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Colic in horses: Effects of dietary factors

Şevket Evci[1,a,*]

[1]*Delice Vocational School, Kırıkkale University, Delice, Kırıkkale, Türkiye*
[*]*Corresponding author*

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ABSTRACT

Studies on colic, an economically important metabolic disease in horses, have typically emphasized maintenance characteristics. However, recent research has demonstrated that nutrient content also contributes to the development of colic. Microbial fermentation of the diet begins in the stomach and continues through the hindgut. During this process, various substrates are produced, including acetate, propionate, butyrate, and methane. The gut contains bacteria such as Firmicutes and Bacteroidetes, but the dominance of one over the other is influenced by the type of substrate available in the gut, such as oat, barley, wheat, corn, etc. Microbial fermentation in the equine cecum is markedly influenced by the pH balance of the nutrient metabolism. This has varying impacts on the cecal microbiota. Investigations into the effects of different feeding methods and nutrients have yielded diverse outcomes for the etiology of colic and post-colic nutrition. The objective of this review is to assess the impact of nutrition and diet composition on the etiology of colic in horses, investigate the role of additives in preventing colic cases, and analyze the results of several studies.

[a] *sevketevci@kku.edu.tr* *https://orcid.org/0000-0002-1512-3412*

Introduction

Horses are herbivores in and graze on extensive grasslands. Their diet has resulted in the development of a unique cecum structure and microbial population, which aids to digest of plant fibers. Feed undergoes microbial hydrolysis, releasing soluble carbohydrates that are then fermented into monocarboxylates acetate, propionate, and butyrate (known as short-chain fatty acids-SCFA). A significant portion of the horse's body energy comes from SCFA absorbed from the cecum and colon (Shirazi-Beechey, 2008). Today, as horse breeding focuses mainly on performance, nutrient needs have become more complex, resulting in high-energy diets with a significant proportion of hydrolyzable carbohydrates. These diets are hydrolyzed to monosaccharides, including glucose, by the action of pancreatic α-amylase and villous membrane disaccharidases in the small intestine. These monosaccharides are then absorbed and provide an energy source in the small intestine (Shirazi-Beechey, 2008; Hesta & Costa, 2021).

The nutritional characteristics of the microbiota in the cecum not only aids the feed digestion but may also contribute to the development of metabolic disorders resulting from microbial imbalances. Colic, the most hazardous condition in horses, frequently arises due to cecum microbiota imbalances (Magdesian, 2003; Shirazi-Beechey, 2008; Hesta & Costa, 2021).

Because colic in horses is an important disorder and has a high rate of occurrence related to feeding; the objective of this study is to provide information on the development of colic cases in horses and their relationship with nutrients, as well as the significance of dietary components in their prevention and treatment. The review aims to present relevant literature on preventive and clinical nutrition methods, and to discuss results related to the topic.

Equine Digestive System

Horses possess a well-developed cecum and colon within their gastrointestinal tractbut have lower microbiota adaptation ability than ruminants (Dougal et al 2013). Thus. However, they are susceptible to gastrointestinal ailments. The diets of many horses differ greatly from those of their wild ancestors. Nowadays, they are often fed only twice a day, consuming starch and sugar-rich, stored feed and concentrates after housing. In some cases, disruption of the microbial balance can lead to gastrointestinal disease. Nutrition is seen as both the cause and treatment of gastrointestinal disease (Argenzio, 1979; Clarke et al., 1990; Hesta & Costa, 2021).

The microbiota is the community of microorganisms in the gastrointestinal environment, while the microbiome is the entire habitat consisting of biotic and abiotic factors, including microorganisms and their genomes (Marchesi & Ravel, 2015). In horses, the gut microbiota appears to be of critical importance in the maintenance of health and the pathophysiology of several diseases (Al Jassim & Andrews, 2009). In addition to their digestive functions, gut microbiota also contribute to immune function (Wu & Wu, 2012). These functions include the connection between the gut and the brain and behavior (Cryan & Dinan, 2012), as well as diabetes and obesity (Biddle et al., 2018). In microbiota-related research, a pathobiotic or opportunistic enteropathogen is a potentially pathogenic microorganism that typically lives as a harmless symbiont but can become an enteropathogen under certain conditions (Hornef, 2015).

