Risk and Reward

A research-based discussion on equine microbiota health implications and strategies.

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Introduction

With significant recent developments in microbiome research, it has been established that almost all non-genetic diseases originate in—or are affected by—the gastrointestinal (GI) tract. The bacteria, fungi, protozoans, and viruses that colonize the GI tract, collectively known as the microbiota, play a crucial role in both health and disease. The microbiota is involved in numerous biological processes such as regulation of immune homeostasis, various metabolic functions, synthesis of vitamins, nutrient uptake, and disease development and resistance. If the delicate balance in which the microbiota reside is disrupted, however, this symbiotic environment breaks down and a state of dysbiosis develops.

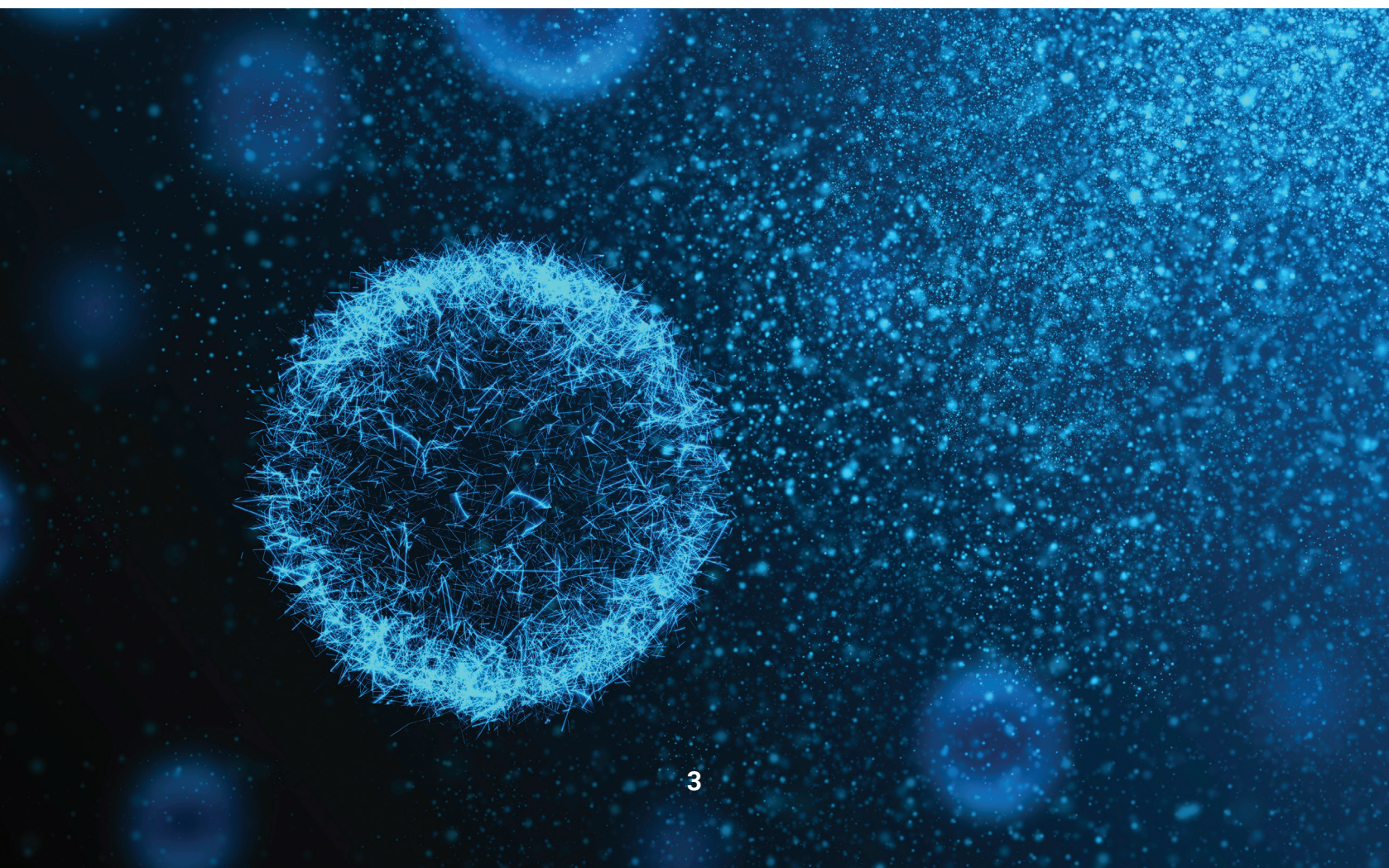
Dysbiosis is known to have broad-reaching effects intestinally and extra-intestinally. Digestive tract issues may include increased susceptibility to infection, local and systemic inflammatory reactions, and diminished nutrient uptake, among others. Non-GI tract effects may include respiratory and metabolic disease, and even obesity.

In the horse, primary manifestations of dysbiosis are typically identified within the GI tract itself presenting as gastric and colonic ulcers, diarrhea, colitis, colic, laminitis, and inflammatory bowel diseases. The exact etiology of these conditions remains not entirely understood, but the preponderance of evidence indicates that dysbiosis and the subsequent immune response may be largely causative.

Studies are now also indicating that dysbiosis can be associated with negative changes in behavior and brain function. It has become understood that the microbiota “communicates” with the central nervous system via a gut-brain axis, a finding which may have far-reaching implications for modulating anxiety, pain, mood, and thus performance, through targeting GI tract health.

