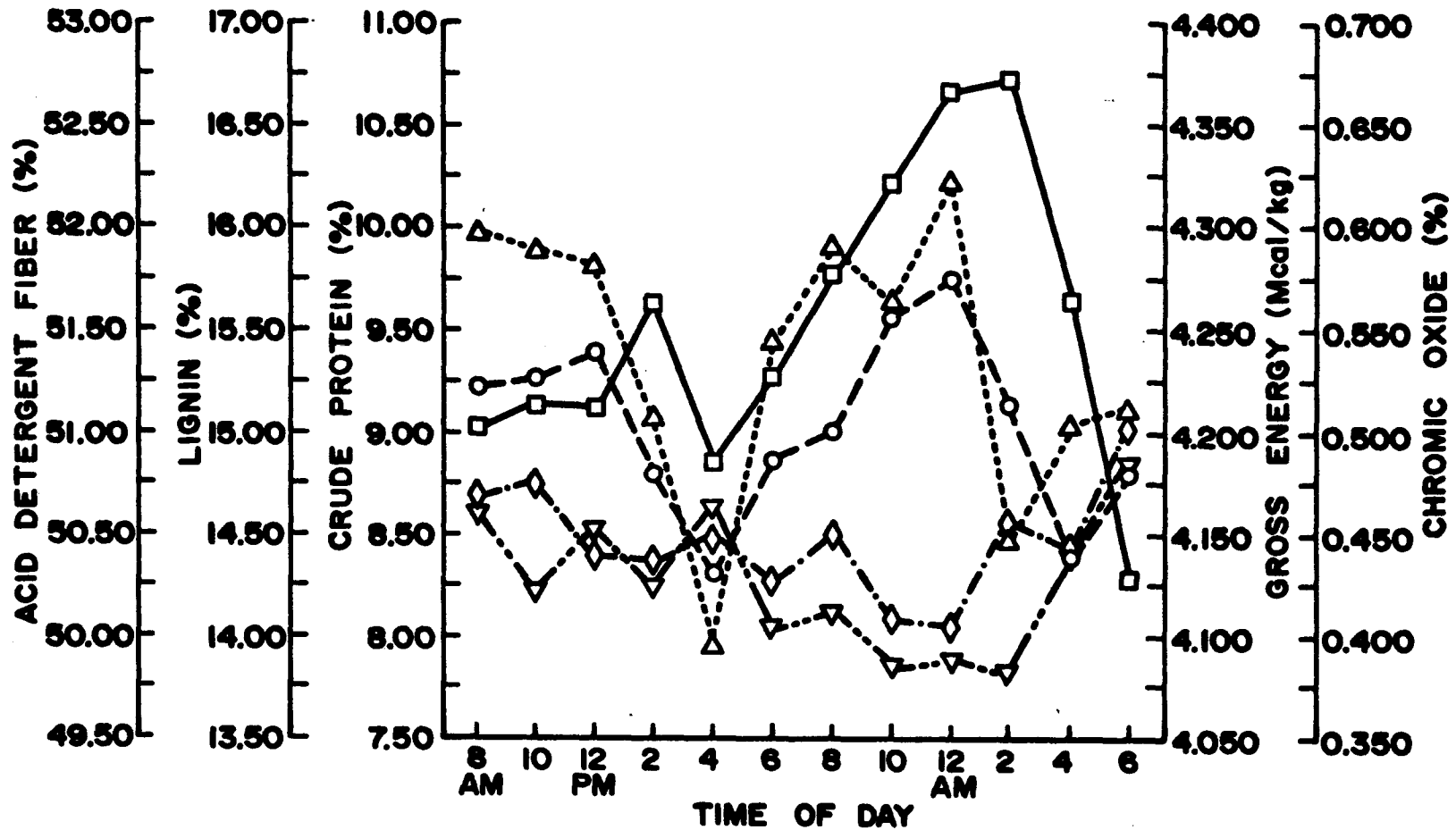
Figure 5. Chromic Oxide Fecal Excretion Hourly Variations (Experiment 1)

were no significant differences in the excretion of any of the parameters investigated according to time of sampling for any dietary treatment, which correlates with findings by Phar, et al., 1970.

Hourly variations between the five parameters are shown in Figure 6. The Y axis consists of values of Mcal/kg for gross energy, % digestibility for ADF, lignin and crude protein, and % concentration in feces for chromium; values arranged such that divisions were .025 Mcal/kg, .25%, and .025% respectively.

