Trends in Equine Nutrition and the Effects of a Hindgut Buffer Product in Overconditioned
Horses

Katlyn M. DeLano

Thesis submitted to the faculty of the Virginia Polytechnic Institute and State University in
partial fulfillment of the requirements for the degree of

Master of Science
In
Animal and Poultry Sciences

Bridgett J. McIntosh, Chair
Sally E. Johnson, Co-chair
Jessica K. Suagee-Bedore

September 12, 2017
Blacksburg, VA

Keywords: equine, nutrition, obesity

Trends in Equine Nutrition and the Effects of a Hindgut Buffer Product in Overconditioned Horses

Katlyn M. DeLano

ABSTRACT

Nearly 50% of the equine population is overweight due to feeding and management practices. Obesity is related to development of diseases that are detrimental to performance and potentially fatal in horses, including insulin resistance, laminitis, and equine metabolic syndrome (EMS). Objectives of this research included first, characterization of nutrition-related management practices of hunter/jumper show industry via a voluntary survey; second, evaluating the Body Condition Index (BCI) in comparison to the Body Condition Scoring system (BCS) in sporthorses; and lastly, determining the effects of a hindgut buffer in overconditioned horses following an abruptly introduced moderate nonstructural carbohydrate (NSC) meal. There were no differences in nutritional management between hunter and jumper disciplines and most representatives (n=89) had no nutritional concerns. Many used trainers (38%) and veterinarians (36%) as sources of nutritional advice rather than professional equine nutritionists (7%). BCI had consistently higher scores than BCS ($P<0.01$), with the largest differences in horses with BCS < 5. Horses were offered a concentrate meal containing 1.2g NSC/kg BW with and without DigestaWell® Buffer (DB). Horses receiving DB had decreased plasma L-lactate ($P=0.05$), and a tendency for increased fecal pH ($P=0.08$) and decreased fecal D-lactate ($P=0.07$). These studies demonstrate a need to improve horse owner education and the relationship between representatives and trained nutritionists to reduce disease incidence, that different equations may need to be developed for a more consistently accurate BCI across various breed and body types, and that DB may have a positive impact on the equine digestive response to NSC.

Trends in Equine Nutrition and the Effects of a Hindgut Buffer Product in Overconditioned Horses

Katlyn M. DeLano

GENERAL AUDIENCE ABSTRACT

Nutritional management is essential to avoiding to diseases associated with equine obesity. Improper feeding practices can lead to nutrition-related diseases including obesity, colic, and ulcers. Half of the equine population is overweight or obese, negatively impacting performance and increasing the likelihood of obesity-related disorders such as insulin resistance, laminitis, and equine metabolic syndrome in response to elevated intake of nonstructural carbohydrates (NSC). The objectives of this research were 1) to generate information regarding hunter/jumper competition horse nutritional management and practices, 2) to evaluate a novel system to quantitatively assess body fat, and 3) to determine the efficacy of a bicarbonate hindgut buffer product in ameliorating the effects of a rapidly introduced moderate starch meal in overweight horses. In the first study, equine representatives (owners, trainers, riders, or grooms) at hunter/jumper horse shows in Northern VA voluntarily completed surveys regarding the nutritional and pasture management of the horses. Many of those surveyed had no nutritional concerns despite the stress and travel associated with competitions, and utilized trainers and veterinarians for nutritional advice rather than professional equine nutritionists. The second study compared the subjective body condition scoring system (BCS) to the newly developed quantitative body condition index (BCI) using several morphometric measurements. The BCI was consistently higher than the BCS, with the largest differences present in horses with a BCS less than 5 on a 1 to 9 scale. The third study evaluated the effects of DigestaWell® Buffer, a bicarbonate hindgut buffer product, in overconditioned horses (BCS $\geq$ 6.5) following a rapidly introduced moderate starch meal. The buffer reduced concentrations of L-lactate in the horses, and tended to increase fecal pH and decrease concentrations of fecal D-lactate. Given these findings, DigestaWell® Buffer alleviated some of the effects of rapid starch fermentation. Together, these studies generated information on nutritional management of performance horses, evaluated the BCI as a method of assessing equine adiposity, and determined the response of overconditioned mares to a moderate starch meal with and without a hindgut buffer. The results of the studies demonstrated a need for further education for equine representatives in the nutritional care of performance horses, a need for further data collection to continue improving the accuracy and consistency of the BCI, and further investigation into DigestaWell® Buffer as a strategy to alleviate the effects of high starch meals in overconditioned horses.

Dedication

       Dedicated to my family and friends who encouraged me to continue my education, and to all the animals in my life that inspired me to pursue a career in animal sciences.

Acknowledgements

I would first like to thank my entire family for jumping into this crazy horse world with me and embracing it wholeheartedly. The countless hours spent working in the barn, riding, and horse showing gave me the determination I've needed to achieve my goals in all areas of life. To my parents, thank you for pushing me to strive for the best, whether it was on a horse or pursuing this degree. I also need to thank Blackie, the trail horse in Colorado to whom I owe the beginning of my passion for horses, and Hunter, the dog that opened the door for many more animals to come into our family's life.

To my friends outside of the MARE Center, especially Nicolle Villers, thank you for grounding me and keeping life in perspective for the last two years. You opened up an entirely new horse community to me here in Virginia, and I will never be able to thank you enough. Thank you also to my friends from back home and across the country for continuing to support me during this journey.

My sincerest thanks to Dr. Bridgett McIntosh, who's encouragement and belief helped me to develop both personally and professionally. Dr. McIntosh opened the door to so many opportunities during the last few years that have allowed to me pursue my career in animal nutrition. Thank you to the rest of my committee, Dr. Sally Johnson and Dr. Jessica Suagee-Bedore, for their guidance and support with my research. Dr. Ashley Wagner, Dr. Pat Harris, and Natalie Henning also contributed to the success of this research through their advice and support.

I could never have gotten this far without the graduate students at Tech and up at the MARE Center. Thank you for being a home away from home, and for giving me a family to laugh and occasionally cry with these last two years. Amanda Reeg, thank you for being my

introduction into the world of research in Kansas, and continuing to be a friend and mentor in Virginia. I hope our friendship continues wherever we wind up in life. Katie, Kristine, and Shayan, I am so fortunate to have had you as both mentors and friends! You have been wonderful people to share this experience with. My sincerest gratitude goes to the staff at the MARE Center, Rita Rollison, Tait Golightly, and Mike Sabus. I could not have succeeded in this program or my research without your support and encouragement.

Table of Contents

List of Tables

List of Figures

Glossary of Terms

Body condition score (BCS)—a subjective assessment on a 1 to 9 scale used for estimating adiposity in the horse. A score of 1 is considered severely thin, 5 is considerd ideal, and a score of 9 is considered grossly obese.

Cresty neck score (CNS)—a scoring system to assess apparent neck crest adiposity in horses on a 0 to 5 scale. A score of 0 indicates no visual appearance of a crest and no palpable crest, while a score of 5 indicates a grossly enlarged crest that permanently droops to one side. An ideal CNS for most horses is a score of 1 or 2.

Equine metabolic syndrome (EMS)—the presentation of a phenotype of obesity or regional adiposity, insulin resistance or hyperinsulinemia, and laminitis or a predisposition to laminitis in horses.

Fructan—collective term for all oligo and poly-fructosyl sucrose consisting of one or more fructosyl links. Fructans are the primary reserve carbohydrate in cool-season grasses and are water soluble. Animals lack the enzymes required to digest fructans, so they are fermented by equine hindgut microbial population.

Grasses—plants in the *Poaceae* family. Grasses are monocots (produce one seed leaf), have parallel leaf veins, are generally herbaceous, and produce seed on an elongated seed stalk.

Insulin resistance—characterized by basal hyperinsulinemia (basal insulin concentration > 20 uIU/mL) and/or an excessive insulin response to glucose challenges.

Legume—a plant in the *Fabaceae* family, notable in that most have root nodules containing nitrogen-fixing bacteria. Legumes are dicots (produce two seed leaves), can be herbaceous or woody, with reticulated leaf veins and a taproot system.

Nonstructural carbohydrates (NSC)—the sum of sugars, starches, and fructans that accumulate in plant cells and are readily mobilized for plant metabolism or translocation to other plant parts.

Obesity—the excessive accumulation of adipose tissue in the body. In horses, a body condtion score greater than 7 on a 1 to 9 scale has been defined as obese.

Starch—polymer of glucose, and are not water soluble. Starches are the primary reserve carbohydrate in legumes, and are part of the reserve carbohydrates in other forages. Unlike fructans, starches are readily hydrolyzed by the animal's digestive enzymes.

Sugar—mono- and di-saccharides, sugars are water soluble and hydrolysable. Examples of sugars include glucose, fructose (mono-saccharides), and sucrose (di-saccharide).

Chapter I

Introduction

Nearly half of the equine population is overconditioned or obese [1,2]. Equine obesity is associated with insulin resistance, increased risk of laminitis, and equine metabolic syndrome (EMS). Laminitis is a devastating systemic disease in horses and ponies that ultimately affects the laminar tissue binding the coffin bone to the inner hoof wall. In severe cases, the coffin bone can become detached and rotate down through the sole of the hoof causing suffering and pain to the animal. In severe cases, laminitis is often fatal to the afflicted animal. Laminitis has several causative factors, most commonly pasture-associated laminitis, followed by grain or concentrate overload and complications of injury, obesity, or pregnancy [3]. Although laminitis is not curable, it may be avoidable through proper nutritional management.

A lack of nutritional knowledge has been observed in horse owners. Most owners measure hay and concentrates by volume, rather than by weight, resulting in inconsistent and inaccurate feeding [4,5]. Responses to surveys have demonstrated misunderstandings regarding terminology and the types of feedstuffs that are regarded as fibrous feeds and what constitutes a concentrate feed [6]. Additionally, popular sources of nutritional information and advice include veterinarians, trainers, and the internet [5]. This shows owners rely on advice that does not come directly from a veterinarian or professional nutritionist, and therefore may not be based in scientific fact. The lack of nutritional knowledge in horse owners observed by current research demonstrates areas to direct future education to maintain and improve the health and well-being of horses. The large population of obese horses indicates many horses receive calories and nutrients in excess of their maintenance and exercise needs.

1

While experienced assessors can recognize obesity, untrained horse owners may not. Many horse owners underestimate body condition compared to experienced assessors [7]. It is therefore important to regularly monitor condition and do so accurately. Several methods of varying accuracy and consistency exist to assess weight and condition, including weight tapes, livestock scales, and body condition scoring (BCS). Weight tapes are reported to be the most commonly used, although the tapes consistently underestimate body weight compared to a livestock scale [2,6,8]. The body condition index (BCI) was derived as a quantitative method of assessing adiposity using several morphometric measurements, and may be useful to horse owners [9].

Between 60% and 100% of horses receive some type of grain-based concentrate daily [5,10–12]. Concentrates have a large proportion of nonstructural carbohydrates (NSC), particularly starch. In large quantities, starch can overwhelm the digestive capabilities of the small intestine and overflow to the hindgut where it is rapidly fermented. Rapid starch fermentation leads to an inflammatory state, particularly in obese horses. Intakes of sugar and starch have been linked to insulin resistance, which also contributes to laminitis [13,14]. Currently recommendations include reducing NSC in the diet, using grazing muzzles, and dry lots. However, many performance horses need the energy supplied by large amounts of concentrate, or owners may not have pasture to support cutting out their horse's primary energy source. Alternatives must be found for these situations.

Objectives

1. Identify the feeding practices and nutritional management of hunter jumper performance horses and ponies.

2. Evaluate the body condition index (BCI) in comparison to the body condition scoring system (BCS) in sporthorses.

3. Evaluate the effects of a bicarbonate hindgut buffer in overconditioned horses following a rapidly introduced starch meal.

Chapter II

Review of Literature

2.1 Introduction

Over half of the equine population is classified as overconditioned or obese, mainly due to feeding practices and a widespread lack of knowledge in horse owners [2,5,7]. The combination of obesity and over nutrition is associated with equine metabolic syndrome (EMS) and an increased risk for laminitis. In several disciplines, the current desirable "winning" phenotype is an overconditioned horse, increasing the perception in owners that an overconditioned horse is normal [15]. Further research is needed to identify the feeding practices, concerns, and knowledge of the owners, riders, and trainers of hunter jumper performance to evaluate nutritional areas in need of improvement. While tools for assessing weight and body condition exist, they are for the majority highly subjective and inconsistent, leaving room for error for inexperienced assessors [16,17]. An accurate and objective method of assessing adiposity must be developed so owners can identify obesity in their own horses. Performance horses usually receive large amounts of concentrates in their diet [10,18]. Nonstructural carbohydrates (NSC) make up a large portion of grain-based concentrates. While forages have higher fractions of simple sugars, concentrates tend to have higher proportions of starch [19]. When fed in high amounts, starch can overflow the small intestine to the hindgut, where it is rapidly fermented. Excessive ingestion of carbohydrates, including pasture and concentrate NSC, is one of the more common causes of laminitis [3]. Current research has focused on reducing NSC intake as well as on developing nutritional supplements such as hindgut buffers to decrease inflammation from these large starch intakes. Further research in feeding strategies to mitigate metabolic diseases is needed to evaluate the effects of hindgut bicarbonate buffer products in overconditioned horses.

4

2.2 Feeding and management practices

2.2.1 Concentrates

Nearly all owners (96%) report feeding at least one concentrate to their horses, with some horses receiving up to four different types of concentrate daily, including pellets, extruded feeds, sweet feed, and combinations of different sweet feeds and pellets [5]. Most (86.8%) of the grain and concentrates fed to horses across the country is purchased in bags from retail sources, while up to 15% feed home grown grain/concentrates [20]. However, many owners (70%) measure feed by volume, rather than by weight, using feed scoops, cans, or cups, or by a "handful" or by "eye" [5,6,21]. A survey at the Winter Equestrian Festival in Florida found all horses and ponies received concentrates measured by volume, rather than by weight [15]. Previous studies have demonstrated that feeding by volume results in a disparity between the weight of feed delivered by owners and the amount they thought they were feeding, with only 60% of horses receiving the intended amount [4]. More competition horses receive some type of concentrate feed as compared recreational horses [12]. Nearly all upper-level performance horses (90%-100%) receive at least one concentrate in their diet [18,21,22].

2.2.2 Hay feeding

In most studies, all owners report feeding hay to their horses, both at home and while at competitions [5,22,23]. Most commonly, horses were fed grass hays or grass-legume mixes including timothy (*Phleum pretense*), ryegrass (*Lolium perenne*), white clover (*Trifolium repens*), and alfalfa (*Medicago sativa*) [15,18,20]. In cases where hay is not offered, horses have access to pasture to meet forage requirements [2]. Again, owners were more likely to feed by flake, with very few (11%) weighing their hay [5]. Because flakes of hay can vary widely in

weight, this can result in a highly variable hay intake [4]. Few owners have their hay analyzed for nutrient content (21%), and are therefore unaware of the quality of hay being fed, which may lead to unbalanced rations [4,5,10].

