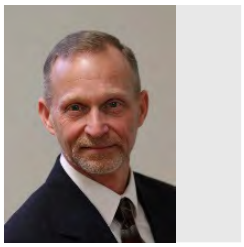

The Basis of Equine Nutrition

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Equine nutrition plays the basis for maintaining the health, performance, and overall well-being of horses. Horse owners and caretakers should understand the fundamental principles of equine nutrition, encompassing the essential nutrients, dietary requirements, and feeding strategies that are integral to the equine diet. By understanding these basics, informed decisions to optimize the nutrition of their animals can be made that are crucial for the health and longevity of horses. A balanced diet ensures the availability of essential nutrients, which are required for growth, reproduction, energy production, and immune function. The digestive physiology of horses is unique, reflecting their evolutionary history as herbivores. The key components of equine nutrition that should be considered include various macronutrients and micronutrients, as well as feeding management.

Horses require a variety of nutrients for optimal health. Macronutrients include carbohydrates, proteins, and fats. Carbohydrates, often primarily derived from forages, typically are the main energy source for horses. Proteins, composed of amino acids, are essential for tissue repair, growth, and enzyme function. Fats provide concentrated energy and are also can be incorporated into the diet to aid in maintaining coat condition – a benefit often favored by horse owners. Forages, such as hay and pasture, are integral to the equine diet. The digestive system of horses is designed for a high-fiber, plant-based diet. The cecum and colon play a central role in fermentation, breaking down fibrous materials and producing volatile fatty acids that serve as an energy source. Forages provide fiber for proper gut function and help prevent digestive disorders like colic. Forages also supply vitamins and minerals, particularly fat-soluble vitamins A, D, and E, as well as calcium and phosphorus. Access to good-quality forage should be the basis of any equine feeding program. Concentrate feeds, including grains and commercial feeds, are often used to supplement the diet when additional energy and other nutrients are required. However, overreliance on concentrates can lead to imbalances and health issues. When introducing concentrates, it is crucial to do so gradually and in appropriate amounts, taking into consideration the horse's activity level and metabolic rate. Micronutrients, such as vitamins and minerals, are essential for various physiological functions. Vitamins play roles in metabolism, immune response, and overall health. Most vitamins are obtained from the diet or synthesized by gut microbes without need for supplementation. Minerals like calcium, phosphorus, magnesium, and trace minerals are important for bone health, muscle function, and enzyme systems. Providing a balanced mineral supplement or through a fortified concentrate is vital when the mineral content of forages is insufficient, which occurs frequently. Water is often the most overlooked nutrient, yet it is the most critical. Horses require access to clean, fresh water to support digestion, thermoregulation, and overall health. Dehydration can lead to colic and reduced performance.

Feeding strategies should be tailored to individual horses based on their age, activity level, metabolism, and health status. Horses in different life stages have varying nutritional requirements. While the requirements of mature horses at maintenance can often be met on a diet consisting almost entirely of forages, with supplementation only required to meet deficient nutrients, optimal nutrition to promote growth and support performance may require growing, performing, or breeding animals to have requirements that may be more challenging to meet on an all-roughage diet. Proper body condition scoring is a valuable tool for evaluating the adequacy of a horse's diet and adjusting feeding plans accordingly. While some mental and health

concerns can be alleviated or prevented by maintaining horses on pasture, obesity and related health issues may be more prevalent with such horses if forage intake is unlimited, potentially predisposing horses to health problems such as insulin resistance or laminitis. These animals often require specialized diets with limited carbohydrates and controlled calorie intake. Consulting with a veterinarian or equine nutritionist is crucial when designing diets for horses with special needs.

Equine nutrition is a multifaceted topic with far-reaching implications for the health and performance of horses. Understanding the basics of equine nutrition, including the role of macronutrients, micronutrients, forages, and concentrates, allows horse owners to make informed decisions regarding their animals' diets. Adhering to proper feeding strategies and considering individual horse requirements will contribute to the overall well-being of these animals.

