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Advances in Equine Nutrition

Volume I

Edited by

J.D. Pagan

PROTEIN REQUIREMENTS AND DIGESTIBILITY: A REVIEW

JOE D. PAGAN
Kentucky Equine Research Inc., Versailles, Kentucky, USA

After water, the major constituent of the horse's body is protein. Eighty percent of the horse's fat-free, moisture-free body composition is protein (Robb *et al.*, 1972). Protein is a predominant component of blood, muscles, organs and enzymes and it is a critical part of the horse's diet throughout its life. The age and use of the horse are the most important considerations in determining protein requirements. In addition, there are several other important factors concerning protein which should be evaluated when selecting a ration for a particular phase of a horse's life. Among the most important of these factors are the digestibility of the protein, the amino acid content of the protein, and the protein to energy ratio (PER) of the ration. These factors are especially important when considering the requirement of the young growing horse.

Protein digestibility

The first factor to consider when evaluating a source of protein for a horse ration is the digestibility of its protein. Unfortunately, the digestibility of the protein in many ingredients commonly used in horse feeds has not been adequately determined. The National Academy of Sciences (NRC 1989) recommended three regression equations for estimating the apparent digestibility of the crude protein content of horse diets. These equations take the form Y = (b)X + (a) where Y = digestible protein content; X = crude protein content; (b) estimates the true digestibility of protein; and (a) estimates the metabolic (obligatory) fecal excretion of protein from that source. The equation to be used for estimating protein digestibility of hay/concentrate diets was taken from a study by Slade *et al.* (1970) in which four different concentrations of protein were fed to horses. In this experiment, the diets consisted of fish meal, almond hulls, and oat hay. The resulting regression equation: DP% = 0.80 CP% - 3.3 had a large metabolic fecal component and only an 80% estimated true protein digestibility. These diets are hardly representative of what is commonly fed to horses and their low protein digestibility may have

been due to the high level of poorly fermentable fiber which these formulations contained (Glade, 1984).

In a series of studies using rations consisting of from 35 to 50% forage and 50 to 65% grain (Pagan, 1982; Pagan *et al*., 1986), protein digestibility was best described by the equation DP% = 0.86 CP% - 1.06. This equation has a much lower metabolic fecal component than the equations published by the NRC, but these diets were also fairly low in fiber (15-30% NDF). In a separate study using a diet which consisted of 75% alfalfa meal and 25% oats, Pagan (1985) measured nitrogen balance at various levels of protein intake. The crude protein requirement for mature geldings was calculated to be 1.30 g CP/kg BW/day. This would equal a requirement of 650 grams (1.44 lb) of CP per day for a 500 kg horse which is very close to the current NRC requirement for mature horses of this weight (656 g CP/day). The calculated digestible protein requirement, however, was 1.05 g CP/kg BW/day or 1.16 lb of digestible protein per day which was 0.52 lb/day higher than estimated by the NRC. The diet used in this experiment contained 17.0% CP and its digestible protein content averaged 13.0% in 12 digestion trials. The regression equation determined by Pagan (Pagan, 1982; Pagan *et al*., 1986) would estimate the DP% of this diet to be 13.6% while the regression equations listed by the NRC would have resulted in DP% estimates of 10 to 12%.

Other investigators have reported estimates for the DP% of grains of 94 to 96% (Glade, 1984) and of mixed hay-grain diets of 87 to 95% (Prior *et al*., 1974; Glade, 1984). A "working average" of 93% has been suggested (Glade, 1984). In any case, it appears that the NRC equations may underestimate the horse's ability to digest protein in common equine rations.

Protein quality

Many of the amino acids which make up the body protein of horses must be supplied in their diets. These amino acids are classified as being essential for growth and reproduction. Sources of feed protein which contain an assortment of amino acids which approximate the needs of the animal are considered of high quality (high biological value), while those which do not are considered low quality.

The amino acid most likely to be deficient in the diets of growing horses is lysine. A great deal of research has been done on the requirement for lysine by growing horses (Hintz, *et al*., 1971; Potter and Huchton, 1975; Ott *et al*., 1979; Ott *et al*., 1981). This research has shown that horses fed diets deficient in lysine will grow more slowly than horses fed a diet high in lysine, even if the crude protein percentages of the diets are identical.

Research at the University of Florida (Graham *et al*., 1993) suggest that the second limiting amino acid for growing horses may be threonine. Yearlings fed corn/oats/soybean meal diets along with coastal bermudagrass hay grew faster with additional

muscle gain when threonine was added to the concentrate at a level of 0.1% of the grain mix.

