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FEEDING MORE AND GETTING LESS: EFFECTS OF HIGH GRAIN INTAKES ON DIGESTIVE CAPACITY AND GASTROINTESTINAL HEALTH OF PERFORMANCE HORSES

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Exercise markedly affects nutrient requirements, especially the demand for energy. The daily digestible energy requirements for hardworking horses (racehorses, three-day event horses, endurance horses) are about double the requirements for a similar horse that is not in work. To meet the elevated energy demand, horse managers typically reduce hay intake and increase concentrate intake. According to reported surveys, racehorses weighing 450 to 550 kg frequently receive 3 to 6 kg of concentrate per day (Gallagher et al., 1988; Southwood et al., 1993) with anecdotal reports suggesting that some horses receive more than 8 kg of grain per day. At these rates of concentrate feeding, it is hard to imagine that horses could not be getting sufficient calories to maintain body weight. However, failure to maintain body condition is a common situation in intensely exercised horses. This paper will discuss some of the possible explanations for the apparent mismatch in calorie intake and energy balance in performance horses.

Energy Utilization

Not all of the energy consumed by horses is available for tissue use. In the United States, dietary energy recommendations for horses are based on digestible energy. Digestible energy (DE) is the difference in the gross energy of the feed consumed and the gross energy of feces (Figure 1). The amount of DE in a feed usually goes up as the amount of fiber goes down, so that a good-quality hay might contain 2 Mcal DE/kg dry matter (DM), while a cereal grain will contain 3.2 to 3.8 Mcal of DE/kg DM. Thus, it is a logical choice to replace hay with grain to increase energy intake. By replacing 5 kg of hay DM with 5 kg of grain DM, total DE intake can be increased 7 to 9 Mcal per day.

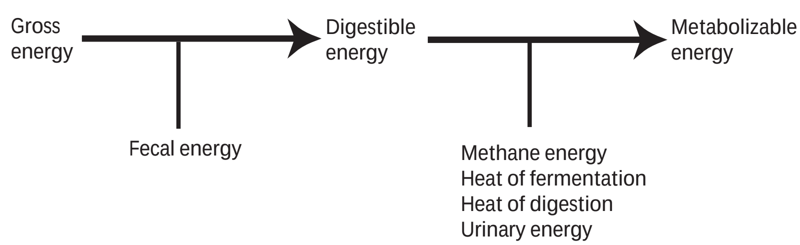

Figure 1. Schematic representation of energy partitioning.

As shown in Figure 1, DE can be further partitioned to metabolizable energy. Metabolizable energy (ME) accounts for losses due to methane, heat of fermentation, heat of digestion, and urinary energy. Because cereal grains are mostly digested in the small intestine, the losses due to fermentation (methane and heat) should be much smaller for grains than for hay. For ruminants, it can be estimated that approximately 25 to 35% of the DE contained in hemicellulose and cellulose is lost during fermentation. When starch is fermented the losses are lower (less methane is produced) but still significant. However, if starch bypasses rumen fermentation and is digested in the small intestine, the conversion of DE to ME is quite high, approximately 95%. Thus, the energetic differences between a diet of all hay and a diet containing hay and grain are magnified at the level of ME. Furthermore, there may be differences in the efficiency of utilization of the products of digestion between an all-hay diet and a diet containing hay and grain. Although the order of events is different for digestion in the horse, the relative losses associated with each type of digestion and the utilization of end products should be similar.

Figure 2 illustrates the potential differences in DE and ME from an all-hay diet and a mixed hay and grain diet. In the example shown here, about 75% of the DE consumed from an all-hay diet is available as ME, whereas almost 90% of the DE from a mixed diet is available as ME. Clearly, there is a theoretical advantage to feeding diets high in concentrate to performance horses with high energy requirements. But there are also potential disadvantages, and there is probably a point at which you can actually feed more, but get less. In Figure 2, it was assumed that all of the starch in the grain would be digested in the small intestine; however, this assumption is probably not valid in most horses.

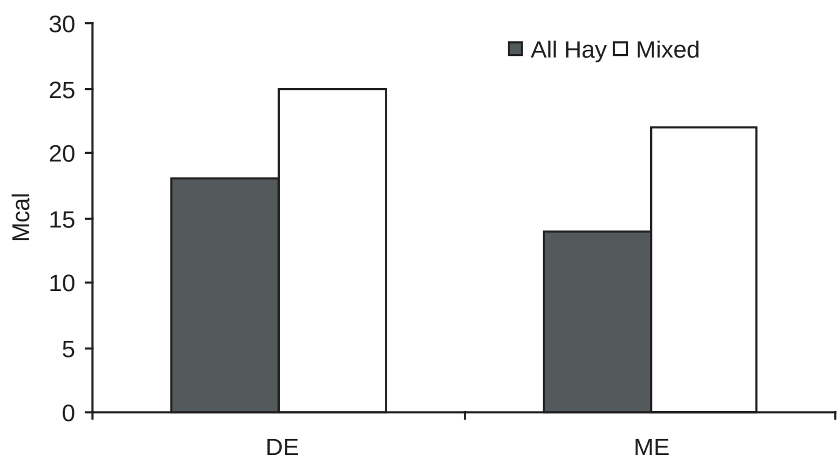

Figure 2. The amount of digestible energy (DE) and metabolizable energy (ME) available in diets containing either 10 kg of hay (All Hay) or 5 kg of hay and 5 kg of grain (Mixed). Note that the theoretical difference in ME between diets is greater than the difference in DE.

