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J.D. Pagan

PROTEIN REQUIREMENTS OF EQUINE ATHLETES

LAURIE M. LAWRENCE
University of Kentucky, Lexington, Kentucky, USA

Protein catabolism as a fuel source during exercise

How much protein does an athlete require? This question has been pondered by athletes and trainers for decades, if not centuries. It has been suggested that the first support for eating high protein diets came from the work of von Liebig who stated that muscle protein provided the primary fuel for muscle contraction (Wilmore and Freund, 1986), but it appears that even early Greek athletes believed that adding meat to their diets would improve performance (Hickson and Wolinski, 1989). Subsequently, the use of protein as a fuel for exercise was discounted. For example, the 1978 NRC for horses states that exercise does not increase the protein requirement. There is little doubt that quantitatively, carbohydrate and fat are much more important fuels for exercise than protein. Nonetheless, recent studies suggest that some protein may be used during exercise, and that under certain situations, protein may contribute up to 15% of the energy utilized during exercise.

The evidence for the catabolism of protein during exercise comes from the observation of metabolic changes during exercise and from studies using radioisotope-labelled amino acids. When amino acids are used for energy, the carbon skeleton is combusted, but the amino group is not used for energy. Therefore, the amino group must be transported from muscle and then used for synthesis of non-essential amino acids or excreted as urea. Nitrogen is transported from muscle following a transamination reaction in which the amino group is removed from one amino acid and attached to pyruvate, forming alanine. The alanine is transported in the blood to the liver where the nitrogen can be used to form urea and the pyruvate is used for gluconeogenesis. Several studies have documented that plasma alanine concentrations increase with exercise in horses (Miller and Lawrence, 1988; Essen-Gustavsson, *et al*., 1991; Miller-Graber *et al*., 1991) indicating that some amino acid catabolism is occurring in equine muscle during exercise. In addition, plasma urea concentrations increase following long term exercise (Snow *et al*., 1982), which is another indication that protein catabolism is occurring during exercise. No studies have examined whether specific amino acids are preferentially catabolized during exercise in the horse; however, studies with humans and rats suggest that the branched chain amino acids, especially leucine, are most important (Young, 1986). Most amino acids in the body are contained in structural proteins, but there are some amino acids free in the plasma and there appear to be some liable proteins in the liver that could provide amino acids for energy production. In addition, exercise may make amino acids available by altering protein turnover, either by increasing protein degradation or decreasing protein synthesis (Booth and Watson, 1985).

Protein use for lean tissue accretion

Some athletes consume high protein diets in order to support changes in body composition, such as increased muscle or lean body mass. This practice is based on the assumption that individuals in training actually do increase lean body mass. In some cases, the absolute amount of lean body mass is not affected by training, although the percentage of the body that is lean mass may be increased. That is, training may result in a reduction in body fat, but not necessarily an increase in muscle mass. In humans, an increase in lean body mass will occur most commonly as a result of strength training. Wilmore and Freund (1986) indicate that weight lifters may experience periods of negative nitrogen balance during heavy training even when protein intakes are high. Effects of training on lean body mass are more likely to occur in the early phases of training and in young athletes that are growing and training simultaneously.

Table 1. DIETARY CRUDE PROTEIN REQUIREMENTS OF 500 KG WORKING HORSES FROM THE 1978 AND 1989 NRC.

Type of Work	*1978*	*1989*
None (maintenance)	630 grams	656 grams
Light	630 grams	820 grams
Moderate	630 grams	984 grams

Protein requirements of athletic horses

In 1978, the National Research Committee Subcommittee on Horse Nutrition indicated that a 500 kg horse in heavy work had the same protein requirement as a similar horse at maintenance, about 630 g of crude protein. Unfortunately, this recommendation was somewhat impractical because it is difficult to formulate palatable diets that meet a hard-working horse's energy needs without exceeding the protein requirement. In 1989 the crude protein recommendations for working horses were increased (Table 1). The NRC cites several reasons for increasing the crude protein requirement.

Horses may lose 1 to 1.5 g N/kg of sweat; thus heavy sweating horses might lose 5-7 g of nitrogen during exercise (Meyer 1987). Freeman *et al.*, (1988) reported that nitrogen retention increased with physical training in horses. In that study, nitrogen losses in sweat were not accounted for and thus the amount of retained nitrogen may have been overestimated; however, in either case it could be concluded that exercise increased the nitrogen requirement. Meyer (1987) indicates that an additional reason for increasing endogenous fecal nitrogen losses associated with the higher dry matter intake.