Results indicate that ADF and lignin correspond well with each other. This is expected since lignin is a component of ADF. In addition, the gross energy excretion pattern also follows a similar pattern as fiber fractions. Surprisingly, the chromium closely corresponds with crude protein excretion variation, which is in agreement with findings of Phar, et al., 1970. It was interesting that the chromium was not more closely associated with the fiber parameters, since lignin has also been considered as an inert marker. However, other experimentors have also found that the hourly variations in the excretion of chromic oxide do not correspond with crude fiber fluctuations (Kane, et al., 1952; Moore, 1957; Davis, Byers and Luber, 1958). Evidence from these data indicates that it is possible that the chromic oxide flow is more associated with the soluble portion of the diet instead of the fibrous portion, flowing at a quicker and more consistent rate.

Since the apparent digestibility values based on the chromium values were either negative or misleading, lignin was used as an alternative ratio calculation, and it has been suggested as an indicator



LEGEND:

- ACID DETERGENT FIBER
- LIGNIN
- △—△ CHROMIC OXIDE
- ▽—▽ CRUDE PROTEIN
- ◇—◇ GROSS ENERGY

Figure 6. Graphical Comparison Between Acid Detergent Fiber, Crude Protein, Gross Energy and Chromic Oxide Fecal Excretion Hourly Variations (Experiment 1)

possibly more suitable under some conditions of experimentation (McLeod and Minson, 1974; Schneider and Flatt, 1975). It has been suggested that lignin, being a complex aromatic polymer which occurs in plant cell walls in close association with cellulose and hemicellulose polysaccharides (Morrison, 1972), is not digested to a significant degree by herbivorous animals. Data cited in the literature suggests that lignin was not digested to a significant degree in either sheep or cows on timothy grass and mixed feeds respectively (Ellis, Matrone and Maynard, 1946), and it is for this reason, plus the unavailability of a total collection unit at that time, that lignin was utilized in the oat digestibility study for calculations as a replacement method for the chromium.

Experiment 1: Oat Grain Digestibility for Mature Horses

The results of these studies indicate that the mature horse can be fed different processed oat grain prepared diets without altering digestibility. However, water-soaking of whole oats (WSWO) did improve ($P < .05$) acid detergent fiber (ADF) digestibility of the grain when calculated by difference. The water-soaking treatment of oats may provide the animal with a more digestible product by softening of the endosperm and waxy coating, thus increasing performance. It is also possible that some limited bacterial action may take place in the soaking process allowing for more extensive digestion to occur through fermentation. The cooking, or steaming process, followed by flaking physically disrupts the grain starch bonds. Flaking reinforces the disruption which occurred during cooking, which aids in making the

nutrients more available to the animal. However, nutrient digestibility did not improve with this treatment.

Apparent digestion coefficients of various prepared oat diets, shown in Table 6, were determined by changes in feed to fecal nutrient:lignin ratios. The only significance noted between dietary fractions was in the ADF and neutral detergent fiber (NDF) fractions. The digestibility of the fiber fractions of the rolled oat (RO) diet was significantly lower ($P < .05$) than the other three dietary treatments. This may be due to the lower control standards during the processing phase, or that the other processing methods provide for greater utilization. No significant differences were noted between the other nutrient parameters.

The digestibility of the prepared oats was calculated by difference and are listed in Table 7. Significant changes are illustrated in the fiber and starch fractions, with RO demonstrating negative fiber digestibility and WSWO and steam processed and flaked oats (SPFO) showing marked improvement for ADF and NDF parameters respectively. There was decreased starch digestibility for both WSWO and SPFO, but no change between the whole oat (WO) or RO diets. For both SPFO and RO, some starch rebonding may have occurred during processing after the initial cooking phase. In the case of WSWO, no explanation for the decreased digestibility could be found. There may have been some adverse bacterial action on the starch granule which could subsequently decrease the digestibility value of the grain, but there is no proof for this conjecture.