Of course, the goal of every owner and rider is maintaining good health in their horses , not just remediating disease. Understanding how best to maintain a healthy GI tract is a crucial component of equine health.

Research into the gut microbiome is moving fast, and it can be hard to keep up. This article highlights some of the most important recent studies in this area—helping horse owners and riders better understand how the gut works, how it affects overall health and performance, and what you can do to support it through daily management and care.



The Role of the Microbiota

Sufficient energy required for maintenance, growth, metabolic processes, and ultimately, performance is derived from what the horse consumes. However, for dietary intake to be fully utilized the GI tract must be in a condition to optimally absorb and convert intake into energy.

The equine gastrointestinal microbiota predominately colonizes the large intestine where the fermentation of structural carbohydrates (fiber) contributes to the production of nutritionally beneficial short chain fatty acids (SCFAs). Not only do SCFAs help to shape the physiology of the GI tract but they are also used as an effective energy source for the horse and its microbiota. SCFAs provide 60 to 70 percent of a horse's energy.

The quality of the diet is not only important for energy production but must also provide the macro- and micronutrients necessary to maintain and support all the biological systems. The equine athlete places even greater demands on these nutritional needs. Further, GI tract health may be placed at greater risk through the feeding of the readily digestible carbohydrates that are often a staple of the performance horse diet. Unfortunately, this divergence from the horse's evolutionary roots can easily disturb the balance of intestinal microbiota and functioning of the GI tract.





The Principal Player in Digestion

The equine digestive system has evolved to derive most of the horse's nutritional needs from a plant-based, high-fiber diet. The structural carbohydrates which constitute this diet—cellulose, hemicellulose, pectin, and lignin—are all resistant to enzymatic digestion. Instead, they are fermented by the action of cellulolytic bacteria that colonize the cecum and colon of the horse. The bacterial population of the microbiota is vast, with up to a billion bacteria per ml of intestinal flora, and has been the focus of much research in the last decade or so. It is now understood that different types of bacteria perform different functions and colonize different areas within the intestine. There are two distinct microbiotas in the horse gut. The first is in the upper GI tract including the stomach, jejunum, and ileum, which displays a high inter-individual difference, possibly due to the variety of environmental bacteria in feed and forage. The microbiota of the lower GI tract, including the cecum and colon, is more consistent between horses, likely due to the need for reliable fermentation.

The variations in the distribution and diversity between individuals helps to explain why some horses may be more predisposed to GI tract disturbances than others. Indeed, some types of bacteria are found to be more prevalent in colic-prone horses, and laminitis is specifically linked to greater populations of streptococcus bacteria.

The equine intestinal microbiota can adapt and change in response to many factors including different types of feed, forage, and drug administration, and may even be influenced by the season, geographical location, and climate. These changes can be beneficial or detrimental depending on the type of change and the speed of its implementation, but the ability of the microbiota to modulate its diversity to cope with environmental changes can help the horse adapt to a range of pressures and ecologies. In essence, the microbiota helps to buffer the gap between internal and external conditions and has likely played a significant role in the success of the species.

Protection From Pathogens

One feature of the microbiota that is becoming more well understood is the crucial role it plays as a defense against pathogens.

While various species are known to change and adapt slowly over time, pathogenic bacteria can evolve rapidly, sometimes within just a few hours, in response to environmental pressures. By cultivating its own swiftly adapting microbes in response, the horse can fight off even completely novel pathogens. Thus the microbiota, not the immune system per se, is the first bastion of defense against infectious agents. It performs this task by secreting bacteriocins to kill or inhibit the growth of pathogenic bacteria, as well as simply outcompeting pathogens for resources. Once a healthy core microbiota is established, it is tough to dislodge.

Gut Repair

The short-chain fatty acids butyrate, propionate, and acetate, all produced from the fermentation of forage, play important roles. First, they are instrumental in the production of energy. They are also intrinsically linked to multiple beneficial effects on the horse's general health.

Integrity of the gut lining is influenced by the actions of butyrate, which has been identified as playing a key role in gut barrier function by improving the tight junctions between epithelial cells and stimulating mucin production. These natural defensive mechanisms keep the gut in optimal shape but also help to reduce the likelihood of illness by resisting pathogenic infiltration.

Propionate is used as a substrate for gluconeogenesis in the liver. This process produces a substantial amount of glucose which helps to maintain glucose homeostasis and has also been implicated in possible benefits to cardiovascular health. Finally, acetate is thought to stimulate immune response as the first line of defense on the mucosal surface of the intestinal tract.



Overall Physical and Mental Health

As a hindgut fermenter, the horse is entirely reliant on its symbiotic relationship with its intestinal microbiota. The health and correct functioning of the microbiota are vital for nutrient absorption, immune function, and numerous biological processes. Often overlooked, however, is the impact intestinal health has on behavior, temperament, and cognitive functioning, with dysbiosis increasingly being identified with mood disorders, anxiety, and depression.

The gut-brain axis responsible for this link represents an exciting new area of research. Complex pathways of the endocrine, neural, metabolic, and immune systems are all involved in the association between the microbiota and the brain. In the pursuit of peak health and performance, the mental health of the horse is just as important as its physical health, and essential to its willingness to train and perform.