There is probably little controversy concerning the recommendation that regular exercise can elevate the dietary protein requirement of horses. However, there is still considerable discussion as to the extent of the elevation. The 1989 NRC recommendation for horses in hard (intense) work (1320 g) is more than double the 1978 recommendation. The 1989 NRC recommendations for work were arrived at by maintaining the same protein:calorie ratio in the diets for working horses as in the diets for adult horses at maintenance (40 g CP/Mcal DE). Meyer (1987) also suggests using the nutrient:calorie ratio as a guide to determining an adequate protein intake. While these recommendations provide a practical way to adjust protein intake for working horses, they are not necessarily accurate estimates of need. Studies that accurately estimate protein or amino acid requirements of horses in work have not been performed. Some estimate of the appropriateness of the NRC (1989) recommendations may be gained by comparing these recommendation to those made for human athletes. Several sources suggest that 1.0-1.5 g of protein per kilogram of body weight is sufficient for most human athletes (Young, 1986; Dohm, 1984; Wilmore and Freund, 1986). Only weight lifters in rigorous strength training may require more than 2 g of protein per kilogram of body weight (Wilmore and Freund, 1986). If these recommendations are applied to 500 kg horses, the protein requirement would be estimated to be between 500 g (at 1 g/kg BW) and 1000 g (at 2 g/kg BW) per day. These values are well below the crude protein recommendations for working horses; however the types of protein consumed by humans and the types of protein consumed by horses are considerably different. While horses frequently consume low quality protein from forages and cereal grains, humans consume high quality protein from animal sources. Once the differences in digestibility and quality of protein are accounted for, the recommendations for human and equine athletes become more comparable. No studies have been conducted to determine whether protein quality is important for equine athletes. However, in humans, it has been reported that 2.0 g of protein per kg BW from lower quality protein sources (vegetable and fish protein) could be replaced by 1.3 g of protein per kg BW from higher quality sources (meat) (Wilmore and Freund, 1986). Hickson and Wolinski (1989) suggest that the preference of early Greek athletes for meat in their diets may have been related to an improvement in protein quality over the more typical vegetarian diet of the time.

Will protein or amino acid supplementation benefit the equine athlete?

Several authors have reviewed the effects of protein supplementation on human athletes with the general conclusion being that protein supplementation (above 1.5 g/kg BW) has little observable benefit (Horstman 1972; Dohm 1984; Wilmore and Freund 1986; Young 1986 Hickson and Wolinski 1989). In horses, studies have typically found no positive effects of high dietary protein. In fact Patterson *et al.*, (1985) concluded that horses at medium or hard work had similar indices of protein status when they consumed isocaloric diets with protein intakes of 0.8 g CP/kg BW or 1.2 g CP/kg BW. However, the intensity of the actual training program in that study is somewhat difficult to interpret. The authors indicated that all horses lost weight while on the study, and the weight loss was greatest in the horses on the lowest protein diet. Furthermore, the horses on the higher protein diet recovered more easily when the horses performed a 1.6 km track test.

Several research experiments have examined the effects of dietary protein on metabolic responses to exercise (Miller *et al.*, 1988, Miller-Graber *et al.*, 1991[a,b]; Pagan *et al* 1987). In two of these studies, lactate accumulation during exercise was lower when horses received a diet containing a high level of protein (Miller *et al*., 1988; Pagan *et al*, 1987) but in a third study lactate accumulation was unaffected by dietary protein level (Miller-Graber, 1991[a]). Pagan *et al* reported that muscle glycogen was somewhat lower in horses receiving a high protein diet; Miller-Graber *et al* found no effect of protein level on muscle glycogen concentration. At this point, there are no solid research data to support the theory that protein supplementation may be beneficial to equine athletes. Even in the human area, benefits have only been sporadically reported, usually with weight lifters, for which the equine world has no real counterpart.

Because the branched-chain amino acids are the primary amino acids catabolized during exercise, researchers have also evaluated supplementation of these amino acids (especially leucine). Glade (1989) has reported that horses receiving a branched-chain amino acid supplement had lower lactate levels than unsupplemented horses; however, the lactate levels were so low (below the anaerobic threshold) and the work bout so mild (walking on an inclined treadmill) that the relevance of these results is questionable. Further research in this area is necessary before recommendations concerning positive benefits can be made.

Can a high protein diet negatively affect horses?