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Dr. Nielsen completed his undergraduate degree in Animal Science at the University of Wisconsin – River Falls and received both his M.S. and Ph.D. from Texas A&M University. He currently is a professor of Equine Exercise Physiology in the Department of Animal Science at Michigan State University where he has a teaching and research appointment. Nielsen has authored 83 peer-reviewed papers and 241 book chapters, conference papers, and abstracts, as well as 67 popular press articles. He has given 65 invited international talks in countries such as Australia, Austria, Brazil, Canada, England, France, Germany, Italy, Mexico, Northern Ireland, Norway, Spain, Slovenia, Sweden, Turkey, and the United Arab Emirates and has given 145 invited talks at national meetings and within the state of Michigan. He has secured $2.8 million in research funding. He is an active member of the American Society of Animal Science, the American Registry of Professional Animal Scientists, and served as the President of the Equine Science Society – an organization that presented him with the "American Feed Industry Association Award in Equine Nutrition Research" in 2017 and the "Outstanding Young Equine Professional Award" in 2001. Additionally, he was awarded the "Outstanding Teacher Award" at the Midwest Section of the American Society of Animal Science and the American Dairy Science Association in 2005 and the "Equine Science Award" by the American Society of Animal Science and Equine Science Society in 2010. Besides having served on the editorial board for the Journal of Animal Science, the Journal of Equine Veterinary Science, The Professional Animal Scientist, and the international journals Comparative Exercise Physiology and the Journal of Istanbul Veterinary Sciences, he is a Diplomat in the American College of Animal Nutritionists and served on the National Academy of Sciences Committee on Nutrient Requirements of Horses. Throughout his academic career, he has maintained involvement in the industry by breaking and galloping racing Quarter Horses and Thoroughbreds for nearly 35 years and became a licensed racehorse trainer in 1997.

Feeding the Equine Athlete: Nutritional Considerations for Optimal Performance

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Feeding the equine athlete is a complex endeavor that requires a deep understanding of the unique nutritional needs and physiological demands placed on performance horses. The key factors that must be considered when formulating diets for equine athletes include energy requirements, protein needs, electrolyte balance, and timing of feedings. By addressing these aspects, horse owners and trainers can enhance the performance and well-being of their animals.

Equine athletes, whether competing in racing, show jumping, dressage, or other disciplines, require attention to their nutritional needs to ensure peak performance and recovery. The energy expended during training and competition places substantial demands on their bodies, necessitating a diet that provides the necessary fuel and nutrients. Energy is the cornerstone of any equine athlete's diet. The energy needs of these animals depend on factors such as exercise intensity, duration, and the individual horse's metabolism. While some equine athletes can perform well on a diet that is composed primarily of forage, many performance horses require grains or concentrates to meet increased energy demands. Carbohydrates are a primary source of energy, and such concentrate feeds can provide readily available carbohydrates that can aid in meeting the increased energy requirements needed for exercise. Whether energy demands are being met or exceeded can be determined by evaluating the body condition scores of horses. Depending upon discipline and type of exercise being performed, the appropriate body condition score will vary. An endurance horse competing for hours would be expected to have lower body fat stores than would a sprinting horse competing for less than a minute. While the endurance horse would have much greater energy demands than would the sprinting horse, carrying the extra weight that accompanies the fat stores is a much greater disadvantage when traveling long distances compared to when only carrying it a short distance. Thus, any decrease in glycogen stores (the storage form of carbohydrates which provides rapidly available energy) that accompanies a body condition score below a 5 in the endurance horse would be offset by the lower energy requirements that accompany carrying less weight.

Proteins are essential for muscle development, repair, and overall tissue health. Equine athletes require higher protein levels than their sedentary counterparts due to the breakdown of muscle tissues during exercise. However, excess dietary protein, beyond their requirements, may not be justified. Also, sometimes the increase in protein requirements is simply met by increasing the amount of feed being provided to meet energy requirements. Hence it is important to evaluate protein requirements on a weight basis (such as grams of protein) rather than the percentage of diet. Further, ensuring the proper supply of amino acids, the building blocks of proteins, may be even more crucial than evaluating just the amount of protein. Providing an excess amount of a poor-quality protein may still not meet the requirements for crucial amino acids such as lysine and methionine.

Equine athletes may lose significant amounts of electrolytes, including sodium, chloride, and potassium through sweat during exertion. Electrolyte imbalances can lead to muscle cramps, dehydration, and decreased performance. Supplementing electrolytes before, during, and after exercise is commonly done to

help maintain proper balance and supports the horse's ability to recover efficiently. However, this tends to be important only if a horse is exercising for sustained periods in warm temperatures when sweat losses would be great. Providing free access to salt can decrease the need for electrolyte supplementation. Further, if providing a commercial concentrate, most feeds would have salt incorporated into the grain mix. Thus, providing extra salt may not be needed for most horses. Also, the forage consumed by most horses would typically provide potassium far in excess of requirements. If supplementation is to be provided, it can be done inexpensively through the provision of regular salt and/or "lite salt" (NaCl and KCl). Water is often referred to as the "forgotten nutrient," yet it plays a vital role in the equine athlete's performance. While there may be some benefits to mild dehydration during short, high-intensity work such as racing, long-term dehydration can impair thermoregulation, muscle function, and digestion. Ensuring access to clean, fresh water, and encouraging adequate consumption after exercise, is essential for maintaining optimal hydration. Likewise, the timing of feedings is a critical consideration in the equine athlete's nutritional plan. Care should be taken to avoid feeding immediately before exercise to prevent digestive discomfort.