Dysbiosis resulting from differential volatile fatty acid production has been frequently observed (Costa et al., 2012; Salem et al., 2019). The gut microbiota of the horse can be influenced by a variety of factors such as age, pregnancy, level of physical activity, and the environment (Weese et al., 2015; Almeida et al., 2016; Costa et al., 2016; Morrison et al., 2018; De La Torre et al., 2019; Lindenberg et al., 2019; Kaiser-Thom et al., 2020). Diet and nutritional supplements have been shown to have a direct effect on specific populations of beneficial bacteria in the horse (Dougal et al., 2014; Langner et al., 2020).

Effects of Nutritional Factors and Probiotics on Gastro-Intestinal Microbiota

Horses in nature have low feed intake but high foraging and locomotion. Domestication and enrichment of the equine diet with energy have altered the foraging behavior, feed consumption habits, and digestive characteristics of horses (Santos et al., 2011). It is widely acknowledged that diet is one of the key factors that affects the intestinal microbiota of horses (Dougal et al., 2014; Harlow et al., 2016; Bulmer et al., 2019; Kaiser-Thom et al., 2020; Morrison et al., 2020). The microbiota of the cecum is even influenced by the frequency of the meals and shows a significant inter-individual variation (Morrison et al., 2018). Prepared diets with high levels of easily soluble carbohydrates lead to an increase in starch-using bacteria, which, in turn, raise lactic acid levels, disturb the ambient pH balance, and reduce bacterial diversity (Hansen et al., 2015; Warzecha et al., 2017). A reduction in the diversity of the caecal microbiota elevates the vulnerability to opportunistic and pathogenic microorganisms. Feeding on pasture-based diets contributes to an increase in diverse microbial agents, leading to the increase in diversity while feeding on starch-rich feeds decreases the diversity and there is an increase only in the density of groups such as *Streptococcus*, *Actinobacteria*, and *Enterococcus* (Hesta & Costa, 2021).

Probiotics are live bacteria administered to enhance intestinal health, while prebiotics refer to nutrients high in carbohydrates that benefit microorganisms in the microbiota when added to the diet or administered alongside probiotics. The therapeutic use of probiotics in treating intestinal dysbiosis during horse breeding remains largely experimental. Currently, there is a lack of consistency among studies regarding the use of probiotics in horses, making it challenging to compare the findings. Due to variability in sample size and study participants, including foals and older horses, as well as the use of fecal samples, the factors impacting the microbiota of the cecum remain unclear (Schoster, 2018). Zavistanaviciute et al. (2019) observed an increase in the number of lactic acid bacteria in fecal matter, a decrease in *Enterobacteria*, and a reduction in blood lactate levels after administering *Lactobacillus plantarum* and *L. paracasei* strains to 34 adult horses. In a separate study, *L. acidophilus, L. buchneri,* and *L. reuteri* were tested in fecal samples from three adult horses. The results showed that there was no decrease in the pH of the secretum. However, an increase was observed among the microorganisms that consume lactate, while a decrease was observed among the amylolytic groups (Schoster, 2018). Studies on prebiotics found that high doses of fructo-oligosaccharide given to 5 cannulated horses for laminitis induction resulted in an increase in the density of *Streptococcus* species in the cecum (Heaton, 2019). In a recent study examining the impact of fructooligosaccharides and inulin administration on the intestinal microbiota of 12 adult horses, researchers found an increase in microbiota diversity in the cecum, a decrease in *Lactobacilli* and *Streptococcus* species in the stomach, and an increase in the density of *Ruminococcus* in the secum and colon (Glatter et al., 2019). The results suggest a potential beneficial effect of fructooligosaccharides and inulin on the horse gut microbiota. To assess the alterations in bacterial population in the equine cecum during the progression of oligofructose-induced laminitis utilizing various techniques, and to examine these changes in caecal lactate.

Although commensal *Clostridia sp.*, which predominate in the cecum microbiota of horses, are used to correct dysbiosis in humans and dogs, prophylactic use of *Clostridium spp* has not been reported in horses (Petrof et al., 2013; Blake et al., 2019). While prebiotics and probiotics, which are commonly used for intestinal dysbiosis, are being considered for use in the more complex equine ecosystem, complex prebiotic and probiotic applications have not been administered, with the exception of yogurt feeding to foals. Postbiotics, which are metabolites produced by microorganisms and can have a direct or indirect impact on intestinal health, have been tested in horses (Cipriano-Salazar et al., 2019; Arnold 2020).