There are a number of different sources of supplemental protein which are commonly used in horse feeds. These include milk proteins, alfalfa meal, and a number of by-product meals made from the production of oils such as soybean meal, linseed meal, cottonseed meal, safflower meal, and sunflower meal. What is often overlooked, however, is the amount of protein and lysine which is supplied by the grain portion of a horse ration. Typically, the grain portion (corn, barley, oats, etc.) contributes about 40 to 50% of the total protein of a feed for growing horses. The amount of lysine supplied from these cereal grains, however, is only about 30 to 40% of the total, since cereal grains are fairly low in lysine. Therefore, the supplemental source of protein used in horse feeds should be high quality. Alfalfa, milk proteins, and soybean meal are all good sources of quality protein for growing horses. Protein supplements which are deficient in lysine include linseed meal, cottonseed meal, and peanut meal.

Protein to energy ratio

In addition to protein, the young growing horse has a requirement for energy in its diet. These requirements are closely linked and a deficiency of either will result in a reduced growth rate. In fact, protein and energy are so closely linked that one should not be considered without the other in rations for growing horses. In other words, it is the ratio of protein to energy that is important for growth rather than either the protein percentage in a ration or even the daily intake of protein, because it is the energy that provides the potential to grow new tissue that will then require protein.

If there is an excess of protein supplied with an inadequate amount of energy, the protein will be oxidized to produce energy. This is a very expensive way to supply energy, however, and it should be avoided whenever possible. Therefore, knowing the ideal protein to energy ratio will greatly increase the precision with which a horse ration can be balanced.

Growing horses

Weanling horses require 50 g CP/Mcal DE (NRC, 1989). The lysine content of weanling diets should be at least 2.1 g/Mcal DE. Yearling and long yearling horses require 45 g CP/Mcal DE and 1.9 g lysine/Mcal DE. Two year olds require 42.5 g CP/Mcal DE and 1.7 g lysine/Mcal DE.

The protein to energy ratio and lysine to energy ratio are only indirectly related to growth rate. It is the total energy intake which will influence how fast the young

horse will grow. Ott (1988) proposed an equation for calculating the DE requirements of yearling horses. This equation incorporates a maintenance energy requirement from the work of Pagan and Hintz (1986) and takes the form: DE (Mcal/day) = 1.4 + 0.03 (BW kg) + 16 (average daily gain (ADG) in kg). According to this equation, a 340 kg yearling would require 11.6 Mcal DE plus an additional 16 Mcal DE for each kg of body weight gained per day. An average Thoroughbred yearling would gain about 0.5 kg BW/day and would therefore require 11.6 + 8 = 19.6 Mcal DE per day. Similar equations can be developed for other ages by taking into account the efficiency of utilization of DE for gain by each age group. Energy requirements for weanlings can be calculated as: DE (Mcal/day) = 1.4 + 0.03 (BW kg) + 10 (ADG kg); and for long yearlings: DE (Mcal/day) = 1.4 + 0.03 (BW kg) + 20 (ADG kg).

A ration for yearlings might consist of 50% timothy hay and 50% grain mix. Since the protein to energy ratio of timothy equals 42.7 g CP/Mcal DE, the grain mix must contain 47.3 g CP/Mcal DE in order to average 45 CP/Mcal DE. Also, the grain must provide 1.93 g lysine/Mcal DE. A mix of 92% oats and 8% soybean meal will provide 47.3 g CP/Mcal DE and 1.97 g lysine/Mcal DE. Of course, this mix would also have to be balanced with the proper amount of minerals and vitamins, but it would provide the proper balance of protein and energy. The ration would contain 2.39 Mcal DE/kg and a yearling would therefore have to eat 8.2 kg (18 lb) per day in order to gain at a rate of 0.5 kg/day.

This method of formulation is superior to using a table listing the protein percentage required by each age group. Basing calculations of the protein requirement of young growing animals on the protein percentage in the diet assumes that the energy concentration of the total diet is constant. For example, the 1989 NRC states that a yearling would require a diet which contains 11.3% protein. This requirement assumes that the total diet contains 2.6 Mcal DE/kg. If the energy density of this diet were greatly different from this, then this concentration of protein would not be appropriate. Rations which are based largely on roughage have much lower energy densities and would therefore require a lower concentration of protein. At the other end of the spectrum are the high fat diets which are becoming more and more popular as diets for young growing horses. These diets have much higher energy densities than common horse rations, and would therefore require a greater protein percentage to obtain similar protein to energy ratios.

It has already been stated that if a diet has a higher than optimal protein to energy ratio then the extra protein will be broken down and used as an inefficient and expensive source of energy. But what happens if the diet has too low a protein to energy ratio? This type of ration will also be used inefficiently by the growing horse and result in a reduced feed to gain ratio. If the protein to energy ratio is a great deal lower than optimal, the young horse will quit eating altogether. Schryver *et al*. (1987) fed twenty-four weanling horses one of three diets which contained either 23.7 g CP/Mcal DE, 40.6 g CP/Mcal DE or 63.8 g CP/Mcal DE. The weanlings fed the low protein diet gained only .06 kg/day during the first five months of the experiment compared to 0.63 and 0.69 kg/day on the middle and high protein diets. The foals on the low

protein diet ate an average of only 2.7 kg/day compared to 4.4 and 4.7 kg/day on the middle and high protein diets, respectively. When these foals were faced with a very low protein to energy ratio they simply decreased feed intake and essentially quit growing altogether.