Feeding the equine athlete is a dynamic process that involves careful consideration of energy requirements, protein needs, electrolyte balance, hydration, and feeding timing. Consultation with an equine nutritionist or veterinarian trained in equine nutrition is crucial for tailoring diets to individual needs. Proper nutrition is a cornerstone of optimal performance, and a well-balanced diet supports muscle development, energy production, and overall well-being. By assessing the horse's condition and performance over time, adjustments can be made to ensure continued optimal nutrition. Horse owners and trainers who prioritize these factors can contribute to the success and longevity of their competitive equine partners.

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Dr. Nielsen completed his undergraduate degree in Animal Science at the University of Wisconsin – River Falls and received both his M.S. and Ph.D. from Texas A&M University. He currently is a professor of Equine Exercise Physiology in the Department of Animal Science at Michigan State University where he has a teaching and research appointment. Nielsen has authored 83 peer-reviewed papers and 241 book chapters, conference papers, and abstracts, as well as 67 popular press articles. He has given 65 invited international talks in countries such as Australia, Austria, Brazil, Canada, England, France, Germany, Italy, Mexico, Northern Ireland, Norway, Spain, Slovenia, Sweden, Turkey, and the United Arab Emirates and has given 145 invited talks at national meetings and within the state of Michigan. He has secured $2.8 million in research funding. He is an active member of the American Society of Animal Science, the American Registry of Professional Animal Scientists, and served as the President of the Equine Science Society – an organization that presented him with the "American Feed Industry Association Award in Equine Nutrition Research" in 2017 and the "Outstanding Young Equine Professional Award" in 2001. Additionally, he was awarded the "Outstanding Teacher Award" at the Midwest Section of the American Society of Animal Science and the American Dairy Science Association in 2005 and the "Equine Science Award" by the American Society of Animal Science and Equine Science Society in 2010. Besides having served on the editorial board for the Journal of Animal Science, the Journal of Equine Veterinary Science, The Professional Animal Scientist, and the international journals Comparative Exercise Physiology and the Journal of Istanbul Veterinary Sciences, he is a Diplomat in the American College of Animal Nutritionists and served on the National Academy of Sciences Committee on Nutrient Requirements of Horses. Throughout his academic career, he has maintained involvement in the industry by breaking and galloping racing Quarter Horses and Thoroughbreds for nearly 35 years and became a licensed racehorse trainer in 1997.

Feeding the orphan foal

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There are many reasons for foals to become orphans. Mare rejection, although rare, can occur. More common scenarios are mare's disease or death or the use of the mare as a surrogate for a different foal among others.

Feeding patterns for the orphan foal should mimic natural feeding, thus, foals should be fed often. While most owner would like to bottle feed, this should be avoided due to the risk of aspiration pneumonia and inconvenience over time. Natural suckling from a bucket works well and it is a very good alternative to bottle feeding. Foals learn to drink from a bucket easily. To train a foal to drink from a bucket, place your clean fingers wet with milk replacer in their mouth to stimulate suckling reflex. While they are suckling, bring the bucket (better to use a flat one first) to their mouth and slowly withdraw your fingers from the foal's mouth. These steps may have to be repeated multiple times until the foal learns to drink. Do not force the foal into the bucket as this will discourage drinking. It is better to lightly warm the milk replacer the first few days. Once the foal is drinking without assistance, a bucket can be hanged in the stall or pen. It is important not to leave the bucket on the ground as foals can get their limbs trapped around the handles. They will also likely dump the bucket by playing or while attempting to drink.

Buckets should be hanged at the foal's shoulder height and the distance should be adjusted as the foal grows. Studies suggest that yellow buckets (or bright color buckets) work best.

To get the foal adapted to feeding of milk replacer start slowly: Feed ½ the recommended amount the first day and gradually increase the amount provided over the next 4-7 days.

While the foal is being trained, a nasogastric tube may be left in place to ensure adequate nutrition. It is better to train the foal when it is hungry (before feeding by NGT). Patience is of extreme importance for success. All feeding equipment should be kept clean and should be washed once or twice a day (or more often if needed).

Daily milk substitute intake: The suckling foal consumes 25% of its body weight (in Kg) of mare's milk every day. The amount gradually decreases to 20% of BW in Kg by 3 weeks of age. The amount of milk substitute recommended per day varies by brand. Therefore, it is very important to follow manufacturer's recommendations for feeding of these products. Electrolyte toxicities and diarrheas can occur if attention is not paid.