When Is More Really Less?

Several studies conducted in the last two decades suggest that the horse may have a limited ability to digest and absorb nonstructural carbohydrates (NSC), particularly starch, from the small intestine. When a small amount of oats was fed to horses, approximately 80% of the starch was digested and absorbed in the small intestine (Potter et al., 1992). When the amount of oats was increased, small intestinal starch digestibility decreased to 58%. Differences in small intestinal starch digestibility have also been reported among different types of grains (Kienzle et al., 1992; Radicke et al., 1991). Processing also appears to play a role in how well horses can digest starch in the small intestine (Potter et al., 1992). The amount of starch that can be tolerated will vary with type of grain and the type of processing; however, a few guidelines have been suggested. To minimize overflow to the large intestine, one researcher has suggested that the maximum amount of starch that should be fed at one meal is 3.50 to 4.0 g/kg BW (Potter et al., 1992). However, Cuddeford (1999) has suggested that other research supports a much lower value of 2.0 g/kg BW. If a concentrate feed contains 50% starch, the maximum amount of grain that could be fed without significant starch overflow to the large intestine is 4 g/kg BW or about 2 kg of grain/500 kg horse.

As more grain is fed, a greater percentage will flow to the large intestine and much of the energetic advantage of feeding grains will be lost. Harmon and McLeod (2000) have suggested that the energetic value of starch that is fermented is only about 75% of the value of starch that is digested in the small intestine.

Gastrointestinal Function

One of the consequences of high grain intakes in horses is the reduced amount of energy available from the grain when it bypasses digestion in the small intestine. Another consequence is the potential effect that excessive NSC flow to the large intestine could have on gastrointestinal function and health. At least one study in recent years has linked large concentrate meals to increased risk for gastrointestinal dysfunction. Tinker and coworkers (1997) examined some of the management factors related to colic incidence in horses. They reported an increased risk for colic when horses received more than 2.5 kg of grain per day, with a further increase in risk when grain intake exceeded 5 kg (Tinker et al., 1997). These amounts of grain are at or below expected intakes in racehorses but are within a range for which incomplete digestion of starch in the small intestine might be expected.

Why would high concentrate intakes increase the risk of colic? In a 1990 review, Clark concluded that large concentrate meals have the potential to alter gastrointestinal motility, stimulate large fluid shifts, and impact the gut microflora. Like the rumen, the equine large intestine is a complex ecosystem consisting of many different types of microbes. Mackie and Wilkens (1988) reported that horses consuming all-grass diets had glucolytic, amylolytic, proteolytic, cellulolytic, hemicellulolytic, and lactate-utilizing bacteria in the cecum and colon. It is generally accepted that the composition of the ruminant microbial population can be influenced by the type of substrate available as well as other factors such as pH. Using ponies, Kern et al. (1973) evaluated changes in the cecal microbial population to diets of all hay or 75% hay and 25% grain. Moore and Dehority (1993) characterized the microbial populations in ponies fed diets containing either a 90:10 or 60:40 hay:concentrate ratio. Kern et al. (1973) found that adding grain to the diet increased the total number of bacteria in the cecum. Moore and Dehority (1993) did not find a significant effect of diet on bacterial numbers in the cecum but did find increased microbial numbers in the colon. Neither study reported a marked effect of diet on the types of bacteria present, possibly because total feed intakes were moderate to low (1.5 to 2.0% of body weight). These results are in contrast to those obtained using a carbohydrate-overload model which found an increase in *Lactobacillus* and *Clostridium* spp. and a reduction in *Enterobacteriaceae* (Garner et al., 1978). These changes represent an increase in acid-producing bacteria and a decrease in acid-utilizing bacteria, particularly lactate utilizers, and would be expected to promote an acidic environment in the large intestine.

The effect of diet on large intestinal pH has been measured in several studies with horses. Figure 3 shows the effect of an all-hay meal or an all-concentrate meal on cecal pH in horses (Willard, 1975). A similar response was reported by Goodson et al. (1985). A reduction pH can have many potential effects on gastrointestinal function. Clark (1990) compared the effect of large concentrate meals in horses to the effects observed in cattle which include damage to the rumen epithelium and a reduction in rumen muscle tone.

