Beating the Metabolic Pull
Part 3 - Energy balance

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In this final article in the series, we'll discuss the possible ways to increase energy during a ride without jeopardizing the overall health of the horse. At the risk of becoming tiresome, remember the order of priorities in protecting metabolic integrity--- hydration, gut motility; and only then, look to increase energy balance. Luckily, these issues are often so closely interrelated that attending to one issue often benefits all three.

Before discussing specific strategies, it's helpful to have a brief review of the energy substrates available to endurance horses (or any other equine athlete). There are essentially three "fuels" utilized during exercise; phosphocreatine, glucose and fats. All three function via different pathways to produce the same end product, adenosine triphosphate (ATP), the actual energy source that drives muscular contraction.

Of these three fuels, phosphocreatine is of the least importance to the endurance horse, and only worthy of brief mention. Think of PC as the "starter fuel" in the muscle cell---it is what will provide immediate energy for the first few seconds of exercise, until other fuel sources arrive in greater quantities for long-term exercise demands.

Glucose is intermediate in both its supply and speed of response during exercise. When molecules of readily-available glucose are stored in plantmaterial, it is referred to as starch, and when stored in the animal body, as *glycogen*. Because the storage of glycogen in the body requires both water and space, relatively little is stored in the body. Fats, on the other hand, are far more efficiently stored and so can be accumulated almost without limit (as some of us have discovered after the holidays). The advantage of utilizing glucose as an energy source is that it is more quickly available than are fats, and while it is most efficiently metabolized in the presence of oxygen, it does not require oxygen to produce energy. During intense exercise, the cardiovascular system of heart and lungs may be unable to supply sufficient oxygen to individual muscle cells. Under those circumstances, energy can continue to be produced for a short period by utilizing those pathways that do not require oxygen. These pathways are referred to as anaerobic, and utilizing them during exercise is referred to as passing an anaerobic threshold. Utilizing these pathways results in the accumulation of the metabolic by-product lactic acid, and thus, the "burn" felt in overworked muscles. This pathway is not meant for long-term exercise, as the accumulation of lactic acid and rapid depletion of cellular glucose stores quickly contributes to muscular fatigue. Therefore, the primary advantage to glucose as an energy source is its versatility in either the presence or absence of oxygen, and its speed in being quickly available on demand.

Fats are the fuel of greatest importance to the endurance athlete. While their utilization *absolutely requires* the presence of oxygen, and is not as quickly available as glucose or phosphocreatine, its supply within the body is almost unlimited in any horse in reasonable body condition. It has been calculated that the average 1100 pound horse has only 45 calories available within body stores in the form of phosphocreatine; approximately 18,000 calories available in the

form of glycogen; and approximately 153,000 in the form of fats. When you consider that an average horse carrying a lightweight rider will utilize more than 19,000 calories during a flat fifty-mile ride at an average speed of 8 mph, it becomes apparent that body stores of glycogen alone are insufficient to fuel the exercise demands of the day.

The disadvantages of fats as a fuel source are that they absolutely require the ongoing presence of oxygen within the cells to produce energy, and they are the slowest of the three sources to become available after the onset of exercise. A third feature, which may at times become a distinct disadvantage, is that while glycogen may be utilized by itself without any other substrate, fats require a small but critical amount of glycogen to produce energy---hence the saying, "fats burn on the flame of glycogen". To use an old analogy---think of glycogen as a smallish pile of fast-burning kindling, and fats as heavy, thick logs. While the logs will supply far more total heat, they cannot burn well without kindling. On the other hand, while kindling will burn rapidly and well, its relatively small supply will soon run out, leaving you without the wherewithal to burn the logs. Therefore, the key element in energy management is to rely on fats as the primary fuel source, and to conserve the limited supply of glycogen for "kindling" and for carefully planned spurts of anaerobic activity which may be necessary to reach your riding goals for the day.

Complex system that it is, the body is well adapted to utilizing the fuel most suited to the exercise at hand. At rest and during moderate exercise, with plenty of oxygen available, the body will utilize primarily fats, the fuel in greatest supply, with just enough glycogen being used as kindling to produce energy at its highest efficiency. As the intensity of exercise increases, as during a tough hill climb or a prolonged sprint, oxygen supplies may become insufficient and energy utilization shifts from the oxygen-using pathways, to those which do not require oxygen. Fats are utilized less and less, while glycogen becomes more and more important---so that at maximum intensity, the reliance on glycogen is approaching 100%. At this intensity of exercise, glycogen stores are rapidly depleted, and the accumulation of lactic acid greatly increased. As complete glycogen repletion may take several days, as well as the complete removal of accumulated lactic acid, an extreme exercise bout of this intensity is best left for either the flat-track racehorses, or if necessary, at the very end of an endurance ride. Once the system is pushed to this level of exhaustion, you had better be close to packing it in for the day!