Developing the Microbiota

Foals are initially colonized with bacteria at birth via the birth canal, a rich source of microbes. The vaginal bacteria are a mix of gut and skin microbes including *Lactobacillus* and *Enterococcus* species (Fraga et al., 2008), although the composition changes during pregnancy to favor *Lactobacillus*, which creates an acidic environment unfavorable to pathogens. The vaginal microbiota can be influenced by the gut bacteria, as demonstrated in studies where oral probiotics remodel the vaginal microbiota (Garcia-Velasco et al., 2017). Antibiotic usage may also affect the balance of the vaginal microbiota, allowing pathogens to dominate, negatively affecting both the mare and the foal. Thus, the condition of the gut microbiota can have a direct impact on reproductive health.

Recent research has found that many of the complex oligosaccharides contained in milk and colostrum are indigestible by the offspring. They can only be processed by specific bacteria, notably *Lactobacillus* and *Bifidobacteria* species. Although it has long been assumed that milk was largely sterile, these milk-sugar-consuming probiotics have been found in the milk of all mammals studied so far. As well as fermenting milk sugars, these bacteria also protect against pathogenic species that are unable to proliferate in such acidic conditions (Costa et al., 2016; Czyżak-Runowska et al., 2018).

Along with these beneficial bacteria, milk contains a variety of immunoglobulins designed to kill pathogens (Quercia et al., 2018). These immunoglobulins reflect the dam's history of bacterial exposure and serve to prime the foal's immune system. These immunoglobulins are thought to be transferred via lymphatic mononuclear cells from the gut to the milk ducts, once again highlighting the importance of good gut health to reproductive success (Perez et al., 2007).

During birth, the foal is often exposed to maternal fecal matter, which introduces a further source of microbial diversity. In addition to this accidental exposure, many foals also actively engage in coprophagy, purposely consuming their mother's feces as a way to kick-start their microbiota.

This period of development engages the foal's immune system, training it to accept these beginner commensals. The microbiota induces a mix of T-cells and T-regulatory cells that will stay with the horse for life, protecting it against pathogens while simultaneously preventing immune reactions against beneficial bacteria.

As the foal starts to graze, its starter microbiota gives way to an adult-looking microbiota, but still remains unique to that individual.

The Gut-Brain Axis

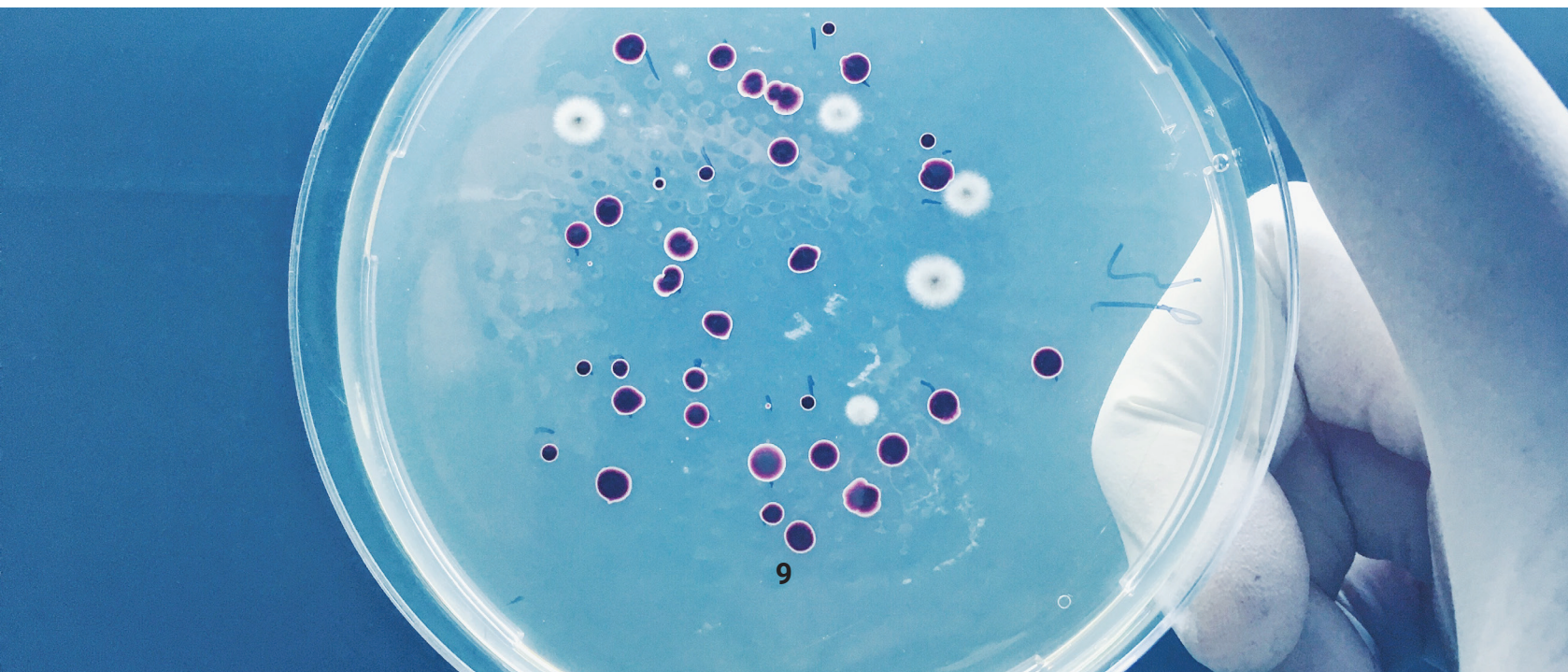
In most animals studied, this early growth period also coincides with brain development. Studies with germ-free animals have shown that a healthy microbiota encourages the expression of brain-derived neurotrophic factor (BDNF) which helps to boost populations of neurons and the growth of synapses in the hippocampus and amygdala (Heijtz et al., 2011). In other words, a healthy microbiota is essential to proper brain development and, ultimately, behavior (Hsiao et al., 2018).