Frequency of feeding: Feed as frequent as possible to mimic natural foal nursing behavior (foals nurse 5-7 times/h!). Feeding large volumes a few times a day predisposes to diarrhea. The advantage of commercial replacements is that they can be left in the bucket for hours before they are no longer good. Milk replacer may have to be changed more often if the weather is hot.

Other feeding considerations: Good quality hay and creep feeding should be gradually introduced from the first days of life to encourage eating. A salt block can also be introduced at ~ 2 weeks of age. Foals should have access to dirt as this is required for iron supplementation. In addition, add adult horse feces from a healthy donor. It is best to select a donor without parasite eggs (or < 200/g of feces). Coprophagy is normal in foals and it is thought to aid healthy GI tract colonization.

Diarrhea is common with diet changes in foals. In general, nutritional diarrhea is self-limiting and does not require treatment but foals should be closely monitored as dehydration is possible.

Foals that are 5-8 day-old usually develop diarrhea ("foal-heat" diarrhea), a normal, self-limiting event that appears to be related to GI microflora population. Environmental temperature should be kept comfortable for foals (around 20°C or 68°F). Shelter should be provided if weather is too cold or if too hot (shade).

To ensure appropriate nutrition, it is important to evaluate the body condition of the foal often. Orphan foals have a delay in growth but should achieve normal condition by the time they are 3-4 months of age. At this age, foals should have an adequate body condition of 6 on a 1 to 9 scale. Foals should not ever be extremely thin, weak, or lethargic.

Vaccination and deworming: There are no special considerations for vaccination or deworming of orphan foals. Vaccine and deworming recommendations are available to the public at the AAEP website (https://aaep.org/guidelines/vaccination-guidelines and https://aaep.org/document/internal-parasite-control-guidelines)

Weaning: Foals can be weaned of the milk replacer and introduced to milk pellets (creep feeding) at an early age, usually around 6-8 weeks. The transition from milk replacer to pellets should be gradual. This can be accomplished by decreasing the amount of milk replacer available while increasing the amount of pellets (as long as the foal eats the pellets). Fresh water should be always available, especially during this transition. As the foal ages, milk pellets can be replaced by other pellets that are adequate for growing foals. These products usually have a higher protein concentration than regular maintenance pellets. In general, a foal should not be drinking milk supplement after 4 months of age.

Behavior: Behavioral problems are very common in orphan foals that are hand-reared; these are more common if foals don't interact with other horses. Excessive attachment to their handlers and failure to properly socialize with other horses are common problems and may difficult training later. Using an old, nice horse as companion is beneficial to correct some of the abnormal behaviors. If multiple orphan foals are present in the farm, they can be managed in small groups to promote interaction.

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Dr. Sanz *graduated as a veterinarian in La Plata, Argentina. She completed an Equine Internship, a Large Animal Internal Medicine Residency and a Master's of Science degree at Washington State University and she is a Diplomate of the ACVIM College. She also completed a PhD in equine immunology at the Gluck Equine Research Center; her research focuses in equine immunology and infectious diseases. She worked as a Senior Lecturer in Equine Medicine at the Onderstepoort Veterinary School in South Africa for 3 years. Dr. Sanz is an Associate Professor in Equine Medicine at Washington State University in the US.*

Feeding Old Horses

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Once horses reach over 20 years of age, they are generally considered senior or aged-normal horses if they are healthy, regardless of being overweight. Once there are clear signs of senescent changes with possible concurrent disease then they are considered geriatric. For aged-normal horses there is little adjustment needed to the diet except working towards the ideal body condition by addressing weight loss or obesity. With the onset of senescent changes, frequent monitoring to identify, address, and ameliorate the inevitable age-related diseases is recommended. Some common problems seen in the equine geriatric are dental disease, arthritis, pituitary pars intermedia dysfunction (PPID), colic, sarcopenia, body mass loss, and attrition of digestive, neural and immunologic systems. Because of the physiological changes normally associated with aging, geriatrics may require special adaptations in health care, environment and diet.

Dental disease, one of the biggest challenges facing the older horse, is the loss of teeth, wearing down of the grinding surface, and diastemata. Older horses have an increased risk of cecal and large colon impactions due to failing dentition, decreased frequency of preventive dental care and reduced intestinal motility. Signs of dental disease are quidding, food pocketing, hypersalivation, facial swelling, halitosis, weight loss and increased risk of choke or colic. The aim of dental treatment is to preserve occlusal surface where possible, remove sources of pain and provide nourishment in a highly digestible form. When long stem forage and/or pasture become impossible to chew, dietary adaptation to alternative fiber sources will be necessary to facilitate adequate forage intake. Shorter stem forage, like chopped hay or hay cubes, hay pellets, and hay replacer served as a wet mash and offered 3 to 4 meals per day compensate for the lack of pasture or hay intake and reduce choking. The addition of a ration balancer with a concentrated source of protein, vitamins and minerals will balance out the shortcomings of a forage only diet. For underweight horses, a senior or high fiber, low NSC type concentrate feed can be served wet. Dietary fat, such as oil or rice bran can be an additional source of concentrated calories.