Hay quality plays an important role in equine diets. Nutrient content of hays is highly variable, but has a dry matter (DM) content of greater than 80%. Hay can maintain nutritional value for several years, levels may decline over time as dust content increases [24]. Ad libitum access to forages, including hay, can exceed daily energy requirements of the horse. It has been recommended to only feed hay less than 10% NSC to horses to avoid exacerbating metabolic disorders [25]. However, only 21% of owners have their hay analyzed, and may be feeding hays too high or low in nutrient value [5]. Soaking hays can decrease NSC fractions when low NSC hay is not available [26,27].

2.2.3 Pasture intake and grazing management

Pasture serves two important purposes for horses, acting as both feed and a place for exercise. Access to pasture varies widely, from no access to unlimited access when not at competitions [10,28,29]. The frequency of hay feeding indicates inadequate pasture access for adequate nutrition, or that feeding of hay may allow owners more control over energy intake than unrestricted pasture grazing. While most animals had access to pasture all year, 4% of horses are stabled 24 hours a day, with the proportion increasing during winter months [11].

Unlimited access to pasture may not be beneficial for all horses, as it may lead to bodyweight gain and obesity. In one study, mature horses consumed calories in excess of the maintenance energy requirement. The horses consumed 0.41kg/h of fescue DM over a 24 h period and an average grass pasture may be as high as 2.7 Mcal/kg DM at certain times. Thus, a 500-kg horse, depending on the pasture, may consume 1.2 to 1.6 times the horse's maintenance

requirements [30]. Pasture NSC depends on many factors, including time of day, weather, and seasonality. Excessive intakes of NSC have been linked to metabolic disorders associated with high glycemic and insulinemic responses, such as pasture-associated laminitis [31,32]. Pasture kept horses are the most at risk for developing laminitis, particularly obese and insulin resistant equines [3,17]. Nonstructural carbohydrate concentrations in pasture have been reported to be highest in the early spring and higher in the afternoon than in the morning [33]. Pasture NSC content can accumulate to greater than 400 g/kg DM in pasture grasses [34].

2.2.4 Supplement use

Supplement use is widespread across disciplines. Over one third of operations in the U.S. reported feeding a vitamin-mineral supplement/premix [20]. A majority of showjumping, dressage, and event horses (87%) received one or more feed supplements, including electrolytes, mineral mixes, magnesium, joint supplements, and salt [18]. Top-level event horses were fed an average of four supplements, most commonly electrolytes, joint supplements, and salt [21]. In a survey of horses brought to a large animal hospital at a veterinary teaching school, some horses received up to 10 supplements [5]. None of the owners in a survey of racehorses in Turkey were aware that horses can balance only their sodium intake, and cannot self-balance other minerals [35]. While the widespread use of supplements likely reflects a desire for improved performance, use of multiple feed supplements can lead to over-supplementation and unknown interactions and interferences.

2.2.5 Nutrition related concerns and sources of advice

Veterinarians were considered an important source of nutritional information by a large percentage (56.9%) of equine operations across the country, with farriers, feed store supply personnel, and trainers also considered important [20]. Veterinarians remain a dominant source

of nutritional advice, although many do not have a nutritional background and the subject is a minor part of veterinary curriculum [6,36]. Following veterinarians, friends and other horse owners, and trainers were most often consulted for horse care advice [5,37,38]. Owners often rely on multiple sources for information, and as the internet and trainers are a popular source, advice may not be based in scientific fact [5]. Nutritional concerns reported by horse owners are relatively low, with few (less than 10 of the 34 surveyed) reporting concerns about colic, ulcers, and weight loss [22]. This is surprising, as competition horses face large amounts of travel and performance stress, increasing their risks for gastric ulcers, joint disorders, decreased appetite, and hyperexcitability [39]. While performance horses such as racehorses, endurance hores, and polo ponies are normally kept at an optimal body condition score (BCS) between 4 and 5 on a 1 to 9 scale, dressage horses and show hunters (BCS 6.3-7.3) have significantly higher BCS than polo ponies and show jumpers (BCS 5.0-5.8). The knowledge of horse owners in regards to nutrition and obesity related diseases such as insulin resistance (IR) and EMS has been reported as below average as compared to colic and laminitis [6]. Due to the reported prevalence of obesity in the U.S. and UK, owner perception may be skewed upwards with owners consistently underestimating body condition [2,7,11,40].

2.3 Methods for assessing body condition

2.3.1 Prevalence of obesity

Surveys by the USDA National Animal Health Monitoring System (NAHMS) estimate that between 1.5% and 3.4% of the U.S. horse population is overweight or obese [20,41]. However, both of the NAHMS estimates were based on self-reported surveys rather than standardized methods for consistently assessing body condition and adiposity. A study of horses in Southwest Virginia found 51% the horses measured to be overconditioned or obese [2], while

other studies found similar obesity rates [40,42]. Obesity is a major health concern in humans and companion animals because of its high prevalence and associations with insulin resistance (IR), diabetes mellitus, cardiovascular diseases, and other disorders. It is a primary component of equine metabolic syndrome (EMS), a condition in horses and ponies also characterized by IR or hyperinsulinemia and a predisposition to laminitis [43]. Due to the prevalence of obesity and its relationship to nutritional disorders, it is important to have accurate assessments of adiposity to prevent disease.

2.3.2 Methods for assessing and monitoring adiposity

A majority of owners (60%) state that they regularly monitor their horses' weight, with most reporting monthly checks [6]. Weight tapes were the most common method, although many reported guessing the weight of their horse, and very few reported using BCS unless specifically asked about its use [6]. While monitoring weight with a scale allows accurate assessment of body changes, most owners do not have access to a scale unless taking the horse to the vet [44]. Horse owner estimates of horse weight are often underestimated, and there is no correlation between weight estimation by eye and years of experience [44–47]. Weight tapes can be useful for monitoring weight changes if consistently placed around the horse in the same way, but have been regarded as inaccurate for determining weight [48–50].

Body condition scoring is a subjective assessment used to estimate adiposity in the horse by palpating areas indicative of changes in stored body fat, including the crest, ribs, tailhead, area behind the shoulder, and withers. Utilizing BCS on a scale of 1 to 9 or 1 to 5 is regarded as one of the most useful tools for weight monitoring and management, but studies have reported that owners do not fully understand how to properly assess horses using BCS [2,6,7,16,51]. Owners often underestimate their horses' condition few owners overestimate condition. Most

9

owners likely classify an over-conditioned horse as ideal body condition, which may be due in part to pressures within performance disciplines, to have a horse that conforms to the winning phenotype [15].

2.3.3 Body condition index

Owners are often unable to accurately assess BCS and adiposity in their horses, due to biases and lack of education. Although BCS is a valuable estimate of apparent adiposity, it is a subjective assessment [16]. It is therefore important to establish a quantitative method rather than a qualitative scale, to monitor body condition in horses. The body condition index (BCI) is a quantitative system that uses several morphometric measurements. Measurements include height at the withers (H, cm), heart girth (HG, cm), belly girth (BG, cm), and neck circumference (NC, cm) [9]. The BCI was derived iteratively using the equation:

$$BCI = [(HG^{0.5} + BG + NC^{1.2}) / H^{1.05}]^{2.2}.$$

The index may be a useful guide for owners in need of an objective method to monitor body condition in an effort to manage and prevent obesity and related disorders.

2.4 Feeding strategies to mitigate disease

2.4.1 Nonstructural carbohydrate overload and insulin resistance

Laminitis is a debilitating systemic inflammatory disease ultimately affecting the hoof laminae, and has been linked to high intakes of nonstructural carbohydrates (NSC) in concentrates and forages. Nonstructural carbohydrates are comprised of simple sugars, starches, and fructans, and are associated with acute metabolic disorders due to the high glycemic, insulinemic, and inflammatory responses they may cause [52]. Laminitis may be triggered by these digestive, inflammatory, and metabolic disturbances.

Endocrinopathic laminitis is a general term describing laminitis that develops in horses with endocrine or metabolic disorders, including laminitis associated with obesity, insulin resistance (IR), or pituitary pars intermedia dysfunction (PPID) [53]. Grazing lush pasture contributes to equine obesity and IR due to the large amounts of energy and sugars present in the grass [52]. Insulin resistance is defined as the failure of tissues to sufficiently respond to circulating insulin and control blood glucose concentration. Equines experience compensated IR, meaning the pancreas responds to peripheral resistance by increasing insulin production in combination with decreased insulin clearance, resulting in a hyperinsulinemic state [54]. An association between resting hyperinsulinemia and laminitis has been developed [55,56]. Insulin stimulates glucose uptake into skeletal muscle and adipocytes and glycogen synthesis in muscle and liver, while simultaneously inhibiting gluconeogenesis in the liver to assist in glucose homeostasis [57]. In addition to its roles in carbohydrate metabolism, insulin regulates vascular endothelial function and has anti-inflammatory effects [58,59]. These vasoregulatory properties may explain why IR is strongly linked to development of endocrinopathic laminitis [52,60,61]. Vasoconstriction is promoted in IR animals and may impair the ability of vessels to respond to vascular challenges as glucose uptake into lamellar epithelial cells is impaired [62].

Obese horses are more likely to suffer from IR, and may be more susceptible to laminitis due to the systemic pro-inflammatory state caused by obesity. In obesity, there is a progressive dysregulation of adipose tissue, amplifying the inflammatory response [63,64]. Systemic releases of pro-inflammatory cytokines such as tumor necrosis factor-α (TNF-α) and interleukin-1ß (IL-1ß) can disrupt insulin signaling and lead to or exacerbate IR and vascular endothelial dysfunction [65]. Preliminary studies in horses and ponies have demonstrated that inflammation may be a factor in obesity-related IR [66]. Insulin resistance may predispose horses to laminitis

11

as disturbances in vascular function could leave the hoof laminae more susceptible to injury when exposed to factors that promote laminitis, such as carbohydrate overload [67].

Laminitis can also occur as a result of digestive disturbance, rather than from an endocrine condition. When excessive amounts of starch or oligofructose are administered to horses, the carbohydrates overwhelm the foregut and enter the hindgut. This induces rapid microbial fermentation of the starch, leading to rapid changes in hindgut bacterial populations. Gram-positive, or lactate-producing, bacteria ferment starch. The proliferation of gram-positive bacteria, especially lactic acid-producing lactobacilli and streptococci, lead to a decrease in cecal, colonic, and fecal pH and an increase in intestinal permeability [68–71]. Epithelial cells lining the cecum show degenerative changes 24 hours after a starch overload, resulting in loss of barrier function, or a "leaky gut" [72,73]. Low pH in the intestine results in the death of large numbers of bacteria, and the release of endotoxins (lipopolysaccharide, LPS) from the cell walls, potentially initiating a systemic inflammatory response triggering laminitis onset [74]. Bacterial fermentation in the hindgut produces two isomers of lactic acid—D- and L-lactate. Only L-lactate is produced by the metabolic activities of mammals, allowing the concentration of D-lactate in blood to be used as an indicator rapid fermentation by bacteria in the hindgut [68]. Concentrations of plasma D-lactate peak approximately 20 hours following carbohydrate intake, and then declines.

Increased plasma LPS concentrations have been reported in horses fed high starch and sugar diets [74]. Lipolysaccharide production and uptake into the gastrointestinal tract can induce transient insulin resistance in horses and increase inflammatory protein production [75,66,76]. Horses receiving LPS treatments had increased concentrations of white blood cell Interleukin-1ß (IL-1ß), Il-6, tumor necrosis factor (TNF) mRNA, and plasma TNF

concentrations, as well as plasma serum amyloid A (SAA) concentrations. In adipose tissue and adipocytes, TNF, interleukin-6 (IL-6), and IL-1ß have been shown to have negative effects on insulin signaling. IL-1ß reduces insulin-stimulated glucose uptake ([77,78]. Laminitis is an painful and debilitating condition, but it can be prevented through proper nutritional management.

2.4.2 Nutritional management

Making recommendations for reducing NSC intake can be difficult due to the various factors influencing their accumulation in forage and feeds. The maximum amount of starch recommended to be fed to horses in a single meal ranges from 2 to 4 g/kg BW to prevent hindgut disorders related to rapid fermentation [79]. Therefore, reducing the amount of feed given in a single meal can aid in avoiding high intakes of simple sugars and starch. Modern diets contain higher levels of easily digestible NSC than equine diets in the past, partly due to daily rations that include grain-based concentrates ranging from 40-70% NSC [80]. It has been recommended to restrict NSC feeding to less than 2 g NSC/kg BW in a single meal [81].

Managing grazing horses to reduce NSC can present a challenge because concentrations of sugar and fructans are variable depending on a number of factors including time day, season, and weather [34]. During the spring and early summer, pasture forages are rich in NSC [34]. Restricting grazing during the growing seasons and allowing grazing only at night when sugars are likely to be low may help restrict intake of NSC. Grazing practices to avoid excessive intakes of pasture NSC include grazing muzzles, use of dry lots, and allowing grazing only during low risk times. Animals wearing grazing muzzles have greater difficulty in accessing longer swards, and also experience a reduced rate of weight gain [82,83]. If possible, feeding hay in a dry lot rather than allowing the horse to graze allows greater control over intake. An NSC content of

less than 10% on an as-fed basis has been recommended [19]. Use of slow feed hay nets further controls intake, while allowing horses to graze for more hours of the day and preventing development of boredom and vices. Forage only diets may not provide adequate minerals, vitamins, or proteins. It is necessary to supplement the diet with a low-calorie ration balancer to balance the diet and provide vitamin E, copper, zinc, selenium, and other minerals typically found in low concentrations in mature forages.

2.5 Summary

The health and well-being of horses is dependent upon proper nutritional management. A significant portion of the equine population is overweight or obese, indicating a need for further education of horse owners in nutrition-related practices [2]. Performance horses spend much of their time traveling and competing and are often under stressful conditions [39]. At high levels of performance, adequate and balanced nutrition are critical to prevent illness, enhance performance, and mitigate responses to high starch diets common to performance horses. Obesity does not seem to be as large of a problem in performance horses as in recreational horses, although show hunter and ponies do seem to be more obese than show jumpers, polo ponies, eventers, and other high level competition animals [15]. It remains important to develop strategies to educate owners and allow for accurate assessment of body condition, as well as evaluating methods to alleviate the effects of high starch diets.