Given the energetics of endurance horse metabolism, how do we put this to use during the riding season? One of the first ways is to utilize a high-fat diet. Although still the subject of research and heated debate, studies in exercising horses have demonstrated several clear metabolic benefits for endurance horses. Its most obvious benefit is that fats are the most concentrated source of calories available, and therefore of the most use in adding calories to an existing ration. Up to several cups of any type of good-quality vegetable oil (with the exception of linseed), or crystallized fat supplements such as FatPak, provide enough additional calories for most horses to maintain a good body condition.

Fats in the diet also have the benefit of decreasing heat production during digestion, thus lowering the heat which must be dissipated through sweat production by as much as 14%. Remember that proteins produce from 3-6 times the amount of metabolic waste heat as do carbohydrates or fats. By supplying calories in the form of fat, instead of protein, the amount of

metabolic heat that must be dissipated is decreased, thereby helping to product hydration throughout the day.

A further benefit is that horses adapted to a high-fat ration over an eleven week period (and it appears to take this long to reap the full effect) demonstrate a glycogen-sparing effect. Essentially, the body becomes more efficient at utilizing the fuel source in greatest supply (fats), and therefore is able to conserve the fuel supply most likely to run out (glucose). By doing so, horses under laboratory conditions were able to exercise for a longer period of time at a lower heart rate, with less lactic acid accumulation, than did horses maintained on a strictly high-grain or high-protein ration.

Does this mean that fats should be fed during an endurance ride? Common sense would say yes, but in reality, the answer is no. Remember that a horse in good body condition---ribs easily felt but not seen, and without jutting hip or pinbones---already has a plentiful supply of body fats onboard to fuel the day's work, even during 100-mile or multi-day rides. Remember also from lprevious discussions in this series that protecting gut motility is a higher priority than is energy balance, and providing bulkier feeds will maintain blood flow to the gut far better than will fats. Therefore, while adapting horses to a high fat ration between rides is an excellent strategy, withdraw the fats the night before in order to encourage forage intake. Utilize rice bran (which has a 20% fat content) as a condiment in mashes to increase palatability, rather than the majority of the meal. After the ride is over, return to including fats in the regular ration. Skipping fats for a few days during a multi-day will not put you back at ground zero in that eleven week adaptation period---simply start the fats again once you arrive back home.

Bottom line---strategies to maintain energy during a ride should be aimed towards protecting and maintaining an ample supply of glycogen, the kindling to burn all those available fats. At the risk of sounding preachy, one of the most obvious elements of your plan is to arrive with a well-conditioned horse. A large part of the physiological response to conditioning is the increase in efficiency of the muscular and cardiovascular system--- not only at delivering oxygen, but also storing glycogen and removing waste products. A horse with borderline conditioning is much more likely to slip over the anaerobic threshold, and use up available glycogen much more quickly than if he were truly fit for the job at hand.

In order to help protect glycogen stores, the first strategy is to start with a full load onboard. "Glycogen loading" has been explored and utilized in human marathon athletes, but seems to be relatively ineffective (and at times, risky) in horses, possibly because they are already evolved to store relatively large amounts of glycogen in muscle and liver tissue, compared to the inferior human athlete. Simply making sure that the glycogen stores are full, without attempting to overfill, is more than adequate. This can be done by slightly increasing the grain ration several days before the ride---an extra two or three pounds spread over several days is sufficient. If your horse is already consuming significant quantities of grain as part of his regular diet, then adding more is probably unnecessary. Decreasing the intensity of exercise for a day or two before the ride, as normally happens anyway, is enough. If it is part of your normal routine to go for a short ride after arriving at base camp, you can certainly continue to do so, but now is not the time to go haring off across the wilderness in a five mile sprint. An easy ride to loosen muscles will keep the glycogen stores where they belong in preparation for tomorrow.

Offering one more moderate meal of grain the evening before the start, along with plenty of free-choice hay and ideally, soaked beet pulp, will "top up" the onboard glycogen stores. Again, just a pound or two of grain will suffice---in order to protect hydration and motility first, the consumption of plenty of hay during the night will do more to produce a successful ride than will "just a little extra" grain.