Osteoarthritis (OA) is the chronic structural deterioration of articular cartilage, exposure of subchondral bone and pain. Lameness can be overt or subtle, depending on the location of the arthritis. Treatment aims to provide comfort and limit progression of the disease. Commonly, NSAIDs are used to manage pain along with intra-articular corticosteroids or IM PSGAGs. Supplements with glucosamine, chondroitin sulfate, hyaluronate, MSM and other nutrients are commonly used. Omega-3 fatty acid supplements, particularly ones high in DHA and EPA such as fish oil, have been found to help joint inflammation. Weight management is important to prevent chronic overloading of joints. Regular hoofcare to properly balance any abnormal loading through joints is essential. Light exercise is important for maintaining muscle mass and joint flexion, although should not be done during an acute flair of OA. Older horses benefit from not being confined to stalls and to have freedom of movement 24/7 to keep the joints lubricated. Modifications to feed pan location, such as feeding at elbow height instead of ground level may be necessary if OA is in jaw, forelegs or cervical spine.

Pituitary pars intermedia dysfunction is a progressive degenerative disease commonly seen in older horses. The origin of the disease is hypertrophy in the pars intermedia affecting hormone regulation. Some of the signs are hypertrichosis, muscle wasting, lethargy, fat redistribution, laminitis, swelling around upper and lower eyelids, polyuria, polydipsia, excessive sweating, delayed wound healing and susceptibility to infections and endoparasites. PPID is diagnosed with a basal ACTH concentration which can be validated with

thyrotropin-releasing hormone (TRH) stimulation test when ACTH results are equivocal. Testing for insulin dysregulation (ID) should be done in PPID horses with laminitis. Pergolide mesylate is recommended for management of PPID. Nutritional management will be dependent on whether the horse is appropriate, over- or under-weight, as well as ID and/or laminitic. For PPID horses with ID, maintenance on a low non-structural carbohydrate (NSC) diet is essential. Low NSC hay (< 10%) is ideal, although higher NSC hay soaked for 60 minutes to leach sugar can be an option. If hay is low in protein or soaked, it is important to supplement with a ration balancer with quality protein to discourage muscle wastage. Overweight PPID horses do well on forage balanced with a quality ration balancer, and those with ID may need to be restricted from pasture. PPID horses that have difficulty maintaining weight may need a low NSC, high fat concentrate feed. To support a healthy immune system, supplement with antioxidants such as vitamins C, E and A, selenium, zinc, and alpha lipoic acid. It is important to stay on top of deworming and vaccination schedules. Clipping the coat may be needed in hot weather and regular bathing to discourage skin disease.

For older horses maintained in a herd, careful observation of bullying or loss of interest in fighting for food so that modifications can be done will minimize stress. Separation for feeding will give a horse more opportunity to eat the entire meal and to monitor feed intake. Thermoregulation is often altered in the older horse from loss of fat cover, changes in hormonal temperature regulation, and decreased heat production from fiber digestion. Shelter and/or blanketing in adverse weather and colder temperatures may be needed. During cold weather, reduction in water intake can result in colic and subsequent impaction due to self-induced dehydration. Careful observance of water intake can help to avoid problems. Feeding meals soaked in warm water and/or adding salt to the meal might entice a horse to increase water intake.

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Dr. Kathleen Crandell earned her MS in Equine Nutrition and Exercise Physiology and PhD in Equine Nutrition and Reproduction from Virginia Polytechnic Institute and State University (Virginia Tech). Dr. Crandell was a Superintendent of the Virginia Tech Middleburg Agricultural Research and Extension Center in Middleburg, Virginia, where she ran an equine research and breeding program with over 100 Thoroughbred horses. For the past 26 years, she has been an equine nutrition consultant for Kentucky Equine Research (KER), responsible for support of the national and international feed mills associated with KER with feed formulation, advising on issues of manufacturing and packaging of equine feeds and customer equine feeding recommendations. She also provides recommendations for nutritional programs of individual horses or farms and equine publications, and has consulted for some of the top equine competitors in the US. Dr. Crandell has presented nutritional seminars for education of the general equine public and scientific community around the world. Dr. Crandell has authored book chapters and articles in refereed journals. She also writes or is interviewed for articles on specific topics in equine nutrition for KER publications, KER.com Equinews website and popular magazines. In addition, Dr. Crandell is an Instructor for Equine Guelph, University of Guelph, Ontario, Canada, teaching an equine nutrition course "Advanced Equine Health through Nutrition", an in-depth study of nutritional related diseases and disorders. Dr. Crandell has been awarded 3 John H. Daniels Fellowships by the National Sporting Library in Middleburg, Virginia, to study historical perspectives on equine nutrition, supplementation and laminitis. Having previously owned a small breeding farm and competed in endurance and competitive trail, she is currently an avid trail rider with her Arabian and half-Arabian horses.