Chapter III

Survey of performance horse nutrition in show hunters and jumpers in Northern Virginia

Abstract

Nutrition is a critical part of the well-being and success of performance horses. The nutritional knowledge of owners, riders, grooms, and trainers is therefore important to the performance of competition horses. The objective of this study was to characterize the nutritional practices and management of hunter/jumper competition horses at two different USEF/USHJA recognized "AA" horse shows. A total of 125 individuals were surveyed at the Upperville Colt and Horse Show (n=50) (Upperville, VA) and Horse Shows in the Sun (n=75) (HITS, Culpeper, VA) during June and July 2016. Of the horses surveyed, the average age was 9.88 yr (range 1-26 yr); there were 91 geldings, 30 mares, and 1 stallion. There were no differences in the number of geldings represented at the horse shows (*P*=0.1), but there were more mares represented at HITS (*P*=0.01). Approximately 56% of the horses were classified as jumpers, 48% as hunters, with the remaining horses categorized as equitation or other. There were significantly more jumpers surveyed at HITS 0.01), and more hunters surveyed at Upperville (*P*=0.02). Breeds consisted of warmbloods (n=87), Thoroughbreds (n=14), ponies (n=14), and stock horses (n=3). There were no differences between the two horses shows in the number of warmbloods represented (*P*=0.20), but there were more surveys collected on Thoroughbreds at HITS than at Upperville (*P*=0.01). A majority of the horses (89.6%) were fed commercial concentrates and had access to pasture when at home (96%) for an average of 9.5 hours a day. However, only 58% of the available pastures had adequate grass forage for nutrition (at least 10.16 to 15.24 cm tall). Sixty percent of surveyed individuals brought hay to the shows, while 36% purchased hay at the show. Approximately 62% of the horses received one or more dietary supplement, including

15

electrolytes, chondroprotectives, probiotics, and various others on a regular basis. While 58% of the individuals were concerned about equine obesity, 23% were concerned about ulcers, 14% with laminitis and insulin resistance, and 14% with colic. The majority of those surveyed (72%) had no concerns about colic, laminitis or insulin resistance, ulcers, tying up, or other nutritional related diseases in horses, despite the frequent travel and potential sudden feed changes associated with horse showing. Most of the individuals referred to multiple sources for information regarding equine nutrition, including trainers (n=75), veterinarians (n=71), feed companies (n=18), nutritionists (n=13), the internet (n=10), and other (n=1). However, 10 individuals (8%) reported using no outside sources of information when making decisions on nutrition and feeding practices. This survey identified nutritional practices and management of performance horses. The survey shows communication between veterinarians, nutritionists, and horse owners could be improved, bettering the health of the horse.

Introduction

Proper nutrition is critical for maintaining health and performance of horses. It is important to meet the horse's energy and nutrient needs according to several variables, taking into account level of exercise, life stage of the animal, and individual variation [84]. The diet must account for forage, concentrates, and supplement use, as well as activity level, age, and individual variation. Performance horses are subject to high levels of exercise and stress, and have stringent nutritional demands above that of a horse at maintenance to meet their energy and nutrient requirements [84]. Underfeeding fiber may result in ulcers and overfeeding calories can lead to obesity [85].

The nutritional knowledge and practices of horses' representatives is essential to counteract the physical stress of training, competition, and travel in performance horses. Studies

16

have evaluated horse owners' knowledge of equine nutrition [5,6]. These studies suggest many owners have an inaccurate understanding of equine nutrition, reporting that owners often feed by volume rather than weight, and misunderstandings of how feeds are classified into different categories, including forages, concentrates, and supplements .

Several surveys have examined the nutritional practices of horse owners. These studies report that most horses receive a concentrate and one or more dietary supplements in addition to pasture and forage [5,6,12]. However, the nutritional management and practices of owners of recreational horses likely differs from that of performance horses. Show jumpers, eventing horses, and dressage horses had a wide variety of turnout practices, ranging from none to 24 hours per day [10,18,21]. All competition horses received a commercial concentrate in addition to roughage, and most received at least one dietary supplement [21].

Feeding practices vary widely, driven by pressures within each discipline to have a horse that conforms to the type of horse that wins [15]. The objective of this study was to add to the body of knowledge regarding nutritional management and practices of show hunter and jumper horses, including feeding and turnout practices, nutritional concerns, and sources of nutritional information.

Materials and Methods

This study was conducted at 2 national equestrian competition facilities in Northern Virginia during the months of June and July of 2016. The 5 d USHJA/USEF recognized competitions included hunter, jumper, and equitation competitions, as well as sidesaddle and various breed classes.

Data Collection

The survey was adapted from a previous study evaluating feeding practices and nutritional knowledge in New England [5] (Appendix 1). Horse representatives (riders, owners, grooms, or trainers) voluntarily completed the survey questionnaire at the Upperville Colt and Horse Show (Upperville, VA, June 2016) and Horse Shows in the Sun (HITS, Culpeper, VA, July 2016). The survey asked the representative to identify and quantify all feed (hay, concentrates, and any additional forage) and supplements offered to each horse, as well as pasture management and demographic information. Information was gathered on a total of 125 horses during the two competitions.

Statistical Analysis

Data were analyzed with a chi-square, utilizzing the FREQ procedure in SAS (v. 9.4; SAS Institute, Cary, NC, USA). The statistical model investigated differences in breed, discipline, and gender between the two horse shows. Results were considered significant at $P < 0.05$ and a trend at $P < 0.1$.

Results

Subjects

Over the 2 horse shows, a total of 125 surveys were completed by representatives of horses. Representatives included owners, riders, trainers, and grooms. Table 1 summarizes the horse demographics indicated by the surveys. There were 89 geldings, 32 mares, and 1 stallion. Breeds included warmbloods (n=87), Thoroughbreds (n=21), ponies (n=14), and stock breeds (n=3). Representatives characterized their horse as belonging to one or more competition categories, including hunter, jumper, or equitation (Table 1). Other competition types included sidesaddle, fox hunting, leadline, and eventing.

Concentrate feeding

Fourteen of the 126 respondents did not answer the question regarding brand or type of concentrate fed, and the remaining 112 respondents reported feeding some type of commercial grain or concentrate. Respondents reported using local feed mills and generic concentrate and grains (n=11). Four respondents reported feeding rolled oats, and one reported feeding spent beer grain made at home. Respondents reported feeding an average of 2.17±1.59 kg of concentrate or grain daily, (range 0 to 6.82 kg/d). Approximately 37% of the horses' representatives reported using feed scoops, coffee cans, or simply measured by eye. The most common concentrate brand fed was Purina (n=50), followed by Triple Crown (n=14), Nutrena (n=6), Tribute (n=5), Southern States (n=5), and Cavalor (n=5) were also fed. Horses were fed either once, twice, or thrice per day (Table 2).

Hay and additional roughage feeding

All horses but one were offered hay. The hays most commonly fed were Timothy (*Phleum pratense*, n=37). Orchardgrass (OG, *Dactylis glomerata*, n=10), coastal bermudagrass (*Cynodon dactylon*, n=2), and alfalfa (*Medicago sativa*, n=6) were also fed (Figure 1). The remainder of hay types included combinations of mixed grass and/or legume hay fed. Additionally, 14 individuals did not know what type of hay their horses were offered. Sixty percent of the individuals surveyed brought hay to the shows, while 36% purchased hay at the show. Only 4% of respondents reported feeding hay by weight, rather than by volume. Hay bale flakes were the most common method of measuring hay consumption (88.8%). About one-fifth of the horses were given additional roughage in their diet, including beet pulp, alfalfa cubes, and other chopped forage (Table 3).

Pasture feeding and management

19

When at home, 96.8% of horses were reported to have access to pasture (Table 3). Only 3 horses had no turnout while not competing. Reported pasture access averaged 9.8 ± 6.5 h/d and ranged from 1 h/d to 24 h/d. Respondents stated that 59.2% of horses had access to pastures containing adequate grass forage for nutrition, with grass at least 10.16-15.24 cm tall.

Supplement feeding

Approximately 62% of the horses received one or more dietary supplements on a regular basis. Most commonly given to horses were joint supplements (n=22), all-in-one performance supplements (n=20), electrolytes (n=10), and gut health supplements (n=10) (Figure 2). Other supplements provided to horses represented in the study included fat, coat, calming, and hoof supplements (Figure 5).

Nutritional concerns and sources of nutrition-related advice

Eighty-nine respondents reported no concerns regarding nutritionally related diseases and conditions (e.g. colic, laminitis, insulin resistance, ulcers, tying up) (Figure 3). Respondents had the option of checking multiple concerns, resulting in a total greater than the number of surveys collected. Of those who reported having concerns, most marked equine obesity (n=58), followed by ulcers (n=23), laminitis (n=14), and colic (n=14). Most of the individuals reported referring to multiple sources of information regarding equine nutrition, including trainers (n=77), veterinarians (n=70), feed companies (n=18), nutritionists (n=13), and the internet (n=9) (Figure 4). Seven individuals reported using no outside sources of information when making decisions on nutrition and feeding practices.

Discussion and conclusions

Data from feeding management surveys are useful when comparing feeding methods in the industry with the research-driven nutritional requirements and recommendations. To our

knowledge, this is the first feeding management study conducted on horses competing in hunter and jumper competitions in the United States, although others have conducted similar surveys exclusively on high-level showjumpers, eventing horses, and racehorses [10,21–23,28,29].

Almost all horses in this survey received at least one type of concentrate feed. However, the quantity fed was reported in not just pounds (lbs) or kilograms (kg), but also quarts and scoops. When measured by volume rather than by weight, only two-thirds of horses received the amount of concentrate intended [4]. Additionally, it has been demonstrated that equine diets often exceed NRC requirements for digestible energy and crude protein [4,10,22]. This wide variety may be indicative of the differences in training level and exercise intensity, or may demonstrate a gap in knowledge between competitors of differing levels. Because a large portion of these horses are not used for heavy work, many could likely do well with good quality grass hay alone or with a low-calorie ration balancer. Many of the horses had their daily ration divided into smaller meals fed two or more times per day.

All but one horse were offered hay, and the horse not offered hay was housed on pasture with adequate forage for nutrition. Timothy hay is a popular hay crop in the Mid-Atlantic area and was fed by many participants in this study. However, nearly one-fifth of the participants did not know what type of hay their horses received. Because owners should ideally analyze their hay and formulate a diet to meet any deficiencies in the hay, lack of knowledge may lead to unbalanced diets and feeding in excess of the horse's needs. Additionally, a majority of the particpants in the study fed hay by flake, rather than by weight. This can result in highly variable hay intake, because flakes of hay can vary widely in weight. A previous study showed only one third of horses received the amount of hay reported by owners, due to the tendency to feed by

flake [4]. An additional 17.6% received additional forage of some type, including beet pulp, rice bran, and alfalfa cubes, although reasons for feeding additional roughage were not given.

Only three horses did not have access to pasture and 68% of horses had access to pasture adequate for nutrition for a mean of 8.9 h/d. Perhaps because this study population included all levels of hunter jumper competition horses, the percentage of animals with access to turnout was greater than previously reported in studies examining horses at high levels of the sport [10,23]. Greater turnout time and more hours of access to forage may help prevent the development of behavioral vices and gastric ulcers [85].

Many supplements are commercially available to horse owners, and are widely marketed to aide a number of performance and health issues. A high proportion of animals in this study (60%) received a median of 1 and up to 4 supplements daily. The supplements most used were joint supplements (n=22), followed by all-in-one performance supplements (n=20), and electrolyte and hoof supplements (n=12). Supplement use in this study is approximately the same as reported in previous studies, or slightly lower [12,18,22]. Supplements are likely given to improve performance as well as health, although the efficacy of many of the supplements fed is unproven [35].

This study agrees with previous studies in that horse representatives often consult multiple sources for nutritional information and advice [5,20]. The most common resources were veterinarians and trainers, followed by feed company representatives. Nearly half of the study participants consult multiple sources for information. This shows that owners likely rely on information that does not come from veterinarians or nutritionists, which may or may not be baised on scientific fact. This combination of suggestions may lead to an unbalanced final diet

wherein over-supplementation of certain nutrients and unintended nutrient interactions may occur.

Interestingly, despite the frequent travel and stress associated with competitions, a majority of study participants had no nutritional concerns about their horses. Transport has been shown to be a significant stressor on horses, increasing the risk of colic and gastric ulcers [85–88]. A previous study by Leahy and others found all examined competition hoses examined to have nutritionally-related problems, including gastric ulcers, joint problens, excitability, and decreased appetite [39]. In this study, concerns mainly centered around equine obesity, with a minority expressing concerns about gastric ulcers, laminitis, and colic. While obesity is a concern in the hunter jumper industry with BCS scores above 6 on the 1 to 9 scale, it is apparent that further education is needed to inform equine representatives about the prevalence of other nutritional issues present in the industry [15].

Assessing the nutritional practices of horse representatives at both competitions revealed a variety of nutritional management methods. While most of the methods used likely resulted in a suitable feeding regime for the horses, a lack of knowledge was apparent in the sources of information and nutritional concerns. To assess feeding practices more thoroughly, it would have been necessary to analyze the diets in greater detail, by collecting and weighing feed for analysis. However, because this study relied on participant reporting, dietary analysis in greater detail was not possible. Accurately identifying the level of activity in the horses would also have been necessary to assess nutritional requirements and ability of representatives to formulate an effective diet. This demonstrates a need for increased communication between the public and veterinarians and nutritionists to increase knowledge of effective feeding practices and nutritionally related diseases.

Table 3.1. Summary and comparison of horse information collected via survey questionnaire at two hunter jumper horse shows in Northern VA.

Type	Upperville horses, n	HITS horses, n	*P*-value
Gender			
Gelding	37	52	$P = 0.11$
Mare	9	23	$P = 0.01$
Stallion	1	0	-
Breed			
Warmblood	38	47	$P = 0.20$
Thoroughbred	4	17	$P < 0.01$
Pony	0	3	-
Stock	6	8	$P = 0.60$
Discipline			
Hunter	27	13	$P = 0.02$
Jumper	9	49	$P < 0.01$
All	10	12	$P = 0.70$
Other	3	0	-

Table 3.2. Frequency of daily concentrate feeding in competition horses at two hunter/jumper horse shows in Northern VA.

Feeding Frequency	Horses, n
Once/day	3
Twice/day	81
Thrice/day	34

Table 3.3. The pasture access and types of roughage fed in addition to hay of competition horses at two hunter/jumper horse shows in Northern VA.

Item	Horses, n
Pasture	
Access to pasture	121
Access to nutritious pasture	74
Roughage types	
Beet pulp	11
Chopped forage	10
Oats	2
Rice bran	1
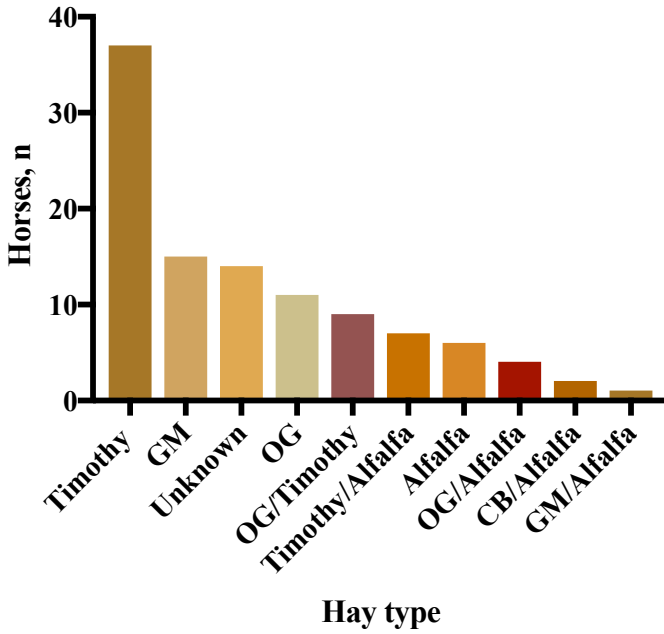
Figure 3.1. Types of hay reportedly offered to horses at two hunter/jumper competitions. Types of hay included alfalfa (*Medicago sativa*), coastal bermudagrass (*Cynodon dactylon*) (CB), timothy (*Phleum pratense*), orchardgrass (*Dactylis glomerata*) (OG). The remainder of hay types included combinations of mixed grass (GM) or legume hay.