Often when veterinarians are faced with a case of epiphysitis or some other metabolic bone disease in young growing horses, they recommend that the foals be placed on a total hay diet or grass hay plus a 10% protein grain mix (Rossdale and Ricketts, 1980). The intention is to slow down growth rate which often will help the problem. However, this type of approach is probably not the best one to use. It would be preferable to feed less of a feed with a proper protein to energy ratio which has been balanced with the correct amounts of vitamins and minerals for a foal of that age.

Broodmares

One of the most important nutrients to consider when feeding the broodmare is protein. Both during pregnancy and lactation, the broodmare uses a large amount of protein for either fetal growth or milk production. Why does the broodmare require protein and how is the best way to supply it?

During pregnancy, fetal growth is very slow during the early months. By the end of the seventh month of pregnancy the fetus has only deposited 10% of its protein content at birth. In the last four months of pregnancy the fetus will deposit about 18 lb of protein as it grows to a birth weight of 120 lb. During the last month of pregnancy alone, the fetus will deposit over 6 lb of protein into its body. Since birth weight is dependent to a large degree on protein deposition, it is critically important that the pregnant mare be fed so that she can supply the growing fetus with an ample supply of protein.

Besides supplying the demand for fetal growth, the mare needs additional protein for other body functions and for the growth of the placenta and amniotic tissues surrounding the fetus. This protein must also be of high quality.

Usually a 13-16% concentrate feed is offered to pregnant mares. When this type of feed is fed at rates from 6 to 10 lb/day, it supplies plenty of protein for fetal growth, providing that it is made using quality sources of protein. Sometimes, however, pregnant mares don't need this much grain. In this case, it is best to feed the mare a more concentrated source of both protein and minerals. A 25-30% protein supplement pellet is excellent for this type of application. It should contain quality sources of protein along with plenty of vitamins and minerals to ensure optimal fetal growth and the birth of a big strong foal. 2 lb of this type of supplement can be fed in place of a regular broodmare feed when the mare doesn't need a bunch of extra calories.

Some people worry that a 25-30% protein supplement supplies too much protein for the mare. In reality, 2 lb of this type of supplement supplies the same amount of protein as 4 lb of a 15% protein feed. The protein from the supplement is of higher

quality since about 2/3 of the protein in the 15% concentrate comes from cereal grain and this protein is low in lysine. Substituting 2 lb of supplement for 6-8 lb of a grain mix actually supplies less total protein, but a similar amount of quality protein.

Lactating mares also require large amounts of quality protein. A lactating mare needs twice as much protein as a barren or early pregnant mare. She needs this much protein because mare's milk is high in protein, typically containing about 20-25% protein on a dry basis. A mare during peak lactation will secrete over 1 lb/day of protein in her milk. This milk protein is very high in lysine and the mare requires high quality protein in her diet to produce it. In fact, the surest way to decrease milk production in a mare is to restrict her protein intake. If energy only is restricted, the mare will use her body fat reserves to produce milk. Restricting protein in the diet will cause a decrease in milk production and foal growth.

Performance horses

The protein requirement of the mature performance horse is fairly low. The 1989 NRC estimated the requirement to be equal to 40 g CP/Mcal DE. This recommendation is probably too generous, since protein requirements don't increase as quickly as energy requirements in the performance horse. Lawrence (1992), however, suggested that higher quality protein in the equine athlete's diet may improve performance.

If the protein requirement of a performance horse exceeds its requirement, then the extra protein can used as a source of energy. The amino acids from this extra protein are broken down by the liver, and the nitrogen from the protein is excreted as ammonia. The carbon "skeletons" that are left can be oxidized to produce ATP or used to make glucose or fat.

Excessive protein intake should be avoided in the exercised horse for a number of reasons:

1) Water requirements increase with increased protein intake.
2) Urea levels increase in the blood leading to greater urea excretion into the gut, which may increase the risk of intestinal disturbances such as enterotoxemia.
3) Blood ammonia increases causing a number of problems such as nerve irritability and disturbances in carbohydrate metabolism.

Increased ammonia excretion in the urine may also lead to respiratory problems because of ammonia buildup in the stall.

Summary

Protein is required by all ages of horses, but the amount and quality required depends on the horse's age and physiological status. Young growing horses and broodmares need the most and best protein while performance horses require less protein. An evaluation of protein supplied from the horse's forage is necessary before correct protein supplementation is possible.

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