Keys of Nutrition in Growing Horses

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Nutrition is of paramount importance during the growth phase of horses, as it directly influences their development, skeletal integrity, and overall health. The critical factors that underpin the nutritional needs of growing horses include energy requirements, protein quality, mineral balance, and dietary management. Understanding these keys to nutrition ensures that young horses achieve their full potential in terms of structure and performance. The growth phase is a critical period in a horse's life, determining its future soundness, performance, and longevity. Proper nutrition during this stage is pivotal, as it provides the building blocks necessary for the development of strong bones, robust muscles, and a healthy immune system. Energy is the cornerstone of growth, as it fuels cellular processes and supports anabolic activities. Young horses require a consistent supply of energy to sustain growth, maintain bodily functions, and support their increasing activity levels. The energy requirements are influenced by factors such as age, breed, size, and activity level. Providing access to a high-quality forage is important for growing horses as it provides a valuable source of energy from carbohydrates and fiber, along with providing other crucial nutrients such as protein and the amino acids from which protein is comprised. High quality protein is essential for the development of tissues, including muscles, tendons, ligaments, and organs. Growing horses have increased protein requirements to support the rapid growth of these structures. The quality of protein, as determined by its amino acid composition, is crucial. Essential amino acids like lysine, methionine, and threonine are particularly important during growth. Ensuring that young horses receive a diet with balanced and digestible protein sources promotes optimal muscle and skeletal development. Minerals are pivotal for the formation and maintenance of bones, which are the foundation of a horse's structural integrity. Calcium and phosphorus are the primary minerals required for skeletal development. Great care should be taken to ensure readily available dietary calcium exceeds phosphorus to avoid skeletal issues such as nutritional secondary hyperparathyroidism. Imbalances or deficiencies of these and other minerals can lead to skeletal abnormalities such as developmental orthopedic diseases. While growth is a natural process, rapid growth rates can lead to developmental issues, particularly if deficiencies or imbalances of nutrients are present in the diet. Overfeeding, especially in terms of energy, can result in excessive weight gain and stress on developing joints. This is particularly relevant in large-breed horses prone to orthopedic problems. Careful dietary management, including monitoring body condition, adjusting energy intake, and ensuring balanced nutrition, helps mitigate these risks. Regular monitoring of a growing horse's body condition, growth rate, and overall health is crucial for assessing the effectiveness of its nutrition plan. Adjustments may be necessary based on factors such as growth rate, activity level, and health status. Consulting with an equine nutritionist or veterinarian trained in equine nutrition can provide valuable insights into refining the diet as the young horse develops. The nutrition of growing horses is a multifaceted undertaking that requires particular attention to energy, protein, minerals, and proper dietary management. Providing a balanced diet that supports optimal growth and prevents developmental issues is key. By adhering to these nutritional principles, horse owners can contribute to the healthy development and future success of their growing equine companions.

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Nutrition for the pregnant and postpartum mare

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Regarding horse soundness, Mexican equestrian traditional knowledge affirms that "horses are worth what they are, and do, whilst foals are worth what they will be, and will do"; and there is enough solid, current scientific evidence to confirm that, among other environmental factors, the nutrition of the broodmare during pregnancy and early lactation affects phenotype of her offspring at both short and long term, especially when nutritional disorders occur during critical periods of development.[1, 2, 3, 4, 5, 6]

A critical period is a point in the life of an organism in which a specific environmental factor is likely to exert its greatest influence,[7] just as it occurs in critical periods of development thru the prenatal and early postnatal life, in which nutritional derangements, and the resulting metabolic disorders,[8] have a major effect on the anatomy, physiology, and behavior of the foal,9 then on its performance when adult.[6]

Since intrauterine growth is determined primarily by the supply of nutrients, both under- and overnutrition of the mare during pregnancy, cause profound effects on the development of body systems that are essential to cope with the extrauterine environment and to perform later in life (e.g. musculoskeletal, cardiovascular, gastrointestinal, nervous, metabolic and endocrine).[2,3,6] The mismatch between offspring phenotype and the environment[1] can be noticed just after birth, when assessing the health and soundness of the newborn foal, or perceived later in life,[10] at some point in growth, foundation, training or work, when physical and mental effort is exerted. Whether physical or behavioral, the outcome has lifelong consequences for horsemanship.[4]