Table 6. Apparent Digestion Coefficients of Various Prepared Oat Diets for Mature Horses (Experiment 1)

Digestion Coefficients(%) Digestible Energy(Mcal/kg)	Dietary Treatments ^a					SEM	CV
	WO + Hay	RO + Hay	WSWO + Hay	SPFO + Hay	Hay		
Dry Matter	65.9	64.5	65.7	66.6	56.0	0.53	3.41
Organic Matter	67.9	67.0	68.1	68.3	65.0	0.37	2.34
Gross Energy	66.1	65.4	66.1	65.7	56.1	0.68	4.36
Digestible Energy	2.9	2.9	2.9	3.0	2.5	0.02	3.00
Crude Protein	82.1	83.1	82.2	83.9	73.5	0.78	4.02
Acid Detergent Fiber	29.3 ^b	22.8 ^c	32.9 ^b	30.1 ^b	45.0	1.03	15.52
Neutral Detergent Fiber	34.1 ^b	27.6 ^c	35.6 ^b	38.5 ^b	46.1	0.97	12.72
Starch	60.0	59.7	56.3	57.8	40.4	1.63	11.79

a. WO = whole oats, RO = rolled oats, WSWO = water-soaked whole oats, SPFO = steam-processed and flaked oats.

^{b,c} Means in same line with different letter superscripts are different (P<.05).

Table 7. Estimated Digestibility of the Various Prepared Oats for Mature Horses
Calculated by Difference (Experiment 1)

Digestion Coefficients(%) Digestible Energy(Mcal/kg)	Dietary Treatments				SEM	CV
	WO	RO	WSWO	SPFO		
Dry Matter	80.8	77.5	80.2	82.5	1.23	6.58
Organic Matter	72.3	70.0	72.3	73.2	0.94	5.54
Gross Energy	81.2	79.4	81.2	80.0	1.16	6.10
Digestible Energy	3.7	3.6	3.6	3.8	0.04	4.70
Crude Protein	93.9	97.5	95.1	99.5	1.89	8.39
Acid Detergent Fiber	5.8 ^a	-10.3 ^c	13.5 ^b	7.9 ^a	----	----
Neutral Detergent Fiber	16.1 ^a	-0.1 ^b	19.8 ^a	27.1 ^c	----	----
Starch	89.5	88.5	80.1	84.1	5.76	20.08

^{a,b,c} Means in same line with different letter superscripts are different (P<.05).

It would appear from this data that processing oats adds little value in mature horse diets. Other workers have reported similar results when evaluating rolled or micronized oats for horses (Householder, Potter and Lichtenwalner, 1977; Klendshoj, et al., 1979). Studies with cattle fed various processed oat diets likewise show no improvement in feeding value (Orskov, et al., 1974; Kimberly, 1976; Nordin and Campling, 1976; Morgan and Campling, 1978). Cost analysis of WO versus RO resulted in a 2-3% increase in price for RO. Therefore, modification of WO has minimal effect on a physiological basis, and expensive processing costs can be avoided.

Experiment 2: Milo Grain Digestibility for Yearling Horses

Apparent digestion coefficients for the 100% alfalfa and 60% alfalfa-40% milo diets are listed in Table 8. There were significant differences ($P < .05$) between the all alfalfa diet and the 60% alfalfa diet plus 40% milo for dry matter (DM), organic matter (OM), gross energy (GE), and lignin digestibility. However, for these same fractions, no difference ($P > .05$) in digestibility between the two milo treatments was observed as both were digested equally well.

The crude protein (CP) nutrient parameter showed a significantly higher digestibility value for alfalfa hay when compared with the 40% dry rolled milo (DRM) diet, but the 40% steam processed and flaked milo (SPFM) diet was not significantly different from either the 100% alfalfa nor the 40% DRM diets. The SPFM showed a slight increase in protein digestibility over DRM, but not significantly. In trials done with cattle, the steam flaked as well as the reconstituted milo increased the

Table 8. Apparent Digestion Coefficients of Experimental Diets for Yearling Horses (Experiment 2)

Digestion Coefficients(%) Digestible Energy(Mcal/kg)	Dietary Treatments ^c			SEM	CV
	1	2	3		
Dry Matter	60.9 ^a	72.1 ^b	72.3 ^b	0.84	3.67
Organic Matter	63.3 ^a	74.7 ^b	74.8 ^b	0.79	3.34
Gross Energy	60.4 ^a	69.2 ^b	70.6 ^b	0.89	3.99
Digestible Energy	2.7	3.1	3.1	--	--
Crude Protein	76.0 ^a	70.2 ^b	72.8 ^{a,b}	1.01	4.16
Acid Detergent Fiber	47.8	56.0	51.9	1.44	8.31
Lignin	22.8 ^a	43.2 ^b	39.9 ^b	2.57	21.84
Neutral Detergent Fiber	46.1	55.2	51.1	1.58	9.34
Starch	62.5 ^a	75.1 ^b	74.9 ^b	1.67	7.12
Ash	42.8	35.4	35.3	1.98	15.70

^{a,b} Means in same row with different letter superscripts are different (P<.05).