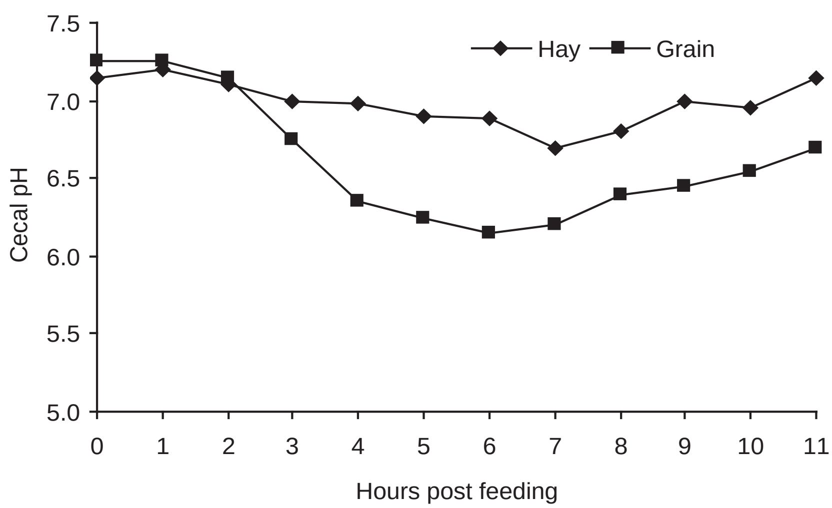

Figure 3. Changes in cecal pH following a meal of hay or a meal of grain (Willard, 1975).

Although the most marked effects of concentrate feeding are observed with the rapid, sudden consumption of large amounts of rapidly fermentable feeds, it is possible that a subacute acidosis may also occur in animals fed a high concentrate diet on a daily basis. In subacute ruminant acidosis, animals frequently exhibit inappetence, reduced weight gain, and reduced feed efficiency. Although subacute acidosis has not been widely recognized in horses, poor appetite is a condition reported in intensely exercised horses and horses receiving large amounts of grain (Ralston, 1992). Southwood et al. (1993) have reported that failure of horses to maintain feed intake is perceived as an important problem in racing stables. According to Owens (1993), the greatest potential to disturb the rumen environment occurs when animals are fed high concentrate diets at infrequent intervals (such as two times per day) and at high rates of feed intake. These characteristics would describe the feeding situation for many intensely exercised performance horses.

In addition to affecting gastrointestinal health, low large intestinal pH may affect digestive efficiency. In ruminants low pH can impair fiber digestion. Low pH may impair the attachment of microbes to cellulose and affect the ability of cellulolytic organisms to thrive, thus altering capacity for fiber digestion (Owens, 1993). In lactating dairy cows, 48 hour in situ neutral detergent fiber (NDF) digestibility was reduced from 51.3% to 36.9% for grass hay and from 49% to 37.2% for alfalfa hay (Krajcarski-Hunt et al., 2002). If a similar response occurred in horses, the effect on the amount of DE available from hay could be significant.

A few studies have examined the effect of forage:concentrate ratios on fiber digestibility in horses. Moore and Dehority (1993) did not find a difference in cellulose digestibility between an all-hay diet and a diet containing 60% hay and 40% concentrate fed to ponies at 1.5% of body weight. Hintz et al. (1971) compared nutrient disappearance from different segments of the gastrointestinal tract in ponies fed diets with varying forage:concentrate ratios. Diets were offered in isocaloric amounts so that the all-hay diet was fed at 2.1% of body weight and the 20% hay:80% concentrate diet was offered at 1.65% of body weight. Animals were slaughtered at 4 hours post-feeding and nutrient digestibilities determined using chromic oxide as a marker. In this study, increasing the amount of concentrate in the diet did not decrease fiber digestibility. However, in a study by Thompson (1982) where digestibility was measured using total fecal collections, fiber digestibility decreased with increasing concentrate intake. Cellulose and ADF digestibility were not decreased by changing the diet from all hay to 60% hay and 40% concentrate, but decreased digestibility of both components was noted when the concentrate portion of the diet was 60 or 80% of the total. Although feeding 80% of the total diet as concentrate may seem extreme, the horses in this study were consuming approximately 4.5 kg of grain per day (about 1% of BW), which is not unlike grain intakes reported for racehorses. Based on the results of these studies, it appears that diets containing large amounts of concentrate may depress the ability of horses to digest dietary fiber. It can be theorized that when large concentrate meals are fed, some NSC escapes small intestinal digestion and is fermented in the large intestine. Not only is the energetic value of the NSC lowered through fermentation, but the effects of fermentation (lowered pH) may depress fiber digestibility, thus producing a further negative effect on the energetic value of the diet.

Summary

Intensely exercised horses require high dietary energy intakes to maintain body weight. Typically these energy needs are met by increasing grain intake and reducing hay intake. When grain intakes are not excessive, this strategy works well because of the increased energy density of grain as well as the increased efficiency of energy use from glucose. However, as grain intakes exceed the capacity of the small intestine for starch digestion and absorption, a situation of diminishing returns is reached. These diminishing returns include a reduction in the amount of net energy derived from each unit of grain consumed and a potential decrease in fiber digestion. Observations in ruminants suggest that high concentrate intakes can produce a subacute acidosis that results in decreased feed intake as well as decreased feed efficiency. If a similar condition exists in horses, it could produce a situation where a horse is being fed more grain, but is still not maintaining body weight.

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