The equine microbiota is in communication with the brain via immune cytokines, stress hormones, bacterial metabolites, and directly via the vagus nerve. Surprisingly, bacteria can produce neurotransmitters, including serotonin, dopamine, and GABA, that may have an indirect effect on gut signaling and brain function.

Microbiota, Disease and Acidosis

Horses have evolved as trickle feeders, a strategy that serves to maximize nutritional intake from a diet of generally low-quality forage. Yet, this natural lifestyle is at odds with the feeding and husbandry of the modern performance horse. By contrast, equine athletes are fed a diet supplemented with energy-dense feed (simple, nonstructural carbohydrates) which is often provided on an intermittent basis. Unfortunately, this type of diet, particularly if compounded by poor digestion, perhaps due to feed size or rapid ingestion, can represent a significant risk for dysbiosis.

In these horses, simple, nonstructural carbohydrates that are poorly digested throughout the small intestine may reach the large intestine where they may cause an increase in the growth of lactic-acid-producing bacteria and a corresponding loss of commensal bacteria. These events can lead to the production of toxins and can reduce the pH of the hindgut, making it more acidic than it should be (Julliand et al., 2001). This condition is known as “hindgut acidosis.” This series of events, starting with the feeding of processed feed and leading to acidosis, causes further beneficial bacteria to die, perpetuating a vicious cycle (Richards et al., 2006). The harmful endotoxins produced as a result can enter the vascular system and create systemic problems such as starch-induced laminitis, colonic ulcers, and tying up (Milinovich et al., 2006). These toxins can also damage the tissue lining the hindgut, resulting in areas of ulceration.



Leaky Gut

The gut is lined by enterocytes, joined together by complex proteins that create what are called “tight junctions.” This arrangement allows nutrients to be absorbed while simultaneously preventing bacteria and toxins from entering the bloodstream.

When the microbiota is disturbed, these tight junctions can be disrupted, leading to increased permeability and infiltration from endotoxins, pathogens, antigens, and hydrolytic enzymes. This condition is commonly referred to as “leaky gut syndrome” and can elicit both acute and chronic symptoms ranging from weight loss and poor performance in mild cases, to inflammatory bowel diseases (IBD), systemic inflammatory response syndrome (SIRS), multiple organ dysfunction syndrome (MODS), or even death, in severe cases.

Stress

As flight animals, horses are particularly susceptible to the negative effects of stress. Environmental challenges activate the hypothalamus, pituitary, and adrenal glands (HPA) which stimulate the release of adrenaline and glucocorticoids in preparation for the horse’s “fight or flight” reaction.

Evolution has honed a system that uses all the horse’s energy to run from a predator, effectively placing the immune system temporarily on hold. Thus, in times of acute stress, the horse’s immune system suppresses cytokine activity, preserving energy for the “flight.” However, when stress becomes chronic, the stress hormone cortisol plays a key role in disrupting the microbiota of the hindgut. Prolonged cortisol circulation can modify the diversity of the bacterial population which, in turn, can limit proper immune response, affect gut motility, reduce the integrity of the gut lining, and inhibit effective cellular turnover and repair.





This also creates an increased vulnerability to pathogenic infection and may promote the growth of pathogenic bacteria.

Some unusual sources of stress—in the form of maternal separation, restraint, crowding, and even noise—also exert an immediate impact on the hind gut microbiota (Bailey, 2014). In a powerful feedback loop, those hindgut changes lead to further stress and more behavioral problems.

In short, modern husbandry and feeding are causative of most hindgut dysbiosis. These risks can be reduced by striving to mirror the horse's natural behavior and diet as much as is practically possible.

Colic

Colic remains the leading medical reason for death in the horse, and while a cause cannot be identified in all cases, it can be agreed that some will be attributed to a disruption of the hindgut microbiota. Changes in diet or management routine are a prime risk factor, creating imbalances between the beneficial and harmful bacteria of the hindgut and alterations to gut motility, which can easily lead to gaseous or spasmodic colics and impactions.

Many colics, like torsions, sand colic, and strangulations, have physical causes that are likely to be unrelated to the microbiota. But for the rest, dysbiosis may play a primary role. Research is ongoing to uncover more about the different etiologies of colic and how best to treat and avoid the conditions associated with this ubiquitous health risk.

Laminitis

It has been well established that laminitis can be triggered by a sudden increase in dietary starch. This directly affects the hindgut by lowering the pH and changing the composition of the microbiota (Biddle et al., 2013).