- c. 1 = 100% alfalfa
 2 = 40% dry rolled milo (DRM) + 60% alfalfa
 3 = 40% steam processed-flaked milo (SPFM) + 60% alfalfa

biological value of grain protein by improving the conversion to higher quality bacterial protein in the rumen (Potter, et al., 1971).

On the other hand, the effect of processing on the digestion of sorghum grain protein for cattle has been shown to be minimal (Potter, et al., 1971). In some cases, the SPFM process also has not significantly changed the protein digestibility, and has been somewhat lower than the DRM (Hale, 1966 and 1973). In yearling horses under the conditions of the Arizona station, the SPFM diet showed a slightly higher protein digestibility than the DRM diet.

The ADF, NDF and starch digestion coefficients showed no differences ($P > .05$) between the three dietary treatments, although values for all three parameters were slightly higher for the 40% grain diets. Ash digestibility was slightly higher for the 100% alfalfa diet, which is probably due to its higher mineral content as compared to the 40% grain rations.

In addition, the DRM diet elicited a slightly higher digestibility value for ADF and NDF fractions over the SPFM treatment, although not significantly. Neutral detergent fiber digestibility for diets containing grain has been shown to be greater than for an all forage diet (Hintz, et al., 1971a). A significant associative effect due to the addition of grain to an all forage diet has not been proven to decrease subsequent digestibility of the forage (Hintz, et al., 1971b).

Estimated digestibility of milo grain was calculated by difference and is shown in Table 9. There were no significant differences between the two dietary treatments although the SPFM process

**Table 9. Estimated Digestibility of Milo Grain for Yearling Horses
Calculated by Difference (Experiment 2)**

Dietary Treatments^a				
Digestion Coefficient(%)				
Digestible Energy (Mcal/kg)	DRM	SPFM	SEM	CV
Dry Matter	88.9	89.3	2.76	7.59
Organic Matter	91.8	92.1	2.67	7.12
Gross Energy	82.3	85.8	2.94	8.57
Digestible Energy	3.6	3.8	0.13	8.57
Crude Protein	61.4	68.1	3.64	13.76
Acid Detergent Fiber	68.3	58.2	4.81	18.64
Lignin	73.9	65.6	9.22	32.38
Neutral Detergent Fiber	68.9	58.7	5.61	21.55
Starch	93.9	93.4	5.71	14.92
Ash	24.3	24.1	7.06	71.51

a. DRM = dry rolled milo
SPFM = steam processed-flaked milo

showed a slightly higher digestibility of energy and crude protein. The DRM diet tended to be higher than the SPFM for ADF, lignin and NDF. Again, these digestibilities are mathematical calculations derived under the assumption that there are no associative effects due to adding grain to the all roughage diet. For the young horse, it appears that results of the dry rolled and steam processed and flaked milo processing methods are similar on a digestibility basis, with no significant differences noted. Therefore, either processing of milo can be fed to horses with equivalent success.

Experiment 2: Water Intake for Yearling Horses on 100%
Alfalfa versus 40% Grain plus 60% Alfalfa Diets

Average fecal outputs and water intakes for the yearling horses in the milo digestibility trial are listed in Table 10. These values were obtained only during the five day total collection period during the digestion trail. There was a significantly greater fecal output and water intake ($P < .05$) noted for those yearlings on the 100% alfalfa diet as compared to the 40% grain plus 60% alfalfa diets. Animals on an all roughage diet tend to show a greater fecal output as well as an increased water intake (Fonnesbeck, 1968), a theory which is supported by this milo trial.

Water intake was also measured throughout the adaptation period prior to the fecal collection. Again, between dietary treatments, the 100% alfalfa diet manifests a significantly higher water intake when animals were in outside pens as well as when housed in the metabolism unit. On an outside versus inside comparative basis listed on Table 11, horses drank significantly more water when outside with no shade.