Figure 3.2. Types of supplements reportedly offered to competition horses at two hunter/jumper competitions in Northern VA.

Figure 3.3. Nutritional concerns among equine representatives at two hunter/jumper horse shows in Northern VA.

Figure 3.4. Sources of nutrition-related advice amongst equine representatives at two hunter/jumper horse shows in Northern VA.

Chapter IV

Evaluation of body condition index in comparison with body condition score in horses and ponies

Abstract

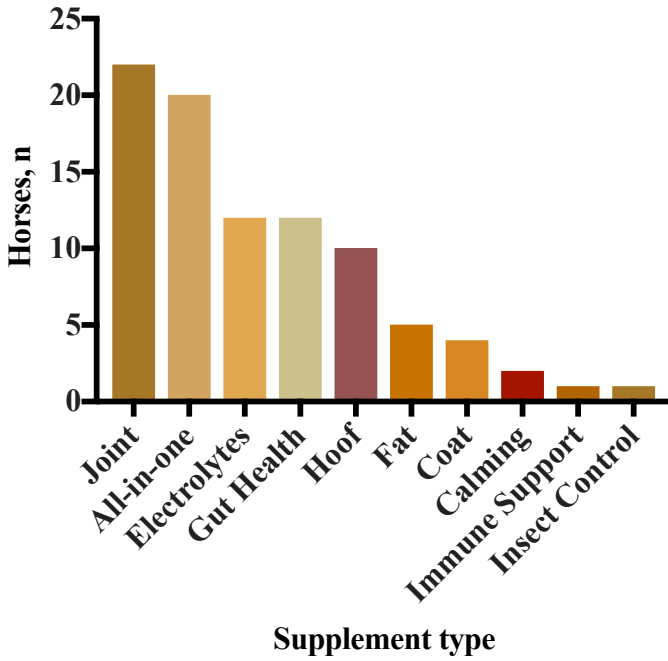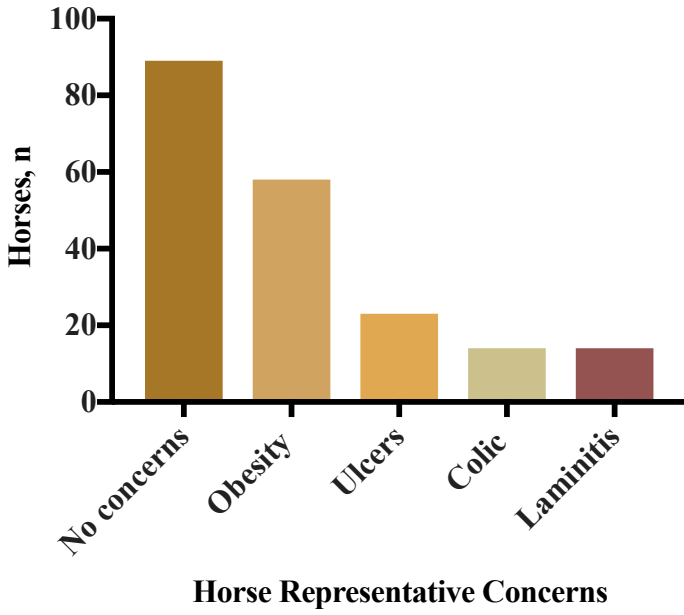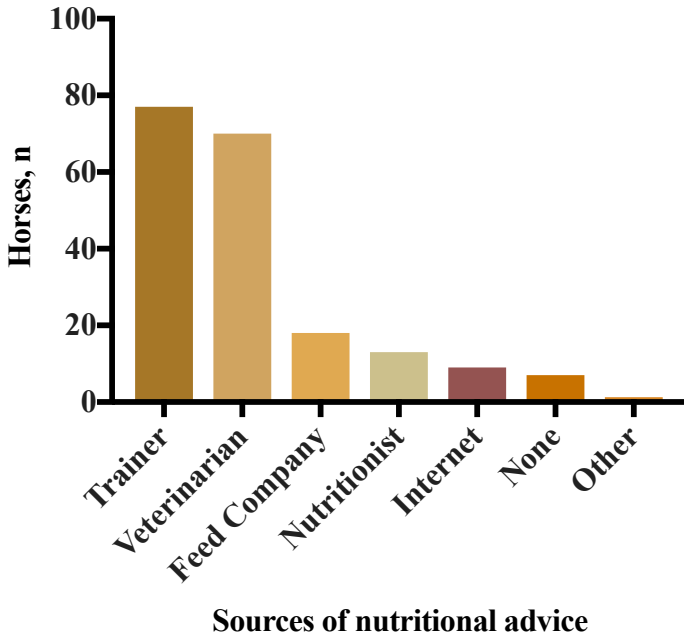Objective assessment of body condition is useful in monitoring health and fitness in performance horses. While relatively accurate and useful for experienced investigators, traditional qualitative body condition scoring systems are subjective and unreliable for inexperienced assessors, underscoring a need for a quantitative index to measure body condition. The purpose of this study was to compare the more subjective body condition scoring system (BCS) to the newly developed body condition index (BCI), similar to the body mass index (BMI) used in humans. The BCI was derived iteratively using objective measurements (cm): BCI = $[(HB^{0.5} + BG + NC^{1.2})/H^{1.05}]^{2.2}$, where HG = heart girth, BG = belly girth, NC = neck circumference, and H = height to the withers. In the current study 126 horses and ponies of varying ages (aged 1 to 26 yr) and breed types (14 Thoroughbreds, 14 ponies, 3 stock horses, and 87 warmbloods) were used to compare the BCS and the BCI. Body condition scores as assessed by experienced investigators ranged from 3.5 to 8 on a scale of 1 to 9 [16]. Body condition index scores ranged from 4.7 to 8.4 on a scale of 1 to 9. Scores were different between the BCI and BCS (P<0.0001); BCI scores were generally higher with a mean difference of 0.65. While the BCI and BCS were not meant to be exact matches (r = 0.34), it is useful to understand the potential causes of variation between the two systems, and where room for improvement exists. Mean differences were similar between Thoroughbreds, ponies, and warmblood breeds (0.67, 0.71, and 0.67 respectively), suggesting the BCI does not have a breed bias, and can cross over different confirmation types. Much of the variation likeley arises from animals with lower BCS

scores. In horses and ponies with a BCS greater than or equal to 5, the mean difference between BCI and BCS was 0.51, but in horses with a BCS less than 5, the mean difference was 1.48. These data suggest the BCI equation may need to be adjusted to better fit horses with a BCS less than 5.

Introduction

In performance horses, particularly show hunters, the 'ideal' phenotype may be above the moderate range on body condition scoring systems, and therefore horse owners may not recognize overconditioning and obesity in their animals [1,7,15]. A prevalent and growing issue in the equine industry, studies estimate 45-50% of horses to be overconditioned or obese [1,2,40,89]. Obesity is a condition in which excessive body fat accumulates to an extent that it may negatively affect the health of an individual, and has been defined as a BCS greater than or equal to 7 on a scale of 1 to 9 [16,67]). Obesity is associated with several health issues, including equine metabolic syndrome (EMS) and increased risk of endocrinopathic laminitis [52]. Body condition scores have been negatively correlated with several performance variables in different industries. Studies in endurance horses and racehorses have shown that horses with a BCS outside the accepted competition BCS range fail to complete races due to metabolic reasons, rather than nonmetabolic issues including lameness that may cause horses within the accepted competition BCS to fail to complete races [90,91].

Objective assessment of body condition is useful in monitoring the health and fitness of performance horses. While relatively accurate and useful for experienced investigators, body condition scoring is subjective and unreliable for inexperienced assessors. Several studies have shown that obesity is a prevalent issue, and that representatives of horses (owners, riders, trainers, etc.) may not be aware that their horse is overconditioned or obese, often

underestimating weight and body condition [2,7]. Lack of obesity awareness is a significant problem, as obesity is associated with both EMS and an increased risk of endocrinopathic laminitis. Accurate assessment of body condition will be useful in monitoring obese animals and weight loss.

Materials and Methods

This study was conducted at two USHJA/USEF recognized competitions in Northern Virginia during the months of June and July of 2016.

Data collection

Horse representatives (riders, owners, grooms, or trainers) voluntarily brought horses to booths set up at Upperville Colt and Horse Show (Upperville, VA, June 2016) and Horse Shows in the Sun (HITS, Culpeper, VA, July 2016). The horse shows gave permission for researchers to set up booths and conduct a voluntary questionnaire-based survey and collect non-invasive measurements of horses and ponies attending the shows.

Questionnaire

Questionnaires were voluntarily completed by representatives of the horse (e.g. owner, rider, trainer, groom), and included questions on the horse's age, breed, and sex, and type of activity. Representatives were also asked whether the horse tended to be overweight (easy keeper) , underweight (hard keeper), both, or neither.

Body Measurements

Several non-invasive measurements were taken by experienced investigators. These included body weight (BW, kg) (measured by portable calibrated weigh scales), cresty neck score (CNS), and body condition score (BCS) [16,17]. The CNS is a subjective measurement to evaluate apparent neck cresty adiposity assessed using a subjective 0 to 5 scale. The BCS scale

of 1 to 9 was used to subjectively assess visual and physical matching descriptors. Measurements

to calculate the BCI included neck circumference (NC, cm), belly girth (BG, cm), heart girth

(HG, cm), and height (H, cm) at the withers (measured on a firm level surface) using a

measuring tape (cm) [9]. Body length (cm)from point of shoulder to point of buttock was also

collected.

Results

A total of 126 measurements and 125 questionnaires were collected from representatives

of horses and ponies at the two horseshows (Upperville Horse Show n=50; HITS Culpeper

n=76). Equine representatives included owners, trainers, riders, and grooms. A summary of the

horse demographic information is provided in Table 1. The population consisted of 89 geldings,

32 mares, and 1 stallion. Horses were an average age of 9.8 ± 3.9 y old with a range of 1 to 26 y.

Most of the horses were Thoroughbreds (16.8%) and warmblood breeds (69.6%), and also

included ponies (11.2%) and a few stock type breeds (2.4%). Many of the horses' representatives

characterized their horse as belonging to more than one competition category, including hunters,

jumpers, equitation, and other. The other competition types listed included sidesaddle,

foxhunting, leadline, and eventing. However, the majority of the horses represented were

characterized as jumpers (56%) followed by hunters (47.2%).

Representatives of the horses were asked to classify their horse as being an easy keeper,

with concerns about obesity, or a hard keeper, with concerns about weight loss. A majority of the

respondents (58.4%) characterized their horse as an easy keeper (Table 2.). Four percent

indicated that their horse's classification fluctuated seasonally, having concerns about obesity in

the summer months and weight loss concerns during the winter months. Thirteen percent of

respondents considered their horse to be a hard keeper. Less than a third of respondents (13.6%)

34

had no weight concerns about their horses. Horses had an average BCS of 5.5 ± 0.7. Although

58.4% of respondents characterized their horses as an easy keeper, only 11.2% of horses were

assessed with a BCS at or above 6.5 (Figure 1). Eighty-two percent of the horses were

considered to be in ideal condition for competing, with BCS between 4.5 and 6. Only 5.6% of

horses had a BCS less than or equal to 4. The average CNS was 2.2 ± 0.8, and ranged from 1 to

4.

Measurements means and ranges for the BCI and BCS are detailed in Table 3. The BCI

was different than BCS (6.14±0.7 versus 5.5±0.7 respectively, $P<0.0001$). The two

measurements had a weak positive correlation (r^2=0.1667; $P< 0.0001$) (Figure 2). Body

condition index scores were generally higher than BCS scores by a mean difference of 0.65, but

differences as great as 2.96 existed between the two methods. Mean differences were similar

between ponies, thoroughbreds, and warmbloods (0.71, 0.67, and 0.67 respectively) suggesting

the BCI may not have a breed bias (Figure 2). However, in animals with a BCS less than 5, the

mean difference was 1.48 versus a mean difference of 0.51 in animals with a BCS greater than 5

(Figure 3). The large mean difference in horses with a lower BCS means these horses may

require an adjusted equation for accurate estimation of adiposity.

Discussion and conclusions

This study compared the body condition score and body condition index score in

performance horses at competitions in Northern Virginia. Although this study looked at high

level completion jumper horses and lighter level competition horses, the average BCS is in

agreeance with previous studies in high level eventing and show jumping competitions, rather

than with studies in leisure horses [21,22]. Studies in leisure horses and the general population of

horses have found much higher rates of obesity than those on competition horses [2,40]. Despite

the likely lighter workload of many of the animals, the prevalence of obesity was less than that of Pony club horses and ponies in Australia [7]. The incidence of overcondition and obesity was only 4%, but 4 of the 5 animals displaying were ponies. While this is a relatively small samples size of ponies, these data may support previous findings that breed is one of the risk factors most strongly related to obesity [92].

Just over half of respondents had concerns regarding obesity and weight gain in their horses. Few respondents (21%) indicated they were concerned about neither weight loss nor weight gain, despite a finding of the commonality of gastric ulcers, decreased appetite, and weight loss in high level event horses [39]. While the hunter jumper competitions included many lower level performance animals, they are still subject to the stress and travel of competitions, so the lack of concern is surprising. The respondents who were concerned with both summer weight gain and winter weight loss follow the pattern outlined by Morrison and others [12]. More competition horses were fed competition mixes and grains in the summer to support higher levels of work, and were found to be fed conditioning feeds in the winter in addition to competition mixes.

The mean differences between different breed types indicated there is not a breed bias in the body condition index. This is in disagreement with a previous study that found ponies and draft breeds to be significantly different from stock type breeds [93]. A larger sample size of ponies and different breeds would be useful to further correct the BCI equation and ensure accurate results. In this study, the largest mean difference was 1.48 in horses with a BCS less than 5. This means that owners with potentially underconditioned or normal animals could measure their horses, and be told they are obese. As many owners already struggle to regularly monitor weight and condition, this finding could be detrimental to the health of the horse. Many

owners do not know what BCS is, or admit to not fully understanding it [2,6]. As the BCI follows the same scales as the BCS, adjustments to the equation may be needed to minimize confusion in the public and ensure correct information is disseminated.

Many owners appear to underestimate body condition in their animals (~54.1%), and there is often disagreement between scores of experienced investigators and scores of inexperienced owners and assessors [7,40]. Although this study did not find a high proportion of obesity, many previous studies have found obesity rates close to 50% [2,7,22]. Because of the tendency for owners to underestimate the body condition of their horses, it is important to establish a greater awareness of how to properly asses body condition. The BCI may prove helpful in the future by establishing a quantitative, rather than subjective method of monitoring and assessing body condition, providing benefits in terms of preventative healthcare in horses and reducing risk of obesity, insulin resistance, and laminitis.