Studies of equine DNA using Polymerase Chain Reaction (PCR) have found a significant difference in the microbiota of horses with laminitis versus controls. *Verrucomicrobia* species are elevated in laminitis while *Firmicutes* is diminished. The most abundant bacteria in laminitic horses included *Streptococcus*, *Clostridium*, and *Treponema* (Steelman et al., 2012). *Streptococcus equinus* was found to be consistently elevated immediately before the onset of laminitis (Milinovich et al., 2007).

Clinical evaluation of the hindgut microbiota has many benefits and such assessments are now even commercially available. By identifying those horses most at risk, steps may be taken to minimize the possibility of disease developing.

Colitis

PCR analysis of horses with colitis shows a significant difference in the microbiota. In a healthy horse, *Firmicutes* is the predominant species (68%), followed by *Bacteroidetes* (14%) and then *Proteobacteria* (10%). Healthy horses have abundant members of the *Clostridia* class as well. Although some species of *Clostridia*, especially *C. difficile* and *C. perfringens*, are well known to be detrimental to health, the vast majority of *Clostridia* species are commensal.

However, in horses with colitis, *Bacteroidetes* is the most predominant species (40%), followed by *Firmicutes* (30%) and *Proteobacteria* (18%). These horses also had significantly greater numbers of *Fusobacteria* (Costa et al., 2012). Hindgut dysbiosis is likely to be significant within the etiology of colitis.

Obesity and Insulin Resistance

Obesity and insulin resistance represent metabolic disturbances in the horse and are risk factors for laminitis. Diet plays a role, as does the microbiota, and studies have found that supplementation with certain prebiotics, particularly short-chain fructo-oligosaccharides, can improve insulin sensitivity in these horses (Respondek et al., 2011).

Fecal transplantation studies with mice have demonstrated a causal role for microbes in obesity. More specifically, the obese phenotype has been shown to be transmissible with microbiota. When fecal matter from an obese mouse is transferred to a germ-free mouse,

obesity is later observed in the recipient mouse. Conversely, transferring feces from a lean mouse is associated with leanness in the recipient mouse (Ellekilde et al., 2014). Similar studies have shown that a transferred microbiota can also improve symptoms of metabolic syndrome (Kulecka et al., 2016).

Obesity can be induced by overfeeding, of course, but these studies show that the composition of the microbiota is also significant.

The Microbiota Affects Performance

Horse owners and trainers know that a horse can signal discomfort by cribbing, biting, or kicking. These problematic behaviors are associated with specific microbes found in the horse's microbiota.

The connection between gut microbes and the brain is called the gut-brain axis, and it explains how an unbalanced microbiota can affect the mood of the horse and thus its performance. It is a two-way communication: stress can promote microbial imbalance, and that imbalance can promote anxiety. Those stressors can include changes in training, travelling, competing, stabling and diet. If the stress continues, pathogens can breach the gut lining and cause inflammation.

Exercise and stress play important roles in the health of the gut microbiota, but the main variation in microbiota is due to diet. That variation is important: the microbiota can contribute more to performance than genetics. Intervening to rebalance the gut microbiota with diet and supplements can improve these behaviors and potentially improve performance.





Colonic Ulcers

A colonic ulcer is a thinness, depression, or lesion in the lining of the colon, typically with associated edematous tissue. Studies by Pellegrini have shown over the years that colonic ulcers are real and prevalent (Pellegrini, 2005). Colonic ulcers are likely to have a bacterial association, as we know that dysbiosis can lead to gut permeability and cell death, obvious precursors to ulceration.

In human medicine, colonic ulcers are known to have multiple causes, including genetics and the host immune system. But studies are also revealing a connection to the microbiota, and fecal transplants are now proving to be of some use in alleviating these conditions (Shen et al., 2018).

Recurrence of Problems

Treating the symptoms of dysbiosis without addressing the underlying cause will frequently lead to recurrence.

This can be detrimental not just from a welfare issue but also in terms of the vet-client relationship. Unfortunately, the chronic stress that a horse may experience in these scenarios can lead to additional health issues, such as colic and laminitis. Complete resolution can only be achieved when a diagnosis and treatment are thorough and comprehensive.

Reduced Performance

Supplementing the diet with nonstructural carbohydrates to meet energy demands without inducing dysbiosis can be a difficult task. The microbiota is central to health, both physically and mentally, and any disruption can be detrimental to the performance of the horse.

Expectations of a horse's performance are typically based on its physical strength or dexterity, but the attitude and temperament of the horse are just as important. The microbiota can affect all these aspects through many channels, including hormones, immune cytokines, the vagus nerve, and gene expression (Richards et al., 2018).



Treatment and Prevention

To achieve and maintain a healthy microbiota in a horse, good husbandry is pivotal. However, for the performance horse facing constant management and nutritional challenges, further support is increasingly necessary.