Table 10. Average Fecal Output, Water Intake for Immature Horses
Fed Different Roughage Levels (Experiment 2)

Diet ^c	Fecal Output		Dry Matter %	Average Water Intake (l/day) for 5 day collection
	as is(kg)	DM(kg)		
1	9.01 ^a	1.70 ^a	19.05	15.84 ^a
2	5.33 ^b	1.16 ^b	21.88	11.85 ^b
3	5.93 ^b	1.19 ^b	20.19	11.55 ^b
SEM	0.40			0.18
CV	10.47			4.19

^{a,b} Means in same column with different letter superscripts are different (P<.05).

- c. 1 = 100% alfalfa
 2 = 60% alfalfa + 40% dry rolled milo
 3 = 60% alfalfa + 40% steam processed-flaked milo

Table 11. Average Water Intake (l/day) for Immature Horses Exposed to Environmental Change (Experiment 2)

	Diet Comparison ^e					Outside vs. Inside		
	1	2	3	SEM	CV	Avg.	SEM	CV
Outside	23.43 ^a	18.05 ^b	19.51 ^{a,b}	0.76	11.22	20.33 ^c	0.64	16.34
Inside	16.16 ^a	11.92 ^b	11.48 ^b	0.24	5.36	13.19 ^d		

^{a,b} Means in same line with different letter superscripts are different (P<.05).

^{c,d} Means in same column for average water intake significantly different.

- e. 1 = 100% alfalfa
 2 = 60% alfalfa + 40% dry rolled milo
 3 = 60% alfalfa + 40% steam processed-flaked milo

Water intake is of primary importance in animal production with special emphasis in arid regions such as Arizona. "When a fibrous mass (CWC) is consumed, sufficient water must be ingested to move it through the digestive tract. When a ratio with less fiber of bulk is ingested, less water is required. As nutrients of the feed are absorbed, the residual bulk is reduced and more water is absorbed from the intestines" (Fonnesbeck, 1968). The colon has been recognized as the main site of net water absorption in the horse (Hintz, et al., 1971a; Robinson and Slade, 1974). The cecum appears to absorb large quantities of water mainly during the period between meals (Argenzio, et al., 1974).

A water intake study was conducted to compare the relative importance of nutrient intake influence on water ingestion (Fonnesbeck, 1968). Intake was found to be highly correlated to the dry matter (.091) and ash (.082) contents, with differences in water intake not consistent with protein intake. Water excretion coincided with water intake in relation to the composition of the diet, which suggests that factors which influence water intake may be directly associated with water excretion. Horses on an all roughage diet consumed 31.4 kg of water per day, while horses on hay and grain diets averaged 17.5 kg per day (Fonnesbeck, 1968). In accordance with existing data (Fonnesbeck, 1968), this trial conducted at the Arizona station found that environment and percent roughage in the diet are highly correlated to water intake.

Experiment 2: Growth Study for Yearling Horses
on 40% Grain Diets

The SPFM diet for our yearling growth trial showed a significant increase for average daily gain (ADG) over the 40% oat diet for the first 28 days, and over the 56 day total, which could be attributed to initial compensatory gain after coming off a restricted intake digestion trial (Table 12). The feed:gain ratio was significant ($P < .05$) for the first 28 days, and the 56 day total between the milo and alfalfa diets and the 40% whole oats, but not between the two milo processings per se. There were no significant differences for the second 28 day period for both ADG and F:G ratio.

Throughout the growth trial, horses were housed in runs which consisted of soil containing high percentages of caliche. Consequently, the ground was fairly hard, which may contribute to abnormal bone development in young growing horses. Along with this problem, all yearlings were being fed a high energy concentrate diet ad libitum. A condition called epiphysitis, which is an inflammation of the epiphyseal area, is identified by an hour glass configuration of the fetlock-pastern area and causes lameness. This condition predominated in one filly in these studies. The filly was predisposed to epiphysitis by having fairly straight pasterns, excessive muscular development, light bone development in the lower legs and small hooves. High concentrate diets accompanied by limited exercise, hard ground conditions and deviations from normal conformation are thought to be major factors involved in the onset of epiphysitis. Treatment after the

Table 12. Average Daily Gain and Feed:Gain Ratio for Yearling Horses Fed 40% Grain Diets (Experiment 2)

Diets ^c	Average Daily Gain			Feed:Gain Ratio		
	1st 28	2nd 28	56 total	1st 28	2nd 28	56 total
1	1.45 ^a	1.36	1.40 ^a	10.16 ^a	12.78	11.11 ^a
2	2.30 ^{a,b}	1.97	2.14 ^{a,b}	6.31 ^b	8.05	6.92 ^b
3	3.28 ^b	1.75	2.52 ^b	5.32 ^b	10.25	6.78 ^b
SEM	0.28	0.21	0.15	0.42	1.32	0.64
CV	35.70	37.35	22.14	17.42	38.25	23.26

^{a,b} Means in same column with different letter superscripts are different (P<.05).