Table 4.1. Summary of hunter jumper performance horse demographics at two competitions in Northern VA. Data are presented as means ± standard deviation (SD) and number of horses (n).

Item	Mean ± SD	Range
Age (y)	9.8 ± 3.9	1-26
Weight (kg)	562.7 ± 92.8	156.8-715.9
Type	**Number of horses, n**	
Horses	111	
Ponies	14	
Warmbloods	85	
Thoroughbreds	21	

Table 4.2. Equine representative classification of weight management type of hunter/jumper horses at two competitions in Northern VA.

Classification	Number of Horses, n
Easy keeper	73
Hard keeper	17
Both	5
Neither	27

Table 4.3. Morphometric measurements and assessments of hunter/jumper horses at two horse shows in Northern VA. Data are presented as means ± standard deviation (SD).

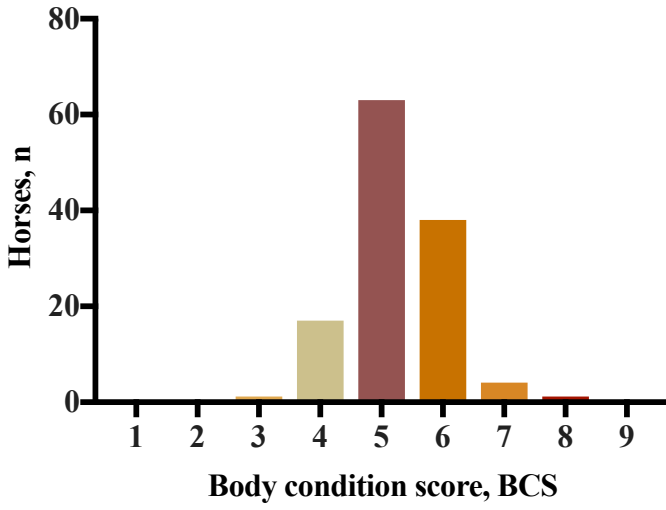| Measurement	Mean ± SD	Range
Height to withers, H (cm)	161.58 ± 11.72	110-182
Neck circumference, NC (cm)	100.32 ± 7.63	65-118
Heart girth, HG (cm)	191.60 ± 12.85	126-214
Belly girth, BG (cm)	208.83 ± 13.67	142-232
Body condition score, BCS	5.5 ± 0.70	2.5-8.0
Cresty neck score, CNS	2.2 ± 0.80	1-4
Body condition index, BCI	6.14 ± 0.66	4.7-8.4

Figure 4.1. The body condition scores (BCS) on a 1-9 scale of horses assessed at two hunter/jumper horse shows in Northern VA.
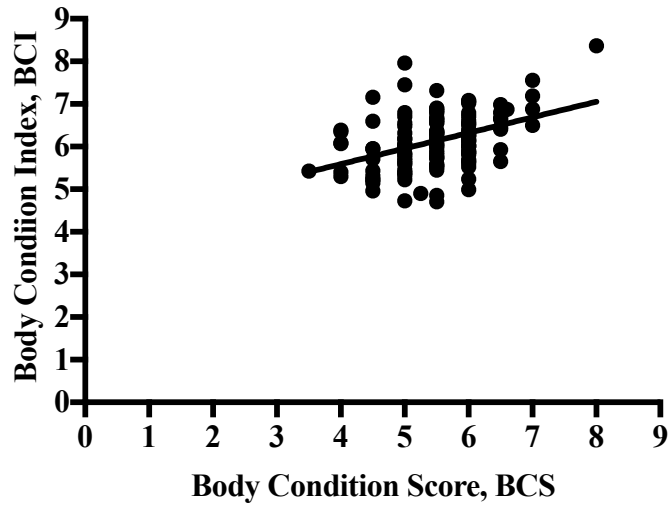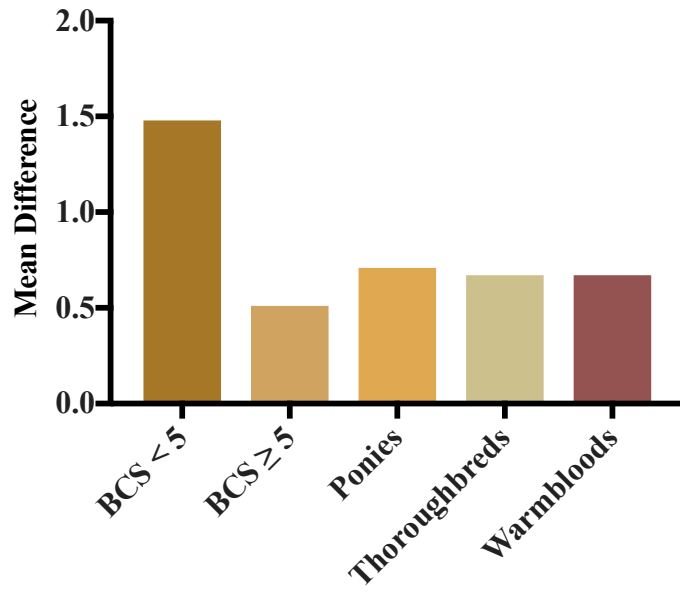
Figure 4.2. Pearson correlation between body condition score (BCS) and body condition index (BCI) in hunter/jumper competition horses, $r^2 = 0.163$.

Figure 4.3. Mean differences between the BCS and BCI in various BCS and breed categories.

Chapter V

Effects of DigestaWell® Buffer in overconditioned horses fed rapidly introduced nonstructural carbohydrates

Abstract

Elevated intake of nonstructural carbohydrates (NSC) in the equine diet is associated with metabolic and digestive disorders, particularly in overconditioned horses. The prevalence of equine obesity and associated diseases necessitates the development of management strategies to counter the effects of elevated NSC intake. The objective of this study was to determine the efficacy of DigestaWell® Buffer (DB) (a proprietary blend of sodium bicarbonate, vitamin B12, and cobalt micro-encapsulated in a vegetable fat matrix) in mitigating the negative postprandial effects of a rapidly introduced moderate NSC meal in overconditioned horses. Six mature warmblood mares (BCS ≥ 6.5; 623±51 kg BW; ages 15±2 yr) were used in a randomized cross-over design with a 10 d washout. Horses received both treatments including a concentrate that provided 1.2 g/kg BW of NSC alone (CON) or the concentrate topdressed with 150 g of DB. For the duration of the study, horses were offered free choice water. Horses were housed in a dry lot for 14 d prior to the study and offered grass hay (12.6% NSC) ad libitum. Horses were placed into 4X4m stalls, offered 2.5% BW grass hay and fitted with long term indwelling venous catheters (MILACATH, MILA International Inc., Florence, KY) between 1600 and 1700. Hay was removed at 2200 and horses were fasted overnight. At 0800 all horses received CON or DB and at 0900 feed refusals and consumption rate were measured. Horses were offered 2.5% BW grass hay each d for the remainder of the study. Blood samples were collected at -1, 1, 2, 4, 6, 8, 12, 16, 24, 36, 48, and 72 h post feeding to measure plasma glucose, D- and L-lactate. Fecal samples were collected -1, 4, 8, 12, 16, 24, 36, 48, and 72 h post feeding to measure pH. Data

were analyzed using mixed models ANOVA with repeated measures for the effects of time, treatment, the time by treatment interaction, and period. Data are presented as means and CI. Plasma glucose increased postprandially ($P<0.0001$) with no effect of treatment. The buffer reduced postprandial L-Lactate concentrations (642.69[612.77-673.91] vs. 600.90[572.93-630.09]umol/L) ($P=0.05$), but did not have an effect on D-lactate ($P=0.58$). Horses on the HB treatment tended to have a higher fecal pH than control horses (6.95±0.034 vs. 6.86±0.034, respectively) ($P=0.08$). Given these findings, we believe DigestaWell® Buffer may mitigate some of the negative effects of rapid starch and sugar fermentation in the hindgut of overconditioned horses. Further research is needed to evaluate the effects of the buffer on the metabolic and digestive responses in horses prone to laminitis.

Introduction

Research has indicated that more than half of the studied populations were overconditioned or obese [2,42,94]. Obesity has been associated with equine metabolic syndrome (EMS), a disease characterized by insulin resistance, regional adiposity, and a predisposition to laminitis. It is possible that consumption of concentrates and feeds high in starches and sugars may increase the degree of insulin resistance in obese horses [95]. Several surveys have shown that concentrates are fed by more than 80% of horse caretakers on a daily basis [6,12]. In competition animals, more than 90% of horses receive concentrate feeds daily [10,22,23]. The adaptation of horses to high starch concentrates may result in a decrease in insulin sensitivity. Resting hyperinsulinemia is associated with laminitis, a debilitating and potentially fatal disease of the hoof laminae, and increased risk has been connected to insulin resisitance [14,17,55]. Because of the cost and pain associated with this disease, it is important to

establish the role of high starch diets in the development of laminits and to find strategies to mitigate the results of consumption of a high starch diet.

When horses are fed excessive amounts of starch, it has the potential to overwhelm the foregut. Upon entering the hindgut, rapid fermentation of the starch induces changes in the microbial populations of the hindgut. Proliferation of gram-positive bacteria, particularly lactic acid-producing lactobacilli or streptoccoci decreases the hindgut pH, resulting in the death of large numbers of bacteria and release of endotoxins from their cell walls [68,74]. The release of endotoxins can initiate a systemic inflammatory response, promoting the production of proinflammatory cytokines. Interleukin-1ß is a proinflammatory cytokine known to reduce insulin sensitivity [96].

Models using oligofructose, another rapidly fermented carbohydrate, have shown differences as soon as 4 hours after dosing [71]. Cecal pH decreases, and concentrations of lipopolysaccharide (LPS) and organic acids such as lactate are increased [74]. Greater concentrations of LPS have been shown to increase concentrations of plasma proinflammatory cytokines and decrease insulin sensitivity [75,76,96].

Continuous production of saliva provides bicarbonate that seems to buffer the proximal region of the stomach, lessening the decline in pH associated with lactic acid [97]. As digesta moves through the gastrointestinal tract, pancreatic juice and bile are continuously produced. As a result, concentrations of pancreatic enzymes and bicarbonate are low in the large intestine. When not overloaded by large doses of starch, the pancreatic juice and bile are sufficiently able to buffer the intestines. When the microbial populations of the hindgut are disturbed, lactic acid production overwhelms the buffering capabilites. Supplementing sodium bicarbonate can help increase cecal pH, and prevent the changes that result from a decreased pH [98]. Therefore, the

objective of this study is to investigate the effects of a rapidly introduced, moderate starch meal on overconditioned horses with and without DigestaWell® Buffer, a proprietary sodium bicarbonate buffer product.

Materials and Methods

Experimental Design

The Virginia Tech Institutional Animal Care and Use Committee approved this research protocol. Six mature, overconditioned warmblood mares (BCS ≥ 6.5; 623 ± 51 kg BW; 15 ± 2 yr) were randomly assigned to one of two treatments in a crossover design with a 10 d washout period. All horses received a concentrate meal providing 1.2 g NSC per kg BW alone (CON, control treatment), or with 150 g DigestaWell® Buffer (a proprietary blend of sodium bicarbonate, vitamin B12, and cobalt micro-encapsulated in a vegetable fat matrix) top-dressed onto their concentrate (DB, DigestaWell® Buffer treatment). The concentrate used was a commercially available sweet feed (Pleasure Sweet, Buckeye Nutrition, Dalton, OH, USA) (Table 1). Prior to the study, horses were housed on a dry lot for 14 d and offered grass hay and water ad libitum (Table 1). Between 1600 and 1700 on d 0, horses were placed in 4x4 m stalls, offered 2.5% BW grass hay and water, and fitted with long-term indwelling venous catheters (MILACATH, MILA International Inc., Florence, KY). Catheter sites were prepped by clipping and sterilizing with chlorhexidine and 70% alcohol. Catheters were kept patent with heparinized saline. Hay was removed at 2200 and horses were fasted overnight. At 0800 horses received CON or DB and at 0900 horses were offered 2.5% BW grass hay, and feed refusals and consumptions rates were measured. Horses were offered 2.5% BW grass hay each day for the remainder of the study and refusals were measured each day. Blood samples were collected at -1, 0, 0.5, 1, 2, 4, 6, 8, 12 ,16, 24, 36, 48, and 72 h post feeding to measure plasma insulin, glucose,

D- and L-lactate, IL-1ß, and LPS. Fecal samples were collected -1, 4, 8, 12, 16, 24, 36, 48, and 72 h post feeding to measure pH and fecal d-lactate.

Plasma Analysis

Blood samples were centrifuged at 3000 x *g* and plasma removed and stored at -20°C until analysis. Plasma was analyzed for concentrations of D-lactate (uM) (D-lactate Assay Kit, Eton Biosciences, San Diego, CA, USA), lipopolysaccharide (EU/mL) (LPS, Endotoxin Detection Kit, InvivoGen, San Diego, California, USA), insulin (uIU/mL) (Mercodia Equine Insulin ELISA, Mercodia, Winston-Salem, NC, USA), interleukin 1-beta (ng/mL) (IL-1ß, Equine IL-1beta ELISA, Kingfisher Biotech, St. Paul, MN, USA), and glucose and L-lactate (ug/dL) (YSI 2300 STAT Plus, YSI Life Sciences, Yellow Springs, OH, USA).

Fecal Analysis

Fecal samples were collected either rectally or fresh of the ground whenever possible. Samples were analyzed for pH immediately following collection (Metler Toledo, Columbus, OH, USA). Samples were then stored at -80°C until analysis for fecal D-lactate (uM) (D-lactate Assay Kit, Eton Biosciences, San Diego, CA, USA).

Data Analysis

Data were analyzed using the mixed models procedure (MIXED) of SAS (SAS v. 9.3, SAS Institute Inc., Cary, NC, USA), using repeated measures analysis of variance (ANOVA) for effects of time, treatment, time by treatment interaction, and period. Where necessary, data are presented as means and CI.

Results

Insulin concentrations increased postprandially for all horses at all timepoints beginning one hour post-feeding ($P<0.0001$), and failed to return to baseline values (Figure 1). One horse

had much greater values than all the others, and was removed from the dataset as an outlier. There was no effect of treatment or a time by treatment interaction on insulin concentrations. Plasma glucose increased postprandially in all horses beginning at one hour post-meal, and returned to baseline values 4 hours after the meal ($P<0.0001$) (Figure 1). There was no effect of treatment, or a time by treatment interaction on glucose concentrations ($P=0.78$ and 0.93, respectively).

The buffer reduced postprandial L-lactate concentrations (642.69[612.77-673.91] vs. 600.90[572.993-640.09]umol/L) ($P=0.05$) in comparison to horses not on the buffer (Figure 2). Plasma concentrations of l-lactate increased at 1 hour and 8 hours after the meal, but were not different at any other time point ($P=0.014$). There was no effect by time and treatment on plasma l-lactate concentrations ($P=0.83$). Concentrations of plasma D-lactate were not different between treatments, and there was no effect of time or time by treatment interaction ($P>0.17$) (Figure 3). The concentration of plasma LPS tended to be lower in horses on the control diet, and higher in horses on the DigestaWell Buffer ($P=0.1$) (Figure 4). There were no differences in IL-1ß concentrations for treatment, time, or time by treatment interaction ($P>0.2$). The IL-1ß concentration in 2 horses was below the standard curve at nearly every point, and one horse was found to be an outlier and dropped from the data set due to IL-1ß concentrations nearly four times greater than the other horses.