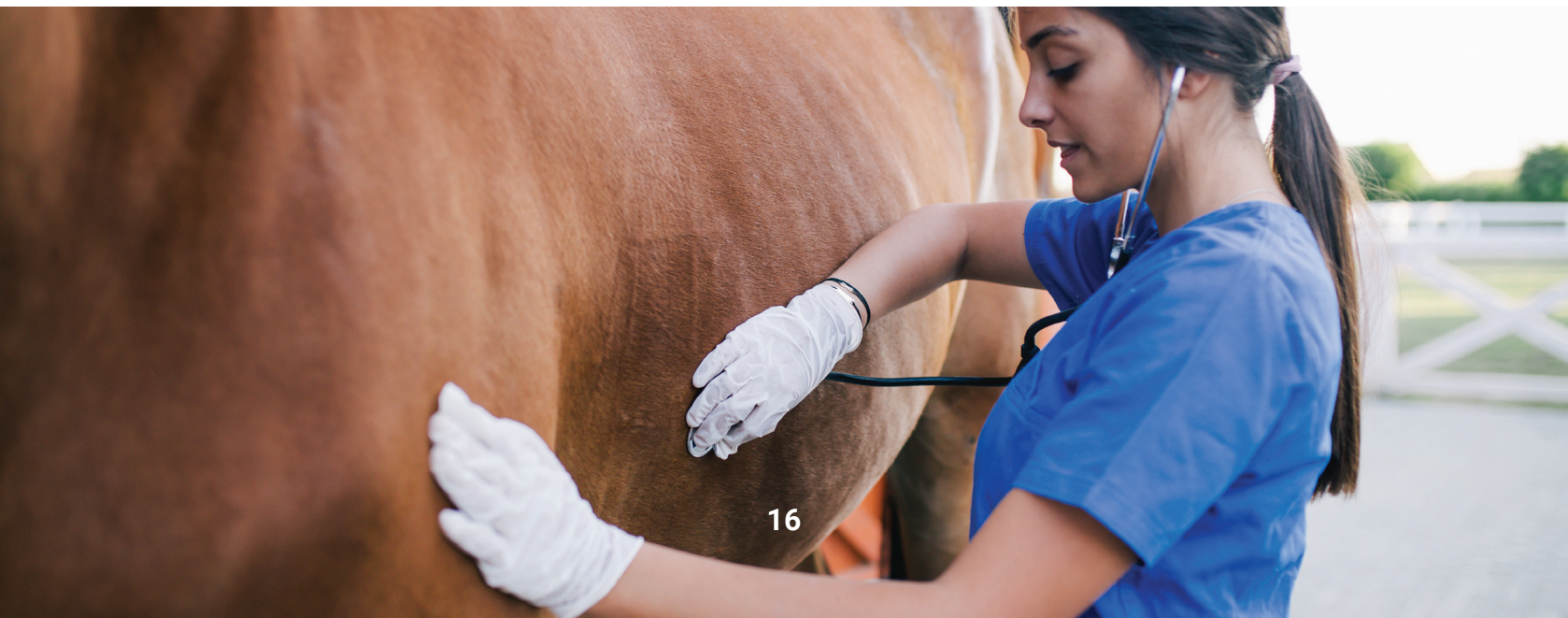
Reduce Stress

It is well accepted that horses prefer a consistent management routine within a low stress environment and don't always cope well with changes.

Moving the horse into a stable from pasture, transporting them to events, or changing their diet, creates stress. Stress causes the release of corticosteroids like glucocorticoid. Chronically elevated glucocorticoid levels are associated with decreases in tight-junction proteins, which increases gut permeability and, as noted, systemic inflammation (Zheng et al., 2017).

Stressors for a horse include:

- changes in feed type, volume, or frequency
- intense training
- transportation
- changes in stabling routine
- performance, including training and competition





By introducing and implementing changes gradually, the risks to GI tract health often associated with these stressors can be reduced, perhaps significantly. Ensuring that the horse is optimally supported inside and out is key to maintaining health both physically and mentally.

Better Feeding

One of the most significant risks in the development of gut dysbiosis is diet-related. The increased energy demands of the competition horse are frequently supplied by adding energy-dense starches and sugars to the ration. But as mentioned, the equine GI tract is poorly equipped to digest them.

Reducing feed volume and providing energy-dense feeds in smaller servings more frequently can improve digestibility, particularly when accompanied by free choice forage. Changes to any feed ration must be made gradually to allow the microbiota to adapt.

Hay provides roughage and prebiotics to the intestinal microbiota and encourages the growth of beneficial fiber-fermenting bacteria. It has been suggested that for colic-prone horses lowering the overall bulk of feeding—preferring soaked alfalfa cubes, beet pulp, or a complete feed that includes sufficient fiber—can be highly beneficial. Supplementing the diet with an oil containing anti-inflammatory omega-3 fatty acids, such as flaxseed oil, can help to reduce inflammation and promote tissue repair.

Some nutritional supplements can also help. The amino acidArginine can help to promote good blood supply to tissues for optimal cell turnover, replenishment and repair. . Threonine can help to rebuild the mucus layer, enhancing the natural defensive mechanisms of the GI tract lining, and prebiotics, such as mannan-oligosaccharide (MOS) and beta glucan, can help to support the growth of beneficial bacteria for maximizing fiber digestion and nutrient uptake.

Pasturing

Horses are nomadic trickle feeders and benefit from free pasture time, mirroring both their natural behavior and diet.

The continuous intake of roughage that grazing provides helps to buffer gastric acidity by creating a fiber mat within the lower portion of the stomach. It also supports optimal health of the hindgut microbiota, with a steady supply of structural carbohydrates for both nutrients and energy.

The Equine Microbiome Project (EMP) is a pioneer in microbiome research and has conducted an interesting study with data collected from 184 horses. Using PCR analysis, each of their fecal microbiotas was sequenced, demonstrating differences between pasture-fed horses and hay/concentrate-fed horses. Pastured horses had an abundance of *Christensenella*, *Oscillospira*, and *Prevotella*, while concentrate-fed horses favored *Streptococcus* and *Lactobacillus* which are strongly associated with gastric and laminitic conditions.