- c. 1 = 40% whole oats + 60% alfalfa
 2 = 40% dry rolled milo + 60% alfalfa
 3 = 40% steam processed-flaked milo + 60% alfalfa

growth trial consisted of turning the animal loose on pasture with no grain intake. After approximately two months, the condition reversed itself.

Looking at feed intake and pounds of gain separately on Table 13, there were significant differences between the 40% WO and 40% SPFM diets for total pounds gain in the first 28 days and the 56 day total, with no significant differences between the DRM and SPFM or DRM and 100% alfalfa. The second 28 day period showed no differences between the diets.

Trials conducted using feeder cattle indicated that when comparing processings of sorghum grain, the steam processed and flaked milo showed a significant increase in gains and feed intake over dry rolled, steam cut or water soaked cut. Feed requirements for steam processed and flaked sorghum were reduced per 100 pounds of gain, with gains increasing approximately 10% and feed requirements decreasing 5% (Hale, 1967b). DRM has a smaller surface area for bacteria to work on, thus possibly inducing a more rapid passage through the gastrointestinal tract. This may be a possible explanation for the lower weight gains for DRM when compared with SPFM (Williamson, 1967).

Very little information is available concerning growth responses in yearling horses fed processed grains. One study, evaluating sorghum grain as a replacement for oats and corn in yearling rations, found that correlations between weight, height, heart girth circumference and nutrient digestibility were generally insignificant (Aber and Potter,

Table 13. Average Feed Intake and Average Pounds Gained for Yearling Horses Fed 40% Grain Diets (Experiment 2)

Diets ^c	Feed Intake (lbs.), DM			Total Gain (lbs.)		
	1st 28	2nd 28	56 total	1st 28	2nd 28	56 total
1	407.72	445.03	843.22	40.67 ^a	38.00	78.67 ^a
2	399.24	424.76	823.99	64.33 ^{a,b}	55.33	119.67 ^{a,b}
3	462.11	447.12	909.27	92.00 ^b	49.00	141.00 ^b
SEM	21.03	24.24	37.32	7.56	5.59	8.05
CV	14.91	16.57	13.04	34.53	35.36	21.34

^{a,b} Means in same column with different letter superscripts are different (P<.05).

- c. 1 = 40% whole oats + 60% alfalfa
 2 = 40% dry rolled milo + 60% alfalfa
 3 = 40% steam processed-flaked milo + 60% alfalfa

1977). From the yearling data gathered in Experiment 2 at the Arizona station, it is possible that the steam processed and flaked milo can increase gain for horses over dry rolled milo and whole oats.

APPENDIX 1

Samples of feed and feces for analysis of crude protein and chromium are first ground to pass through a 20-40 mesh screen. From 0.2g to 0.5g sample (dry weight) is then added to the 40mm x 300mm digestion tubes along with 10ml concentrated sulfuric acid, 1.0g potassium sulfate, and 0.1g sodium selenite. This mixture is then cooked at 400° C until a clear amber solution is noted. Up to this point, the procedure for crude protein and chromium is identical.

Crude Protein

Now 3.0 additional grams of potassium sulfate are added to the digestate and the mixture is diluted to 100ml. After transferring the resulting solution to sample bottles, they are ready for analysis on the Auto Analyzer (Technicon Auto Analyzer II, Industrial Method No. 506-77A).

Chromium Oxide

Add 5ml distilled water to the digestate in the digestion tubes along with 0.4g periodic acid. This mixture is then heated to boiling for about one and one-half hours, or until all or most of the color is dispelled. This resulting mixture is then diluted to 100ml, transferred to sample bottles, and analyzed by Atomic Absorption Spectrophotometry equipped with an air:acetylene flame (Auble, 1982).

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