Horses receiving the buffer tended to have higher fecal pH values compared to control horses (6.95±0.034 vs. 6.86±0.034, respectively) ($P=0.08$) (Figure 5). At hours 4, 8, 12, 48, and 72 after the meal, fecal pH was higher than baseline values ($P<0.01$). During hours 16, 24, and 36 fecal pH was not different than baseline. Concentrations of fecal D-lactate did not differ by time or time by treatment interaction ($P>0.3$). There was a tendency for horses receiving the

buffer to have greater concentrations of fecal D-lactate than horses not receiving the buffer (P=0.07).

Discussion and conclusions

Many horses receive a concentrate or grain based diet, and therefore consume an elevated level of NSC. Nearly all competition and performance horses receive at least one type of concentrate in their diet [18,21,28], and surveys have shown that more than 60% of horses, including leisure horses, receive some type of concentrate daily [12,20]. Although horses most likely evolved eating a made up of slowly fermentable carbohydrates rather than rapidly fermented starches and sugars, the concentrates fed today are usually high in NSC. Intake of high levels of NSC can overwhelm the digestive capacity of the equine foregut, allowing starch to overflow into the hindgut. This overflow and fermentation can disturb microbial populations, leading to increased lactic acid production and a drop in pH [99]. As bacteria not tolerant to lower pH die, their cell walls release endotoxin. A lower pH can lead to a "leaky gut," allowing the LPS to escape into the bloodstream of the horse and increase inflammatory protein production [75,66,76]. The proinflammatory cytokine IL-1ß has been shown to increase as a result of LPS [100]. Bacterial fermentation in the hindgut also results in the production of two isomers of lactic acid. L-lactate is produced by the metabolic activities of the animal, while D-lactate is an indicator of bacterial lactic fermentation [68]. Following a large starch meal, D-lactate concentrations spike after approximately 20 hours. The goal of this study was to determine whether feeding a timed-release supplement containing bicarbonate, cobalt, and vitamin B12 (DigestaWell Buffer™) could alleviate the increases in inflammation following the meal.

In this study, all horses had increased concentrations of insulin and glucose following the meal. This indicates the horses responded glycemically to the meal. However, in the overconditioned horses in this study, concentrations of IL-1ß did not differ between treatment groups, and did not differ from baseline levels. These data do not agree with previous studies in which metabolically normal horses demonstrated increased plasma IL-1ß concentration 1 hour after a moderate NSC meal [100]. The same study also reported changes in LPS concentrations following the meal. However, this study showed a tendency for LPS concentrations to be slightly higher in horses offered the CON compared to the DB. Horses offered the DB had a tendency to have a higher fecal pH than control horses, indicating that DigestaWell Buffer™ may have had an effect despite the conficting results. Given the conflicts in these findings, we believe metabolically normal and obese horses likely have different gut microbiomes, and overconditioned horses respond differently to the high starch dietary insults.

Obese animals, particularly those with a history of laminitis, have been shown to have different fecal microbiota than metabolicly normal animals [101]. In particular, obese horses have increased numbers of Verrucomicrobia, which could be an adapted protective effect in response to EMS and obesity [102]. Akkersmansia, a genus of mucin-degrading bacteria belonging to the Verrucomicrobia phylum, aids in maintaining the integrity of the mucin layer and decreasing inflammation [103]. Although the authors noted that differences in the microbiota between EMS horses and normal horses were limited, the present changes could indicate that the differences are capable of influencing health.

This study also measured concentrations of plasma and fecal D- and L-lactate, two isomers by lactic acid. D-lactate, produced by gastrointestingal bacteria, is indicative of microbial fermentation, and we hypothesized that rapidly introduced starch consumption would

51

increase concentrations as reported in other species [104]. However, concentrations of both

plasma and fecal D-lactate did not differ betweent the two treatments. However, concentrations

of L-lactate were decreased in the treatment horses. Fecal pH had a tendency to be higher in

treatmetn horses compared to control horses. It is possible D-lactate is not produced in suffcent

concentration to be measured following a starch meal, or it is converted to L-lactate via racemase

enzymes produced by intestinal bacteria [105]. The reduced concentrations of L-lactate in this

study could in this case indicate a decreased concentration of plasma D-lactate as well. It is also

possible that D-lactate could be rapidly metabolized by the liver, but the capacity to metabolize

D-lactate has not been studied in the horse as it has in other species such as cattle [104].

All horses on this study had elevated postprandial concentrations of glucose and insulin,

but treatment groups had no differences in concentrations of plasma Il-1ß or plasma and fecal D-

lactate. However, there were indications that the gastrointestinal tract was buffered against starch

fermentation in horses who consumed DigestaWell Buffer™ with the moderate NSC meal. The

increased fecal pH and decreased concentrations of L-lactate in treatment horses indicates that

DigestaWell Buffer™ was at least partially successful in mitigating the effects of rapidly

introduced high starch intake. Further research is needed to determine differences in the

microbiota of obese animals, as these differences may be the reason behind the lack of

inflammatory response seen in this study.

Table 5.1. Nutrient analysis of hay fed during the study and washout periods, concentrate offered during study periods, and DigestaWell® Buffer (DB) topdressed on the concentrate offered to DB horses.

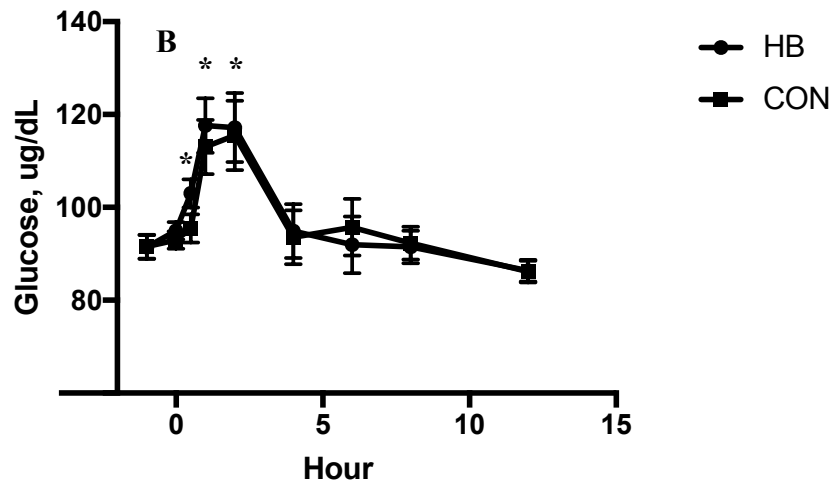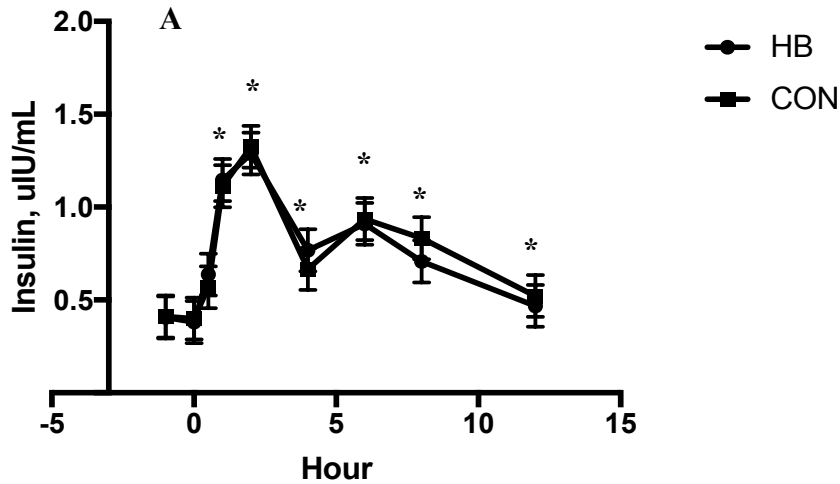| Nutrient	Hay	Concentrate	DigestaWell® Buffer
Crude protein, % DM	10.4	12.0	
Crude fat, % DM	14.5	6	
Nonstructural carbohydrates, % DM	12.9	37.1	
Starch, % DM	2.3	31	
Neutral detergent fiber, % DM	67		
Acid detergent fiber, % DM	39.6		
Calcium, % DM	0.41		
Phosphorous, % DM	2.13		
Magnesium, % DM	1.54		
Potassium, % DM	13.92		
Sodium Bicarbonate, % DM			0.60
Cobalt, mg/g			0.10
Cobalamin, mg/g			0.01

Figure 5.1. Insulin (A) and glucose (B) concentrations in horses following consumption of a meal providing 1.2g/kg BW NSC. Means for insulin and glucose were affected by time ($P<0.0001$), but not by treatment or time by treatment interaction. *Means are different from hour -1 ($P<0.01$).

Figure 5.2. Plasma L-lactate concentrations in horses following consumption of a meal providing 1.2g/kg BW NSC. Means for L-lactate concentration were lesser in the treatment group ($P=0.05$) compared to the control group. *Means are different from hour -1 ($P=0.014$).
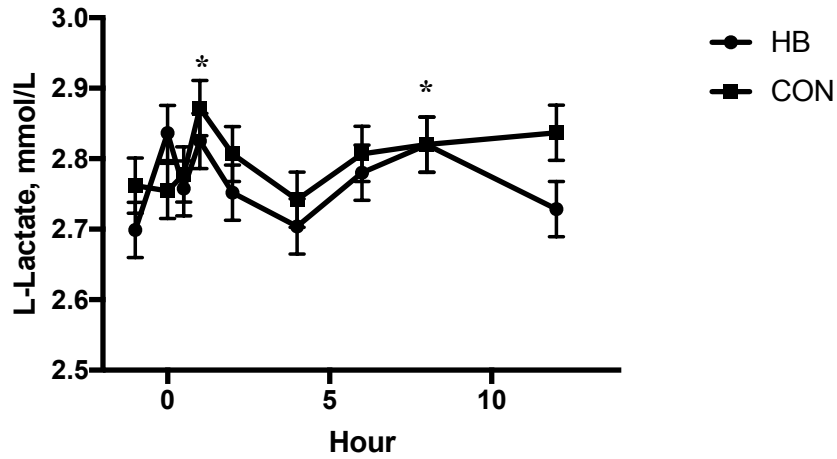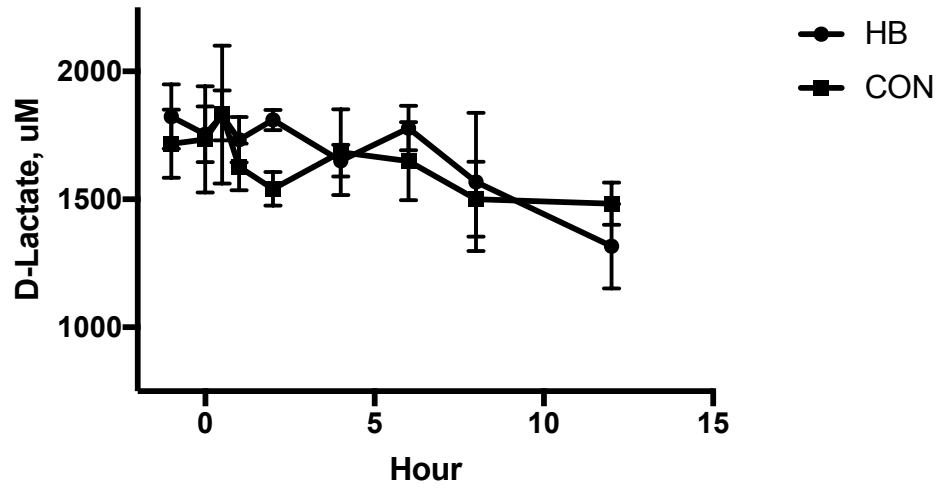
Figure 5.3. Plasma D-lactate concentrations in horses following consumption of a meal providing 1.2g/kg BW NSC. There were no effects of time, treatment, or time by treatment interaction on plasma D-lactate ($P>0.17$).
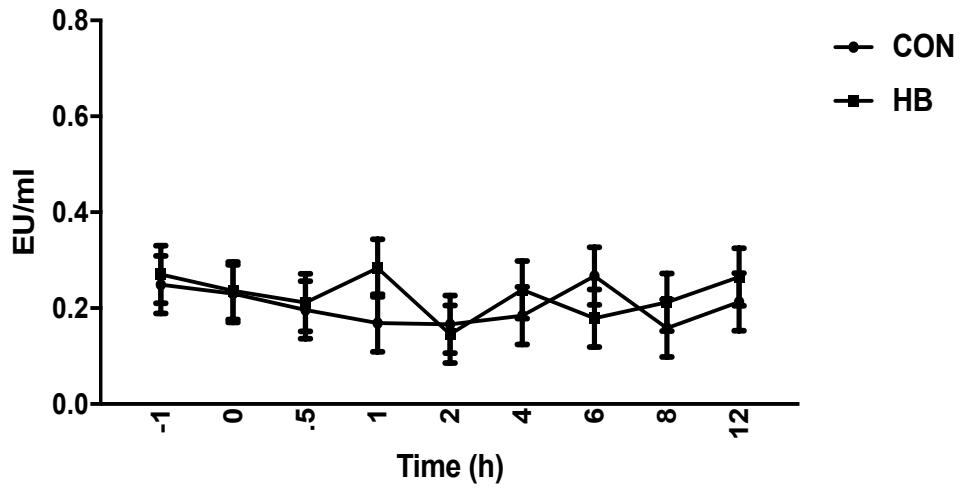
Figure 5.4. LPS concentrations in horses following consumption of a meal providing 1.g/kg BW NSC. LPS means tended to be greater in treatment horses (P=0.1) compared to control horses. There was no effect of time or time by treatment interaction.
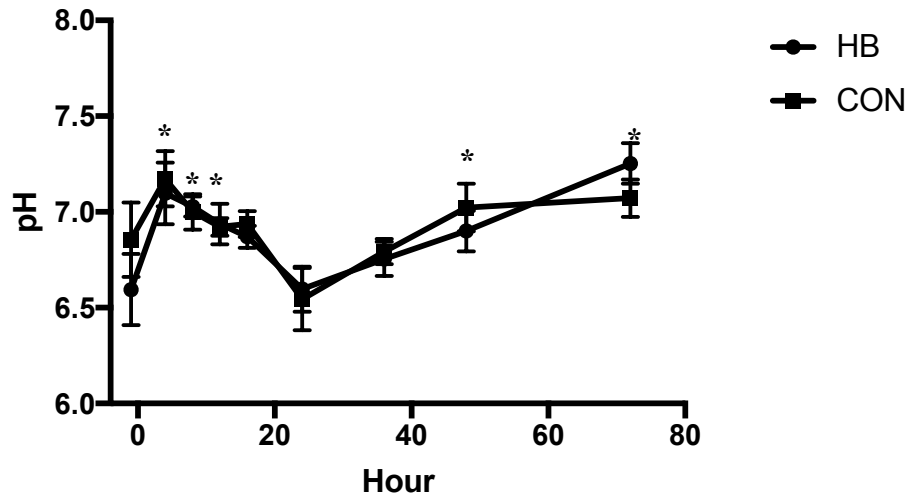
Figure 5.5. Fecal pH in horses following consumption of a meal providing 1.2g/kg BW NSC. Fecal pH means tended to be greater in the treatment group compared to the control group (*P*=0.08). *Means are different from hour -1 (*P*<0.01).