The Effect of Nutrition in Colic Cases

Colic is the most common metabolic phenomenon in horses, with an incidence ranging from 3.5% to 10.6% per year (Wwambacq et al., 2020). Colic is caused by many conditions, each of which may be associated with specific risk factors such as changes in diet, feeding practices, exercise patterns and housing, or inappropriate parasite control programs. When considering the causes of colic, one must also take into account influential factors such as genotype, exercise patterns, age, and gender. There are limited studies examining the direct relationship with nutrition. The identification and prevention of risks are the most crucial factors in dealing with colic cases (Curtis et al., 2019). Additionally, a history of colic represents a

strong risk factor for future attacks, and a prevalence of 36.5% has been reported for recurrent colic (Scantlebury et al., 2011). Although risk factors like breed, age, and season are unalterable, nutritional management is usually more flexible and can be adapted easily. Although a large number of studies have examined the relationship between dietary practices and gastrointestinal dysfunction, the precise mechanisms that link diet to intestinal dysfunction are still incompletely understood. Determining the relationship between colic and diet is challenging due to the wide variety of dietary components and feed additives employed in equine breeding, as well as individual variations and differences in exercise structure. However, recent epidemiologic studies support the idea that dietary composition and dietary changes are significant risk factors for the development of colic (Cohen et al., 1995; Hudson et al., 2001; Hillyer et al., 2002; Archer and Prodman, 2006; Harris et al., 2017; Troya et al., 2020).

Any modification of concentrate or supplemental feeds, including switching to a new batch, can increase the likelihood of colic (Hudson et al., 2001). Studies conducted on horses with colic symptoms have shown that changes to the diet made within a two-week period were effective, and gradual adaptation was essential (Harris et al., 2017). In the etiology of colic, feeding frequency, type, and quantity of carbohydrate-rich concentrate or supplemental feeds are significant contributing factors (Hillyer et al., 2002). Feeding more than 2-5 kg of high carbohydrate concentrate feed per day significantly increases the risk of colic due to incomplete pre-cecum starch digestion. In horses, adaptation to high starch levels with increased α-amylase levels is limited and slow. Therefore, feeding high starch/sugar concentrate can result in intraluminal colonic lactic acidosis, a decrease in fibrolytic microbial species, and an increase in acidophilic microbial species (Durham, 2009; Hesta & Costa, 2021). Significant variations in genes linked to starch digestibility have been detected among different races, implying a correlation between genetics and dietary management (Archer & Proudman, 2006; Salem et al., 2019). The incorporation of germinated barley in the diet was noted to diminish the frequency of colic in horses grazing in pastures, potentially due to the prebiotic characteristics of this feed (Troya et al., 2020).

The recommendation to limit the feeding of starch to 2 g/kg/BW in horses with a history of colic or a predisposition to colic is considered high. The controlled administration of 1 g/kg/BW of starch is suggested (Cohen et al., 1995). It should also be noted that corn and oats have varying effects on the fecal microbiota, and the appropriate amount to administer may depend on the source of starch. Increasing meal frequency or substituting starch-rich concentrates with highly digestible fiber sources and feeds rich in vegetable oil or fat may enhance the capacity to hydrolyze starches in the cecum of horses with high energy requirements (Durham, 2009; Hesta & Costa, 2021). To this end, diets with a lower concentration of starch are often preferred to diets with a higher concentration of starch.

Alfalfa hay is preferred over grass hay due to its higher buffering capacity (Nadeau et al., 2000). However, the form of alfalfa hay remains important. In some studies, weaned foals fed short-cut alfalfa hay and molasses alfalfa hay developed more pyloric lesions than those fed grass hay or a mixed diet (Fedtke et al., 2015; Vondran et al., 2016). During the studies, the short cutting of alfalfa hay resulted in an increase in the number of damaging surfaces, causing harm to the pyloric epithelium. Such damage can cause pyloric stenosis and delay gastric emptying. However, these harmful effects were not seen in adult horses fed alfalfa pellets, even though the particle size was reduced (Vondran et al., 2016). Adult horses fed only alfalfa hay had more severe glandular lesions, which improved after pasture feeding. Fecal particle size like undigested feed particles and volume, texture, etc., was greater in adult horses that were fed alfalfa hay in comparison to meadow hay. However, no detrimental effects were observed on the glandular mucosa. Moreover, when fed with alfalfa hay for three weeks, mild squamous lesions disappeared (Bauerlein et al., 2020). The study reveals that not only the nutrient content and composition but also the method of preparation is crucial in devising age-specific diets as age plays a decisive role in colic and other gastrointestinal diseases.