Although many trainers provide high dietary protein in an effort to improve performance there may be negative effects instead. Glade (1979) surveyed feeding practices in Thoroughbred race horses and found a positive correlation between race time and dietary protein intake; race time was increased by 1 to 3 seconds for every 1000 g of

CP ingested above the 1978 recommendation. Meyer (1987) indicates that digestible protein intakes above 2 g/kg BW should be avoided in endurance horses because of effects on water intake, urea and ammonia metabolism. Although an elevation in plasma ammonia level was not observed, Miller-Graber *et al.*, (1991[b]) found that exercising horses consuming 1741 g CP/d (> 3 g CP/kg BW) excreted more urea in sweat and had higher plasma urea levels than horses consuming 863 g of CP. In addition, these authors measured urinary orotic acid clearance. Orotic acid production increases when the urea cycle is impaired or when the capacity of the urea cycle to cope with excess nitrogen is overwhelmed. An increase in orotic acid production appeared to be present post-exercise in the horses consuming the high protein diet, suggesting that an intake of 1741 g of CP per day may have exceeded the capacity of the urea cycle. As noted previously, muscle glycogen levels may be affected by dietary protein level (Pagan *et al.*, 1987) which may be detrimental to some types of athletic endeavors. Another potentially deleterious effect of excessive protein intake is increased urinary nitrogen excretion. Meyer (1987) suggests that increased urinary nitrogen may contribute to increased aerial ammonia levels which could negatively impact on respiratory health.

Conclusion

The National Research Council (NRC) Subcommittee on Horse Nutrition increased the dietary crude protein allowance for working horses in 1989. The recommendations were based on some experimental information and practical considerations. Comparison of the recommendations for horses to those used for human athletes suggests that the NRC allowances are adequate. There is no evidence in either the human or equine research literature that protein supplementation above the recommended levels is beneficial to athletic performance. Some studies have suggested that high dietary protein intakes may have metabolic effects that would be deleterious to performance, but critical performance testing has not been conducted.

References

Booth FW and Watson PA. Control of adaptations in protein levels in response to exercise. Fed Proc 1985;44:2292.

Dohm, GL. Protein nutrition for the athlete. Clin Sports Med 1984;3(3):595.

Essen-Gutavsson B, Blomstrand E, Karlstrom K, *et al*. Influence of diet on substrate metabolism during exercise. Equine Ex Physiol 1991;3:288.

Freeman DW, Potter GD, Schelling GT, *et al*. Nitrogen metabolism in mature horses at varying levels of work. J Anim Sci 1988;66:407.

Glade MJ. Nutrition and performance of racing Thoroughbreds. Equine Vet J 1983;15:31.

Glade MJ. Effects of specific amino acid supplementation on lactic acid production by horses exercised on a treadmill. Proc Eleventh Equine Nutr Physiol Symp 1989:244.

Goodman MN and Ruderman NB. Influence of muscle use on amino acid metabolism. In, Terjung RL, (ed), Exercise and Sports Science Rev, Franklin Inst Press, Philadelphia 1982:1.

Hickson JF and Wolinski I. Human protein intake and metabolism in exercise and sport. In, Hickson JF, Wolinski I (ed), Nutrition in Exercise and Sport, CRC Press, Boca Raton 1989:5.

Horstman D. Nutrtion. In, Morgan WP (ed) Ergogenic Aids and Muscular Performance, Academic Press NY 1972:343.

Meyer H. Nutrition and the equine athlete. Equine Exer Physiol 1987;2:644.

Miller PA and Lawrence LM. The effect of dietary protein level on exercising horses. J Anim Sci 1988;66:2185.

Miller-Graber PA, Lawrence LM, Foreman JH *et al*. Dietary protein level and energy metabolism during treadmill exercise in horses. J Nutr 1991[a];121:1462.

Miller-Graber P, Lawrence L, Foreman J, *et al*. Effect of dietary protein level on nitrogen metabolites in exercised Quarter Horses. Equine Exer Physiol 1991[b];3:305.

NRC. Nutrient Requirements of Horses. National Academy Press, Washington DC 1978.

NRC. Nutrient Requirements of Horses. National Academy Press, Washington DC 1989.

Pagan JD, Essen-Gustavsson B, Lindholm A, and Thornton J. The effect of dietary energy source on exercise performance in Standardbred Horses. Equine Exer Physiol 1987;2:686.

Patterson PH, Coon CN and Hughes IM. Protein requirements of mature working horses. J Anim Sci 1985;61:187.

Snow DH, Kerr MG, Nimmo MA, and Abbot EM. Alterations in blood, sweat, urine and muscle composition during prolonged exercise in the horse. Vet Rec 1982;110:377.

Wilmore JH, and Freund BJ. Nutritional enhancement of athletic performance. In, Winnick, M (ed). Nutrition and Exercise. John Wiley & Sons, NY 1986:67.

Young V. Protein and amino acid metabolism in relation to physical exercise. In, Winnick, M (ed). Nutrition and Exercise. John Wiley and Sons, NY 1986:9.