Chapter VI

Conclusions

The purpose of these studies was to identify the nutritional practices and management of show hunter and jumpers, assess the prevalence of obesity and evaluate a quantitative method to estimate adiposity in sporthorses, and to evaluate the effects of a hindgut buffer product in overconditioned horses following an abruptly introduced moderate starch meal. Most research on nutritional management has focused exclusively on either recreational horses or high level showjumping, eventing, or racing competition horses, while this research focused on both show hunter and jumper horses and examined nutritional practices, concerns, and sources of nutritional advice.

The first study utilized a voluntary survey at two hunter/jumper competitions in Northern VA during the summer of 2016. While horse representatives (owners, trainers, riders, or grooms) completed the surveys, morphometric measurements of the horse were taken for the second study to compare the body condition scale (BCS) to the body condition index (BCI). The first survey found feeding practices consistent with previous survey of performance horses, and that horse representatives had few nutrition-related concerns than anticipated, considering travel and other stresses associated with horse showing. An unexpected result was the low number of overweight and obese horses present at the horse shows, considering previous studies finding show hunters and pony hunters are often overweight. Additionally, the BCI is likely a suitable alternative from the BCS for many horses and owners, but there is a need for more data collection to further examine differences in breed and body type.

During the third study, overweight warmblood mares were offered a moderate starch meal with and without DigestaWell® Buffer. This study was unique in that it utilized overweight

horses with a history of laminitis and insulin resistance rather than metabolically normal horses. There were no differences in inflammatory or metabolic markers between the treatment and control groups, however differences were present in decreased plasma L-lactate in tereatment horses, as well as a tendency for higher fecal pH and lower fecal D-lactate in treatment horses. These results indicate DigestaWell® Buffer alleviates some of the effects of a starch overload, and warrants further investigation in the future.

The findings from this research support a need for further nutritional education for equine representatives. Future work should aim to improve relationships between equine representatives, trainers, veterinarians, and professional equine nutritionists to ensure ideal diet formulation and to improve nutritional knowledge in the equine industry. The prevalence of equine obesity indicates a gap in knowledge of how to assess condition and the implications of obesity and related diseases. The BCI will be a useful tool in the future for horse owners to objectively assess adiposty in their horses, allowing timely changes to feeding programs to prevent weight gain or loss. Further research is required to evaluate the effects of buffer products as a tool to mitigate the effects of NSC on the metabolic, digestive, and inflammatory responses of horses in different settings, including daily concentrate feeding and pasture grazing.

Laminitis is not a curable disease, and cannot be treated to full soundness recovery. As such, it is important to develop awareness of nutritional practices that lead to obesity and insulin resistance, and increase the chances of laminitis development. It is equally as important to focus research efforts on methods to avoid and prevent laminitis by educating the equine industry and developing effective means to combat development of nutrition-related diseases and increase quality of life for equines.

References

[1]   Stephenson HM, Green MJ, Freeman SL. Prevalence of obesity in a population of horses in the UK. Vet Rec 2011;168:1. doi:10.1136/vr.c6281.

[2]   Thatcher CD, Pleasant RS, Geor RJ, Elvinger F. Prevalence of Overconditioning in Mature Horses in Southwest Virginia during the Summer. J Vet Intern Med 2012;26:1413–8. doi:10.1111/j.1939-1676.2012.00995.x.

[3]   USDA. Lameness and laminitis in U.S. horses. Natl. Anim. Heal. Monit. Syst., 2000, p. 1–34 #N318.0400.

[4]   Honoré EK, Uhlinger CA. Equine feeding practices in central north carolina: a preliminary survey. J Equine Vet Sci 1994;14:424–9. doi:10.1016/S0737-0806(06)82009-5.

[5]   Hoffman CJ, Costa LR, Freeman LM. Survey of Feeding Practices, Supplement Use, and Knowledge of Equine Nutrition among a Subpopulation of Horse Owners in New England. J Equine Vet Sci 2009;29:719–26. doi:10.1016/j.jevs.2009.08.005.

[6]   Murray JAMD, Bloxham C, Kulifay J, Stevenson A, Roberts J. Equine Nutrition: A Survey of Perceptions and Practices of Horse Owners Undertaking a Massive Open Online Course in Equine Nutrition. J Equine Vet Sci 2015;35:510–7. doi:10.1016/j.jevs.2015.02.005.

[7]   Potter SJ, Bamford NJ, Harris PA, Bailey SR. Prevalence of obesity and owners??? perceptions of body condition in pleasure horses and ponies in south-eastern Australia. Aust Vet J 2016;94:427–32. doi:10.1111/avj.12506.

[8]   Elizabeth L, Wagner P, Patricia J, Tyler M. A Comparison of Weight Estimation Methods in Adult Horses. J Equine Vet Sci 2011;31:706–10.

[9]   Potter S, Harris PA, Bailey SR. Derivation of a new body condition index to estimate body fat percentage from morphometric measurements: Comparison with body condition score. J Equine Vet Sci 2015;35:410–1.

[10]   Martin L, Geffroy O, Bonneau A, Barré C, Nguyen P, Dumon H. Nutrient intake in high performance show-jumping horses in France. Nutr Exerc Horse 2008;125:333–9.

[11]   Wylie CE, Ireland JL, Collins SN, Verheyen KLP, Newton JR. Demographics and management practices of horses and ponies in Great Britain: A cross-sectional study. Res Vet Sci 2013;95:410–7. doi:10.1016/j.rvsc.2013.05.004.

[12]   Morrison PK, Harris PA, Maltin CA, Grove-White D, Barfoot CF, Argo CMG. Perceptions of Obesity and Management Practices in a UK Population of Leisure-Horse Owners and Managers. J Equine Vet Sci 2017;53:19–29. doi:10.1016/j.jevs.2017.01.006.

[13]   Treiber KH, Boston RC, Kronfeld DS, Staniar WB, Harris PA. Insulin resistance and

compensation in Thoroughbred weanlings adapted to high-glycemic meals. J Anim Sci 2005;83:2357–64.

[14]   Treiber KH, Kronfeld DS, Geor RJ. Insulin Resistance in Equids: Possible Role in Laminitis. J Nutr 2006;136:2094–8.

[15]   Martin O. Feeding horses at the Winter Equestrian Festival: a review of common practices. Proc. 2010 Kentucky Equine Res. Nutr. Conf., 2010, p. 127–31.

[16]   HENNEKE DR, POTTER GD, KREIDER JL, YEATES BF. Relationship between condition score, physical measurements and body fat percentage in mares. Equine Vet J 1983;15:371–2. doi:10.1111/j.2042-3306.1983.tb01826.x.

[17]   CARTER RA, TREIBER KH, GEOR RJ, DOUGLASS L, HARRIS PA. Prediction of incipient pasture-associated laminitis from hyperinsulinaemia, hyperleptinaemia and generalised and localised obesity in a cohort of ponies. Equine Vet J 2009;41:171–8. doi:10.2746/042516408X342975.

[18]   Verhaar N, Rogers CW, Gee EK, Bolwell CF, Rosanowski SM. The Feeding Practices and Estimated Workload in a Cohort of New Zealand Competition Horses. J Equine Vet Sci 2014;34:1257–62. doi:10.1016/j.jevs.2014.08.008.

[19]   Frank N. Endocrinopathic laminitis, obesity-associated laminitis, and pasture-associated laminitis. AAEP Proc., 2008, p. 341–6.

[20]   NAHMS USDA. National Animal Health and Monitoring System, Equine Mortality and Morbidity Info Sheet 1998.

[21]   Burk A, Williams C. Feeding management practices and supplement use in top-level event horses. Comp Exerc Physiol 2008;5:85–93. doi:10.1017/S1478061508062786.

[22]   Pratt-Phillips SE. Feeding Practices and Nutrient Intakes Among Elite Show Jumpers. J Equine Vet Sci 2016;43:39–43. doi:10.1016/j.jevs.2016.04.097.

[23]   Brunner J, Wichert B, Burger D, von Peinen K, Liesegang A. A survey on the feeding of eventing horses during competition. J Anim Physiol Anim Nutr (Berl) 2012;96:878–84. doi:10.1111/j.1439-0396.2012.01324.x.

[24]   Müller CE. Impact of harvest, preservation and storage conditions on forage quality. EAAP Sci Ser 2012;132:237–54. doi:10.3920/978-90-8686-755-4_29.

[25]   Borgia L, Valberg SJ, Watts K, Pagan J. Glycemic/insulinemic response to feeding hay with different water soluble carbohydrate content in healthy and polysaccharide storage myopathy-affected horses. J Equine Vet Sci 2009;29:355–7.

[26]   Martinson K, Jung H, Hathaway M, Sheaffer C. The Effect of Soaking on Carbohydrate Removal and Dry Matter Loss in Orchardgrass and Alfalfa Hays. J Equine Vet Sci 2012;32:332–8. doi:10.1016/j.jevs.2011.11.009.

[27]   Longland AC, Barfoot C, Harris PA. Effects of soaking on the water-soluble carbohydrate and crude protein content of hay. Vet Rec 2011;168:618–618. doi:10.1136/vr.d157.

[28]   Williamson A, Rogers CW, Firth EC. A survey of feeding, management and faecal pH of Thoroughbred racehorses in the North Island of New Zealand. N Z Vet J 2007;55:337–41. doi:10.1080/00480169.2007.36790.

[29]   Brunner J, Liesegang A, Weiss S, Wichert B. Feeding practice and influence on selected blood parameters in show jumping horses competing in Switzerland. J Anim Physiol Anim Nutr (Berl) 2015;99:684–91. doi:10.1111/jpn.12266.

[30]   Jackson S, Pagan JD. Equine nutrition evaluation. Large Anim Vet 1993;48:20–4.

[31]   Garner HE, Hutcheson DP, Coffman JR, Hahn AW, Salem C. Lactic acidosis: a factor associated with equine laminitis. J Anim Sci 1977;45:1037–41.

[32]   Kronfeld D, Harris P. Equine grain-associated disorders. Compendium 2003;25:974–83.

[33]   Kagan IA, Kirch BH, Thatcher CD, Strickland JR, Teutsch CD, Elvinger F, et al. Seasonal and Diurnal Variation in Simple Sugar and Fructan Composition of Orchardgrass Pasture and Hay in the Piedmont Region of the United States. J Equine Vet Sci 2011;31:488–97. doi:10.1016/j.jevs.2011.03.004.

[34]   Longland AC, Byrd BM. Pasture Nonstructural Carbohydrates and Equine Laminitis. J Nutr 2006;136:2099S–2102S.

[35]   Demirel G. Feeding practices for racehorses in Turkey. İstanbul Üniversitesi Vet Fakültesi Derg 2006;32:79–86. doi:10.16988/IUVFD.88377.

[36]   Roberts JL, Murray JA. Survey of equine nutrition: Perceptions and practices of veterinarians in Georgia, USA. J Equine Vet Sci 2013;33:454–9. doi:10.1016/j.jevs.2012.08.001.

[37]   Martinson K, Hathaway M, Wilson JH, Gilkerson B, Peterson PR, Del Vecchio R. University of Minnesota horse owner survey: Building an equine extension program. J Ext 2006;44.

[38]   Bolwell CF, Rogers CW, Rosanowski SM, Weston JF, Gee EK, Gordon SJG. Cross-Sectional Survey of the Management and Training Practices of Endurance Horses in New Zealand: A Pilot Study. J Equine Vet Sci 2015;35:801–6. doi:10.1016/j.jevs.2015.07.019.

[39]   Leahy ER, Burk AO, Greene EA, Williams CA. Nutrition-associated problems facing elite level three-day eventing horses. Equine Vet J 2010;42:370–4. doi:10.1111/j.2042-3306.2010.00233.x.

[40]   Wyse CA, NcNie KA, Tannahill VJ, Murray JK, Love S. Prevalence of obesity in riding horses in Scotland. Vet Rec 8AD;162:590–1.

[41]   NAHMS USDA. National Health Monitoring System, Part 1: Baseline Reference of Equine Health and Management 2005.

[42]   Pratt-Phillips SE, Owens KM, Dowler LE, Cloninger MT. Assessment of Resting Insulin and Leptin Concentrations and Their Association With Managerial and Innate Factors in Horses. J Equine Vet Sci 2010;30:127–33. doi:10.1016/j.jevs.2010.01.060.

[43]   Frank N, Geor RJJ, Bailey SRR, Durham AEE, Johnson PJJ, American College of Veterinary Internal Medicine. Equine metabolic syndrome. J Vet Intern Med 2010;24:467–75. doi:10.1111/j.1939-1676.2010.0503.x.

[44]   Johnson EL, Asquith RL, Kivipelto J. Accuracy of weight determination of equids by visual estimation. Proc. 11th Equine Nutr. Phsysiology Symp., 1989, p. 240.

[45]   Householder DD, Gibbs PG. A method demonstration comparing visual estimation and use of a prediction equation to actual scale weights of horses. Pres. Gulf Coast Women's Equine Assoc. Meet., 1990.

[46]   Gibbs PG. Weight estimation and determination of horses using scales, visual appraisal and a prediction formula. Pres. Purina Mills Certif. Deal Work., 1993.

[47]   Potter GD, Gibbs PG. Body condition scoring and weight estimation of horses. Pres Texas Agric Sci Teach Work 1993.

[48]   Ellis JM, Hollands T. Accuracy of different methods of estimating the weight of horses. Vet Rec 1998;143:335–6. doi:10.1136/vr.143.12.335.

[49]   Wagner EL, Tyler PJ. A Comparison of Weight Estimation Methods in Adult Horses. J Equine Vet Sci 2011;31:706–10. doi:10.1016/j.jevs.2011.05.002.

[50]   Becvarova I, Pleasant RS. Managing obesity in pasture-based horses. Compend Contin Educ Vet 2012;34:E1-4.

[51]   Geor RJ. Nutrition and exercise in the management of horses and ponies at high risk for laminitis. J Equine Vet Sci 2010;30:463–70. doi:10.1016/j.jevs.2010.07.011.

[52]   Treiber KH, Kronfeld DS, Hess TM, Byrd BM, Splan RK, Staniar WB. Evaluation of genetic and metabolic predispositions and nutritional risk factors for pasture-associated laminitis in ponies. J Am Vet Med Assoc 2006;228:1538–45. doi:10.2460/javma.228.10.1538.

[53]   Johnson PJ, Messer NT. Cushing's syndromes, insulin resistance and endocrinopathic laminitis. Equine Vet J 2004.