Many riders are in the habit of providing a grain meal to their horses first thing in the morning, in order to have "plenty of energy during the day". Remember that wheat bran counts more as a grain than as a forage, although less so than do oats, corn or barley. The theory in feeding "breakfast" is that by maintaining high plasma glucose levels, glycogen stores will be spared for use later in the day. Again, common sense would say this is a good thing to do, but in reality, grain in the morning works against the production of energy. The starch content within grain is quickly broken down to simple sugars in the small intestine prior to absorption. As blood glucose rises, insulin is released from the pancreas to regulate and move the glucose into storage. The steeper the rise in glucose, the greater the insulin release and the more quickly glucose is moved from circulation and into storage. Plasma glucose levels quickly drop, not only back to baseline, but below previous levels. The net effect is that for several hours after a grain meal of several pounds or more, plasma glucose levels will quickly spike, and then decrease sharply, making glucose relatively unavailable as a fuel source until the system stabilizes. This phenomenon is called the *hypoglycemic rebound effect.*

At the same time, high plasma glucose and insulin levels have the effect of decreasing fat utilization, so that not only is glucose relatively unavailable, but so are fats. The result is a decrease in endurance and speed for several hours, directly opposite to the desired effect. By feeding the last grain meal no sooner than four to five hours before exercise begins, you are giving the body a chance to digest, absorb and stabilize glucose and insulin levels well before exercise demands begin. Not only will glucose be available in ample quantities, but so will fats very soon thereafter. Remember that excitement releases adrenaline, and adrenaline releases glucose. Most endurance horses will have no trouble whatsoever generating sufficient glucose during the first loop!

Can this hypoglycemic rebound effect occur during the ride as well? Absolutely. Research has indicated that any grain-based meal of several pounds or more, whether the grain consists of corn, barley, oats or sweet feed, has the same effect. Remember also from previous articles that large meals, spaced more than a few hours apart, also has a detrimental effect on fluid balance---a second reason to avoid large, sporadically spaced meals during ride day.

To avoid these effects, remember the rule of small and frequent---rather than grain only at vet checks, carry a small baggie or two of grain between vet checks to offer every hour or so. This not only will avoid swings in insulin and fluid balance, but will also provide a small, steady source of glucose throughout the day without decreasing the utilization of fats. The net effect is increased energy and better performance without jeopardizing the overall metabolic health of the horse. Remember that providing bulk as well throughout the day is the higher priority in maintaining hydration and motility, so include fresh green grass, hay or soaked beet pulp mash as well throughout the day as your ride plan allows.

A recent and controversial innovation is the use of carbohydrate supplements that can be syringed at intervals during a ride as a replacement or supplement for grain. To date, no published research studies have thoroughly investigated its use or effects on the endurance horse, and the only existing information is anecdotal. The theory behind its use is the same as that for grain, and the same caveats apply. Too much of *any* carbohydrate source at any one time can cause fluid shifts, hypoglycemic rebound, as well as the potential for colic or laminitis if greatly overused in a metabolically stressed horse. Poor results are by far most likely to result if carbohydrates are used as a replacement for proper and long-term conditioning, or in an effort to obtain performance beyond the current capabilities of the horse. Carbohydrates of any type will not only will **not** turn an exhausted, dehydrated horse into a winner, it can potentially turn a possible completion into a metabolic disaster if every other detail discussed in this series hasn't first been seen to. **Those who have done their conditioning homework and use carbohydrates thoughtfully in conjunction with a realistic and sensible ride plan, are by far to be most likely to garner a demonstrable benefit as "icing on the cake" without risk to the metabolic whole.**

To summarize the main strategies in this article:

1. Remember that glycogen is the fuel in shortest supply, and plan your ride strategy to conserve glycogen, staying primarily below the anaerobic threshold, while relying on fats as the primary fuel.
2. Maintain your horse on a high-fat ration in between rides, but avoid feeding fats on ride day.
3. Provide a "full tank" of glycogen by increasing the grain ration slightly for several days before the ride, with the last meal being no closer than 4-5 hours before the start.
4. Provide small, frequent amounts of grain along the trail every hour or two, avoiding large, sporadic meals, along with bulkier forages.
5. If used at all, utilize carbohydrate supplements as "icing on the cake", never as a replacement for doing your homework.