Tinker et al. (1997) conducted a one-year study on 31 horse farms to assess the risk of colic and found that a change in concentrate feeding increased the risk of colic by a factor of 3.6 compared to non-colic. In addition, feeding high levels of concentrate at 2.5 kg/day DM increased the risk of colic by a factor of 4.8, and feeding 5 kg/day DM increased the risk of colic by a factor of 6.3. The study also highlights that intensive use of processed feeds such as pellets in diets tends to increase the risk of colic. In a recent prospective, case-control study, researchers found no significant association between the amount or type of concentrate feed provided and colic risk. However, the same study suggested that horses grazed on pasture may have a lower risk of developing colic (Cohen et al., 1999). According to the study, replacing high quality hay in the diet with less digestible hay or feeding horses wheat straw or corn stalks may increase the likelihood of colonic impaction. Consuming diets high in concentrates and low in roughage has been linked to the manifestation of gastric ulcers and has been hypothesized to trigger colic symptoms (Kauter et al., 2019).

Poor quality hay with low digestibility has been found to increase the chance of horses developing severity of colic (Hudson et al., 2001). The digestibility of feed decreases by 0.5% for every 1% increase in NDF concentration in horses (Hansen and Lawrance, 2017). In addition to fiber concentration, fiber composition also affects digestibility. Changes in feeding practices and activity levels on modern equine farms have led to an increase in grain/starch and a decrease in fiber in their diet (de Fombelle et al., 2003; Sadet-Bourgeteau & Julliand, 2010). One reason for these nutritional changes is to provide quick energy release to match the high pace of the horse. In addition, high-starch diets increase the energy density of the diet and the availability of starch for enzymatic digestion by horses. This is beneficial for sports horses as energy-dense feed supports the energy demands placed on them during work. However, this shift in the diet may have influenced the alteration of the intestinal microbial community due to the drastic changes in substrates. The microorganisms in the equine gut react similarly to the rumen when faced with sudden changes in diet, which can lead to disruptions in microbial growth (Vörös, 2008; Elhandour et al., 2018).

Bailey et al. (2004), showed that high-starch diets can disrupt normal hindgut microflora when compared to fibrous diets. This change in microbial composition is caused by alterations in hindgut pH and could affect cellulolytic activity in the hindgut. For example, a study found that changing a horse's diet from 100% haylage to a mix of 50% hay and 50% concentrate resulted in a tenfold increase in the population of Lactobacilli and Streptococci in their feces (Vörös, 2008). The gut of horses fed 100% haylage had a high abundance of cellulolytic microbes such as Ruminococcus flavefaciens, Ruminococcus albus, and Fibrobacter succinogenes (Bailey et al., 2004). There is a similarity between the microbial community shifts in both foregut and hindgut fermenters, particularly when concentrate feeds are provided. It can be assumed that these changes in the microbial community would also occur in the cecum-colon chamber, as the hindgut is the channel through which feces pass. This statement suggests that regardless of an animal's digestive system, the primary substrate in its diet will affect the distribution of microbes in its fermentative chamber and feces. Research has shown that horses fed a forage-only diet exhibit greater microbial stability and diversity compared to those fed a starch-rich ration (Willing et al., 2009).

Conclusion

The relationship between colic, one of the gastrointestinal disorders of horses, and nutrition was reviewed, especially in terms of the effects on the intestinal microbiota. In addition to the fact that gas formed during carbohydrate metabolism causes colic, examination of the physical effects of food forms on the digestive system has shown that colic-like clinical symptoms can be caused by various injuries. Unlike other livestock, it is impossible to provide a specific dietary recommendation for horses due to individualized feeding, the general lack of dietary control and performance-based supplementary feeding. Although differences in sampling and methodology preclude direct comparison of studies on the use of prebiotics, probiotics, and postbiotics to prevent colic in feeding practices, their results demonstrate the potential usefulness of these additives in preventing colic. Various studies have shown that both the way the feed is prepared and the key components of the diet, such as diet composition, nutrient content, and additives, may play a role in the development of colic. Additionally, additional research and further clinical nutrition studies are needed to investigate the effect of advanced feed production techniques on the cecal microbiota in horses. As a result, in cases of colic in horses, which is of high economic importance and directly affects horse health, it appears that nutrition is also important, as well as care conditions or infectious diseases. Developing correct and need-oriented rations and additives, both in preventing and preventing colic formation, is important in the management of colic cases in horses.

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