[54]   De Graaf-Roelfsema E. Glucose homeostasis and the enteroinsular axis in the horse: A possible role in equine metabolic syndrome. Vet J 2014;199:11–8. doi:10.1016/j.tvjl.2013.09.064.

[55] McGowan CM, Frost R, Pfeiffer DU, Neiger R. Serum insulin concentrations in horses with equine Cushing's syndrome: response to a cortisol inhibitor and prognostic value. Equine Vet J 2004;36:295–8. doi:10.2746/0425164044877288.

[56] Treiber K, Carter R, Gay L, Williams C, Geor R. Inflammatory and redox status of ponies with a history of pasture-associated laminitis. Vet Immunol Immunopathol 2009;129:216–20. doi:10.1016/j.vetimm.2008.11.004.

[57] Saltiel AR, Kahn CR. Insulin signalling and the regulation of glucose and lipid metabolism. Nature 2001;414:799–806. doi:10.1038/414799a.

[58] Hansen TK, Thiel S, Wouters PJ, Christiansen JS, Van Den Berghe G. Intensive insulin therapy exerts antiinflammatory effects in critically ill patients and counteracts the adverse effect of low mannose-binding lectin levels. J Clin Endocrinol Metab 2003;88:1082–8. doi:10.1210/jc.2002-021478.

[59] Wilcox G. Insulin and insulin resistance. Clin Biochem Rev 2005;26:19–39. doi:10.1016/S0025-7125(03)00128-7.

[60] Asplin KE, Sillence MN, Pollitt CC, McGowan CM. Induction of laminitis by prolonged hyperinsulinaemia in clinically normal ponies. Vet J 2007;174:530–5. doi:10.1016/j.tvjl.2007.07.003.

[61] Muniyappa R, Lee S, Chen H, Quon MJ. Current approaches for assessing insulin sensitivity and resistance in vivo: advantages, limitations, and appropriate usage. AJP Endocrinol Metab 2007;294:E15–26. doi:10.1152/ajpendo.00645.2007.

[62] Eades SC, Stokes AM, Johnson PJ, LeBlanc CJ, Ganjam VK, Buff PR, et al. Serial alterations in digital hemodynamics and endothelin-1 immunoreactivity, platelet-neutrophil aggregation, and concentrations of nitric oxide, insulin, and glucose in blood obtained from horses following carbohydrate overload. Am J Vet Res 2007;68:87–94. doi:10.2460/ajvr.68.1.87.

[63] Shoelson SE, Herrero L, Naaz A. Obesity, Inflammation, and Insulin Resistance. Gastroenterology 2007;132:2169–80. doi:10.1053/j.gastro.2007.03.059.

[64] Hutley L, Prins JB. Fat as an Endocrine Organ: Relationship to the Metabolic Syndrome. Am J Med Sci 2005;330:280–9. doi:10.1097/00000441-200512000-00005.

[65] Muoio DM, Newgard CB. Mechanisms of disease: molecular and metabolic mechanisms of insulin resistance and beta-cell failure in type 2 diabetes. Nat Rev Mol Cell Biol 2008;9:193–205. doi:10.1038/nrm2327.

[66] Vick MM, Adams AA, Murphy BA, Sessions DR, Horohov DW, Cook RF, et al. Relationships among inflammatory cytokines, obesity, and insulin sensitivity in the horse. J Anim Sci 2007;85:1144–55. doi:10.2527/jas.2006-673.

[67] Geor RJ. Metabolic Predispositions to Laminitis in Horses and Ponies: Obesity, Insulin

Resistance and Metabolic Syndromes. J Equine Vet Sci 2008;28:753–9. doi:10.1016/j.jevs.2008.10.016.

[68]   van Eps AW, Pollitt CC. Equine laminitis induced with oligofructose. EQUINE Vet J Equine Vet J 2006;38:203–8. doi:10.2746/042516406776866327.

[69]   Milinovich GJ, Trott DJ, Burrell PC, Van Eps AW, Thoefner MB, Blackall LL, et al. Changes in equine hindgut bacterial populations during oligofructose- induced laminitis. Environ Microbiol 2006;8:885–98. doi:10.1111/j.1462-2920.2005.00975.x.

[70]   Milinovich GJ, Trott DJ, Burrell PC, Croser EL, Al Jassim RAM, Morton JM, et al. Fluorescence in situ hybridization analysis of hindgut bacteria associated with the development of equine laminitis. Environ Microbiol 2007;9:2090–100. doi:10.1111/j.1462-2920.2007.01327.x.

[71]   Milinovich GJ, Burrell PC, Pollitt CC, Klieve A V, Blackall LL, Ouwerkerk D, et al. Microbial ecology of the equine hindgut during oligofructose-induced laminitis. ISME J 2008;2:1089–100. doi:10.1038/ismej.2008.67.

[72]   Krueger AS, Kinden DA, Garner HE, Sprouse RF. Ultrastructural study of the equine cecum during onset of laminitis. Am J Vet Res 1986;47:1804–12. doi:10.1017/S000748530002229X.

[73]   Weiss DJ, Evanson OA, MacLeay J, Brown DR. Transient alteration in intestinal permeability to technetium Tc99m diethylenetriaminopentaacetate during the prodromal stages of alimentary laminitis in ponies. Am J Vet Res 1998;59:1431–4.

[74]   Bailey SR, Adair HS, Reinemeyer CR, Morgan SJ, Brooks AC, Longhofer SL, et al. Plasma concentrations of endotoxin and platelet activation in the developmental stage of oligofructose-induced laminitis. Vet Immunol Immunopathol 2009;129:167–73. doi:10.1016/j.vetimm.2008.11.009.

[75]   Tóth F, Frank N, Elliott SB, Geor RJ, Boston RC. Effects of an intravenous endotoxin challenge on glucose and insulin dynamics in horses. Am J Vet Res 2008;69:82–8. doi:10.2460/ajvr.69.1.82.

[76]   Wearn JG, Suagee JK, Crisman M V., Corl BA, Hulver MW, Hodgson DR, et al. Effects of the insulin sensitizing drug, pioglitazone, and lipopolysaccharide administration on markers of systemic inflammation and clinical parameters in horses. Vet Immunol Immunopathol 2012;145:42–9. doi:10.1016/j.vetimm.2011.10.007.

[77]   Lagathu C, Yvan-Charvet L, Bastard J-P, Maachi M, Quignard-Boulangé a, Capeau J, et al. Long-term treatment with interleukin-1beta induces insulin resistance in murine and human adipocytes. Diabetologia 2006;49:2162–73. doi:10.1007/s00125-006-0335-z.

[78]   Jager J, Grémeaux T, Cormont M, Le Marchand-Brustel Y, Tanti JF. Interleukin-1β-induced insulin resistance in adipocytes through down-regulation of insulin receptor substrate-1 expression. Endocrinology 2007;148:241–51. doi:10.1210/en.2006-0692.

[79]   Potter GD, Arnold FF, Householder DD, Hansen DH. Digestion of starch in the small or large intestine of the equine. Pferdeheilkunde 1992.

[80]   Richards N, Hinch GN, Rowe JB. The effect of current grain feeding practices on hindgut starch fermentation and acidosis in the Australian racing Thoroughbred. Aust Vet J 2006;84:402–7. doi:10.1111/j.1751-0813.2006.00059.x.

[81]   Meyer H, Radicke S, Kienzle E, Wilke S, Kleffken D, Illenseer M. Investigations on Preileal Digestion of Starch from Grain, Potato and Manioc in Horses. J Vet Med Ser A 1995;42:371–81. doi:10.1111/j.1439-0442.1995.tb00389.x.

[82]   Longland AC, Barfoot C, Harris PA. Effects of Grazing Muzzles on Intakes of Dry Matter and Water-Soluble Carbohydrates by Ponies Grazing Spring, Summer, and Autumn Swards, as well as Autumn Swards of Different Heights. J Equine Vet Sci 2016;40:26–33. doi:10.1016/j.jevs.2015.09.009.

[83]   Longland AC, Barfoot C, Harris PA. Efficacy of Wearing Grazing Muzzles for 10 Hours per Day on Controlling Bodyweight in Pastured Ponies. J Equine Vet Sci 2016;45:22–7. doi:10.1016/j.jevs.2016.04.015.

[84]   NRC. Nutrient Requirements of Horses. 2007.

[85]   Buchanan BR, Andrews FM. Treatment and prevention of equine gastric ulcer syndrome. Vet Clin North Am - Equine Pract 2003;19:575–97. doi:10.1016/j.cveq.2003.08.012.

[86]   Tinker MK, White NA, Lessard P, Thatcher CD, Pelzer KD, Davis B, et al. Prospective study of equine colic risk factors. Equine Vet J 1997;29:454–8. doi:10.1111/j.2042-3306.1997.tb03158.x.

[87]   Friend TH. Dehydration, stress, and water consumption of horses during long-distance commercial transport. J Anim Sci 2000;78:2568–80.

[88]   Hillyer MH, R Taylor FG, Proudman CJ, Edwards GB, Smith JE, French NP. Case control study to identify risk factors for simple colonic obstruction and distension colic in horses. EQUINE Vet J Equine Vet J 2002;34:455–63. doi:10.2746/042516402776117746.

[89]   Harker IJ, Harris PA, Barfoot CF. The body condition score of leisure horses competing at an unaffiliated championship in the UK. J Equine Vet Sci 2011;31:253–4.

[90]   Lawrence L, Jackson S, Kline K, Moser L, Powell D, Biel M. Observations on body weight and condition of horses in a 150-mile endurance ride. J Equine Vet Sci 1992;12:320–4. doi:10.1016/S0737-0806(06)81345-6.

[91]   Kearns CF, McKeever KH, John-Alder H, Abe T, Brechue WF. Relationship between body composition, blood volume and maximal oxygen uptake. Equine Vet J Suppl 2002;34:485–90. doi:10.1111/j.2042-3306.2002.tb05470.x.

[92]   Dugdale AHA, Grove-White D, Curtis GC, Harris PA, Argo CMCG. Body condition

scoring as a predictor of body fat in horses and ponies. Vet J 2012;194:173–8. doi:10.1016/j.tvjl.2012.03.024.

[93] Suagee-Bedore JK, Linden DR. Morphometric comparisons of draft, pony, and horse breeds. J Equine Vet Sci 2017;52:94–5.

[94] Coffman JR, Colles CM. Insulin Tolerance in Laminitic Ponies. Can J Comp Med 1983;47:347–51.

[95] Hoffmann G, Bentke A, Rose-Meierhöfer S, Ammon C, Mazetti P, Hardarson GH. Estimation of the Body Weight of Icelandic Horses. J Equine Vet Sci 2013;33:893–5. doi:10.1016/j.jevs.2013.01.002.

[96] Gao D, Madi M, Ding C, Fok M, Steele T, Ford C, et al. Interleukin-1 mediates macrophage-induced impairment of insulin signaling in human primary adipocytes. AJP Endocrinol Metab 2014;307:E289–304. doi:10.1152/ajpendo.00430.2013.

[97] Al Jassim RAM, Andrews FM. The Bacterial Community of the Horse Gastrointestinal Tract and Its Relation to Fermentative Acidosis, Laminitis, Colic, and Stomach Ulcers. Vet Clin North Am - Equine Pract 2009;25:199–215. doi:10.1016/j.cveq.2009.04.005.

[98] Taylor EA, Beard WL, Douthit T, Pohlman L. Effect of orally administered sodium bicarbonate on caecal pH. Equine Vet J 2014;46:223–6. doi:10.1111/evj.12111.

[99] Harlow BE, Lawrence LM, Hayes SH, Crum A, Flythe MD. Effect of dietary starch source and concentration on equine fecal microbiota. PLoS One 2016;11. doi:10.1371/journal.pone.0154037.

[100] Suagee JK, Splan RK, Swyers KL, Geor RJ, Corl BA. Effects of High-Sugar and High-Starch Diets on Postprandial Inflammatory Protein Concentrations in Horses. J Equine Vet Sci 2015;35:191–7. doi:10.1016/j.jevs.2014.12.014.

[101] Steelman SM, Chowdhary BP, Dowd S, Suchodolski J, Janečka JE. 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 2012;8:231. doi:10.1186/1746-6148-8-231.

[102] Elzinga SE, Weese JS, Adams AA. Comparison of the Fecal Microbiota in Horses With Equine Metabolic Syndrome and Metabolically Normal Controls Fed a Similar All-Forage Diet. J Equine Vet Sci 2016;44:9–16. doi:10.1016/j.jevs.2016.05.010.

[103] Everard A, Belzer C, Geurts L, Ouwerkerk JP, Druart C, Bindels LB, et al. Cross-talk between Akkermansia muciniphila and intestinal epithelium controls diet-induced obesity. Proc Natl Acad Sci 2013;110:9066–71. doi:10.1073/pnas.1219451110.

[104] Ewaschuk JB, Naylor JM, Zello GA. D-lactate in human and ruminant metabolism. J Nutr 2005;135:1619–25. doi:135/7/1619 [pii].

[105] Harmon DL, Britton RA, Prior RL, Stock RA. Net portal absorption of lactate and volatile fatty acids in steers experiencing glucose-induced acidosis or fed a 70% concentrate diet ad libitum. J Anim Sci 1985;60:560–9.

Appendix A

1. Your name: _____ email: _____ Phone: _____
2. Address: _____
3. Are you the ____ Owner ____Rider ____Groom ____Trainer (check all that apply)
4. Age of your horse: _____ yrs. Sex of your horse: __ Mare____ Gelding ___ Stallion
5. Breed of your pony/horse (circle one): _____ Height: _____hh
6. What discipline(s) or division(s) do you compete in with this horse? (please circle all that apply)
   - a) Hunter b) Jumper c) Equitation d) Other (please specify) _____
7. Is your horse an easy keeper (concerns about obesity)? ___ Yes ____No; or is your horse a hard keeper
   (concerns about maintaining weight or weight loss) ___ Yes ___No
8. Does your horse receive grain/commercial concentrates? ___Yes ___No
9. What brand and specific formula(s) do you currently feed? (please list all) ____ _____
10. How much grain do you feed per feeding _____lb_____lb_____lb
11. How many feedings per day? _____
12. What type(s) of hay do you feed? _____
    - a) How much hay do you feed (total per day)? _____ flakes; or _____lbs
    - b) Do you bring hay to the show? ___ Yes ___No; Purchase hay at the show? ___Yes ___ No
13. Do you feed other types of roughage? (chopped forage, pellets, cubes, beet pulp, etc.) If so, please list: _____
14. Do you feed supplements on a regular basis? ___ Yes ____ No; if yes, please list type and amount: _____
15. Does your horse have access to pasture at home? ___Yes ___No.
    - a) How many hours turnout /day_____
    - b) Does the pasture provide adequate grass forage for nutrition (at least 4-6" tall)? ___ yes___no
16. Are you concerned about any of the following nutritional related diseases for your horse?
    - a) Colic b) Laminitis/Insulin Resistance c) Ulcers d) Tying up e) Other_____
17. Who do you use for advice when making decisions on nutrition and feeding?
    - a) Nutritionist b)Veterinarian b) Trainer c) Feed company d) Internet e) Other___