These functional differences in microbiota are likely to play a significant role in many digestive disorders.

Fecal Microbial Transplant (Transfaunation)

Fecal microbial transplant (FMT) has been extremely successful in treating persistent *Clostridium difficile* in human medicine. Unfortunately, though frequently necessary, antibiotic use can easily disrupt the delicate microbiota by targeting a broad spectrum of bacteria. Sporulating species such as *C. difficile* can often resist antibiotic treatment, making it particularly difficult to resolve. FMT has been used very successfully in treating *C. difficile* in humans and, with a 90 percent success rate, the technique has crossed over into veterinary medicine. Horses can also suffer from *C. difficile* and other microbial infections, manifesting as enterocolitis, inflammatory bowel disease, and chronic diarrhea. Interest in using FMT to treat these conditions is growing.

During FMT, fecal matter from a healthy, dewormed horse is liquefied and filtered before being introduced via a nasogastric tube into the stomach of the diseased horse. While reports suggest that it may be of benefit, further research is warranted to establish efficacy, indications, preparation, and delivery (Mullen et al., 2018).

Probiotics

Probiotics are live beneficial bacteria, and supplementation to support gut health in horses is a controversial area of gastrointestinal medicine. Research has remained inconclusive despite good reports within human medicine, and benefits for the equine GI tract are questionable.

In the US, supplement manufacturers have no obligation to test their products, and many probiotic formulas are not created under good manufacturing practices (GMP). Studies have shown that many probiotic supplements are inadequately labeled, the CFU (colony-forming unit) counts are often incorrect, and the viability of the probiotics post-gastric digestion is queried. Further research is necessary, but to date there is minimal proof that probiotics are a useful addition to the equine diet (Schoster et al., 2014).

Prebiotics

Prebiotics provide a food source for the commensal microbes already established in the gut. These include oligosaccharides, named after the key sugar, including fructo-oligosaccharides (FOS), galacto-oligosaccharides (GOS), mannan-oligosaccharides (MOS), and others. The category also includes longer chain and branched sugars, such as beta glucan.

Studies have shown more promise for the use of prebiotics, and viability is less of an issue compared to probiotics. Thus, prebiotics may be more beneficial to GI tract health than probiotics.



Conclusion

Good for horses

Supporting your horse's gut health with the right diet and targeted nutritional support can help reduce the risk of issues like colonic ulcers, laminitis, and colic. A healthy hindgut helps your horse feel and perform at their best—physically and mentally. When the gut microbiome is stable, horses often show improved condition, willingness to work, and a more relaxed attitude.

Good for owners

Gut health problems can be stressful, expensive, and upsetting—especially when they affect your horse's wellbeing, performance, or routine. By putting the microbiome at the heart of your feeding and management decisions, you're giving your horse the best chance of staying healthy, happy, and competition-ready.

Good for everyone

Prevention is always better than cure. By learning how to support a healthy gut and avoid common pitfalls that disrupt it, owners and riders can make smarter day-to-day choices that lead to fewer problems down the line. A happy gut really can make a huge difference.

References

Bailey, M.T., 2014. Influence of stressor-induced nervous system activation on the intestinal microbiota and the importance for immunomodulation. In: Lyte, M., Cryan, J. (Eds.), Microbial endocrinology: the microbiota-gut-brain axis in health and disease. Advances in experimental medicine and biology (vol. 817), Springer, New York, NY, pp. 255–276. doi: 10.1007/978-1-4939-0897-4_12.

Berg, J., Chambers, B., Siegel, H., & Biddle, A.S., 2017. Equine microbiome project: understanding differences in the horse gut microbiome related to diet. J. Equine Vet. Sci. 52, 94.

Biddle, A.S., Black, S.J., & Blanchard, J.L., 2013. An in vitro model of the horse gut microbiome enables identification of lactate-utilizing bacteria that differentially respond to starch induction. PLoS ONE, 8 (10), e77599.

Costa, M., Arroyo, L., Allen-Vercoe, E., Stämpfli, H., Kim, P., Sturgeon, A., & Weese, J., 2012. Comparison of the fecal microbiota of healthy horses and horses with colitis by high throughput sequencing of the V3-V5 region of the 16S rRNA gene. PLoS ONE, 7 (7), e41484.

Costa, M., Stämpfli, H., Allen-Vercoe, E., & Weese, J., 2015. Development of the faecal microbiota in foals. Equine Vet. J. 48 (6), 681–688.

Czyżak-Runowska, G., Wójtowski, J., Niewiadomska, A., & Markiewicz-Keszycka, M., 2018. Quality of fresh and stored mares' milk. Mljekarstvo 68 (2), 108–115. doi: 10.15567/mljekarstvo.2018.0204.

Daly, K., Proudman, C., Duncan, S., Flint, H., Dyer, J., & Shirazi-Beechey, S., 2011. Alterations in microbiota and fermentation products in equine large intestine in response to dietary variation and intestinal disease. Brit. J. Nutr. 107 (7), 989–995.