Therefore, considering that nutrient availability, transport, and partitioning during critical periods affect cell multiplication and differentiation, as well as tissue development and maturation, with the latter still during early lactation, it seems sensible to approach the nutrition of the broodmare from the concept of fetal programming;[4,6,11,12] particularly when reproductive technologies are implemented,[13] due to their effects on fetoplacental and postnatal development.[2,3]

Certainly, although the supply of nutrients and oxygen depends on both their availability in the mare and the functional capacity of the placenta,[4,12] through this lecture, the need of ensuring nutrient availability in the mare is highlighted, leaving placental function for further review.[2,3,12]

Concerning nutritional disorders, under- and overnutrition, as well as macro and trace elements deficiencies or excesses, are commonly found in the equine world, because nutritional requirements and nutritional value of feedstuffs in horses are rarely estimated in practice. Undernutrition is the result of an inadequate supply of nutrients, although it can also result from malabsorption, impaired metabolism, loss of nutrients, or increased requirements due to disease or other environmental stresses.[12] Overnutrition has become a common condition in the horse industry as a result of excessive ingestion of nutrients, not only due to the disproportionate addition of concentrates and supplements but also to the misinformed introduction of some forages, whose contents of protein, minerals and non-structural carbohydrates may exceed horses natural needs. Likewise, mineral deficiencies, excesses, and imbalances, result from the poor application of available information on equine mineral nutriton.[14]

Because dietary management of broodmares is essential for breeding and successfully raising healthy foals,[15] equine veterinary professionals[16,17,18] play a key role in providing nutritional advice according to life stage of individual equids, as well as in designing feeding programs to sustainably promote the health, welfare, productivity and performance of equine populations. Fortunately, there are educational programs,[19] innovating methods,[20] and progressive technology,[21] to enable veterinarians to clearly and confidently guide the horse industry in the proper use of feeding resources and the implementation of nutritional strategies.

A One Welfare approach,[22] considering animal, human and environmental factors, facilitates the development of effective, affordable and sustainable nutritional programs. Animal aspects include breed, age, body weight, body condition, physiological state, and health status; whilst purposes of breeding, industry requisites, type of system, and management practices, are some human influences. Among environmental components, geography, climate, season, fauna, flora, diseases, resources, and facilities are most important.

The aim of a nutritional program is to guarantee that requirements for maintenance, fertility, pregnancy, and lactation are met. Implications of nutrition during pregnancy have already been discussed, so it is opportune to mention that nutrition for lactation is crucial, primarily, because the immediate neonatal period is a critical period of development,[3,5] during which maturation of some tissues takes place and, furthermore, because the mare has to reach her potential of milk production, with proper quality to feed a foal that, by weaning, has to be around eighty percent of its adult height and fifty percent of the expected adult body weight. Although other factors like age, parity and breed are involved, maternal nutrition influences colostrum quality, as well as milk yield and composition.[5,27] As an ultimate reason to warrant nutrition during lactation, it is the fact that most sectors of the horse breeding industry expect taking advantage of the natural ability of the mare to become pregnant again shortly after parturition, in order to produce a foal by the same, ecologically or economically, convenient season each year.

In view of that, the nutrition of the broodmare for pregnancy and lactation begins months before conception to extend longer than lactation, especially when she becomes pregnant at foal heat. The controlling nutritional requirement is energy,[23] although protein,[24] amino acids,[24] fatty acids,[25] minerals,[14] and vitamins[26] must also be met, making sure not only that amounts are sufficient but also that ratios (e.g. DE:CP; Ca:P; Zn:Cu) are balanced according to physiological state;[27,28,29,30,31] namely maintenance (for cyclicity and fertility), pregnancy (initial, middle and final third) and lactation (first and second half).

Finally, from the plains to the breeding centers, guaranteeing the nutrition of the broodmare is as challenging as interesting; challenging because horses, breeds and equitation exist in a wide variety of conditions; interesting because, whatever the form of equitation, nutrition for welfare and performance has to be addressed before conception. Therefore, making a sensible use of resources,[32] besides applying concepts of evolutionary veterinary science,[1,33,34] will result in improvements in the management of animal health, welfare, productivity and performance, to have a sound horse world.