Ellekilde, M., Selfjord, E., Larsen, C., Jakesevic, M., Rune, I., Tranberg, B., Vogensen, F., Nielsen, D., Bahl, M., Licht, T., et al., 2014. Transfer of gut microbiota from lean and obese mice to antibiotic-treated mice. Sci. Rep.-UK 4 (1), 5922. doi: 10.1038/srep05922.

Fraga, M., Perelmuter, K., Delucchi, L., Cidade, E., & Zunino, P., 2007. Vaginal lactic acid bacteria in the mare: evaluation of the probiotic potential of native *Lactobacillus* spp. and *Enterococcus* spp. strains. Antonie van Leeuwenhoek, 93 (1-2), 71–78.

García-Velasco, J., Menabrito, M., & Catalán, I., 2017. What fertility specialists should know about the vaginal microbiome: a review. Reprod. BioMed. Online, 35 (1), 103–112. doi: 10.1016/j.rbmo.2017.04.005.

Heijtz, R., Wang, S., Anuar, F., Qian, Y., Bjorkholm, B., Samuelsson, A., Hibberd, M., Forssberg, H., & Pettersson, S., 2011. Normal gut microbiota modulates brain development and behavior. P. Natl. Acad. Sci. USA 108 (7), 3047–3052. doi: 10.1073/pnas.1010529108.

Hsiao, E., McBride, S., Hsien, S., Sharon, G., Hyde, E., McCue, T., Codelli, J., Chow, J., Reisman, S., Petrosino, J., et al., 2013. Microbiota modulate behavioral and physiological abnormalities associated with neurodevelopmental disorders. Cell, 155 (7), 1451–1463.

Kulecka, M., Paziewska, A., Zeber-Lubecka, N., Ambrozkiewicz, F., Kopczynski, M., Kuklinska, U., Pysniak, K., Gajewska, M., Mikula, M., & Ostrowski, J., 2016. Prolonged transfer of feces from the lean mice modulates gut microbiota in obese mice. Nutr. Metab. 13 (1), 57. doi: 10.1186/s12986-016-0116-8.

Milinovich, G.J., Trott, D.J., Burrell, P.C., Croser, E.L., Al Jassim, R.A., Morton, J.M., van Eps, A.W., & Pollitt, C., 2007. Fluorescence in situ hybridization analysis of hindgut bacteria associated with the development of equine laminitis. Environ. Microbiol. 9 (8), 2090–2100.

Mullen, K., Yasuda, K., Divers, T., & Weese, J., 2016. Equine faecal microbiota transplant: current knowledge, proposed guidelines and future directions. Equine Vet. Educ. 30 (3), 151–160.

Perez, P., Dore, J., Leclerc, M., Levenez, F., Benyacoub, J., Serrant, P., Segura-Roggero, I., Schiffrin, E., & Donnet-Hughes, A., 2007. Bacterial imprinting of the neonatal immune system: lessons from maternal cells? Pediatrics, 119 (3), e724–e732.

Quercia, S., Freccero, F., Castagnetti, C., Soverini, M., Turroni, S., Biagi, E., Rampelli, S., Lanci, A., Mariella, J., Chinellato, E., et al., 2018. Early colonisation and temporal dynamics of the gut microbial ecosystem in Standardbred foals. Equine Vet. J. 51 (2), 231–237.

Respondek, F., Myers, K., Smith, T.L., Wagner, A., & Geor, R.J., 2011. Dietary supplementation with short-chain fructo-oligosaccharides improves insulin sensitivity in obese horses. J. Anim. Sci. 89 (1), 77–83.

Richards, A., Muehlbauer, A., Alazizi, A., Burns, M., Findley, A., Messina, F., Gould, T., Cascardo, C., Pique-Regi, R., Blekhman, R., et al., 2019. Gut microbiota has a widespread and modifiable effect on host gene regulation. mSystems, 4 (5), e00323-18. doi: 10.1128/mSystems.00323-18.

Richards, N., Hinch, G.N., & Rowe, J.B., 2006. The effect of current grain feeding practices on hindgut starch fermentation and acidosis in the Australian racing Thoroughbred. Aust. Vet. J. 84 (11), 402–407. doi:10.1111/j.1751-0813.2006.00059.x.

Schoster, A., Weese, J., & Guardabassi, L., 2014. Probiotic use in horses – what is the evidence for their clinical efficacy? J. Vet. Intern. Med. 28 (6), 1640–1652.

Shen, Z., Zhu, C., Quan, Y., Yang, Z., Wu, S., Luo, W., Tan, B., & Wang, X., 2018. Relationship between intestinal microbiota and ulcerative colitis: mechanisms and clinical application of probiotics and fecal microbiota transplantation. World J. Gastroentero. 24 (1), 5–14.

Steelman, S.M., Chowdhary, B.P., Dowd, S., Suchodolski, J., & Janečka, J.E., 2012. Pyrosequencing of 16S rRNA genes in fecal samples reveals high diversity of hindgut microflora in horses and potential links to chronic laminitis. BMC Vet. Res. 8 (1), 231.

Zheng, G., Victor Fon, G., Meixner, W., Creekmore, A., Zong, Y., Dame, M.K., Colacino, J., Dedhia, P., Hong, S., & Wiley, J., 2017. Chronic stress and intestinal barrier dysfunction: glucocorticoid receptor and transcription repressor HES1 regulate tight junction protein Claudin-1 promoter. Sci. Rep.-UK 7 (1), 4502. doi: 10.1038/s41598-017-04755-w.



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