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Management of Metabolic Diseases

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Metabolic diseases are becoming increasingly more common in the modern equine. Equine metabolic syndrome (EMS) is a term coined to describe a collection of metabolic risk factors, mainly insulin dysregulation (ID), hyperinsulinemia-associated laminitis (HAL), and obesity. Insulin dysregulation is characterized by high resting insulin, high postprandial insulin, or insulin resistance at the tissue level. The severity of ID can vary greatly between individuals and is often seen in obese horses while less commonly in non-obese horses. Hyperinsulinemia-associated laminitis, also known as pasture-associated laminitis, is thought to be a result of chronically high insulin levels having adverse effects on laminar tissues, and causing mild to moderate lameness which can progress to classical laminitis. Divergent hoof rings can be indicative of insidious HAL and disruption of the internal structural changes in the hoof. Dietary sugar, starch and fructans can be instigators of HAL in susceptible animals. Although the exact mechanism has not been completely elucidated, the most popular theory is that hyperinsulinemia induces inappropriate stimulation of insulin-like growth factor-1 receptors on lamellar epidermal cells. Obesity is a common characteristic of the EMS horse.

With the clinical signs of EMS in obese individuals, some or all the following may be present: weight loss resistance, clinical laminitis, divergent hoof rings (subclinical laminitis), cresty neck, subcutaneous adipose tissue deposits, preputial or mammary gland enlargement. Manifestation of EMS in non-obese individuals commonly presents as clinical or subclinical laminitis. Many genetically at-risk non-obese EMS horses are not obese because they are maintained in controlled environment and/or have been obese historically. EMS may coexist with pituitary pars intermedia dysfunction (PPID) in older horses. More information on PPID will be discussed in the accompanying abstract on Feeding Old Horses by this author.

While there are a number of tests currently used for diagnosing EMS and ID, the two recommended tests are the Oral Sugar Test (OST) and Insulin Tolerance Test (ITT). Resting insulin and glucose blood levels can be used alongside the dynamic tests as a two-step approach to ID testing. The combined glucose-insulin test, frequently-sampled intravenous glucose tolerance test, and euglycemic-hyperinsulinemic clamp procedure are considered too complex and expensive for routine clinical use but can provide relevant information in a research setting.

Management of EMS in obese individuals involves dietary changes and restrictions such as restricting or eliminating grazing access, as well as elimination of treats, grain and most concentrate feeds (except a ration balancer type feed). Hay fed should be low non-structural carbohydrate (NSC) content, preferably < 10%. For weight loss, offer the equivalent of 1.2-1.5% BW in hay, on a dry matter basis, and avoid higher calorie hays such as alfalfa. For hays with higher NSC content, soaking for 60 minutes can leach out some of the sugar but the amount lost can be variable dependent on the hay and is not 100% reliable for sugar reduction. For situations where lower NSC hay is not available, then up to 50% of the hay can be replaced with good quality straw but needs to be introduced into the diet very gradually to avoid colic. To avoid prolonged periods of fasting, slow feeder hay nets or small frequent meals can be used. If small amounts of grazing are tolerated, then a grazing muzzle can be used to limit the amount of grass consumed. To balance out the vitamin and mineral shortcomings of the hay/pasture, particularly if the hay is being soaked, the diet should include either a low NSC ration balancer type concentrate feed for when the protein content of the hay is low or questionable, or a vitamin mineral supplement when protein is adequate in the hay or horses that are extremely sensitive to any concentrate. If desired weight loss is achieved, then amounts of hay and

pasture access can be gradually increased to a level that maintains the weight loss but does not cause an increase in body condition. Supplements commonly recommended for ID are magnesium, chromium, and resveratrol as well as some herbal blends. While minerals like magnesium are required in the diet, the above-requirement supplementation has not been studied very well as treatment for ID. Off label use of the following drugs are currently being used in the treatment of EMS: high dose levothyroxine, metformin hydrochloride, and sodium-glucose co-transporter 2 (SGLT2) inhibitors. As exercise is likely to be beneficial for weight loss and maintenance of reduced body condition as well as improving insulin sensitivity, any level of exercise tolerated is recommended unless laminitis is present. Ideally, horses should be maintained in a low stress environment and housed with a companion if restricted to a drylot. Avoiding confinement in a stall, if at all possible, except during laminitis treatment, is desirable. Conscientious hoof care is also essential in the treatment of EMS.

Treatment of non-obese EMS horses is similar except weight loss is not desirable. The horses should still be maintained on a low-glycemic diet, such as low NSC hay and a low NSC concentrate feed or ration balancer. However, the non-obese EMS horse may be able to tolerate higher amounts of a low NSC, high fat, and high-quality fiber concentrate feed such as one with beet pulp and soy hulls. Medication with metformin or SGLT2 inhibitors can be used if dietary restrictions are not effective at controlling ID. Exercise and stress management are equally important as long as the horse is not laminitic.

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