Nutritional Management of Growing Horses

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Horses are raised to become sound athletes, and therefore optimal growth is preferred to maximal growth, which may be required in other livestock production systems. In horses, optimal growth rate results in a desirable body size at a specific age with the least amount of developmental problems.

While the genetic makeup, or genotype, ultimately determines a horse's mature size, nutrition plays an important role in achieving mature size and optimum growth rates. Other factors including the environment and how the growing horse is managed will influence growth.

Managing equine growth is a balance between producing a desirable individual for a particular purpose without creating skeletal problems that will reduce a horse's athletic ability. Growing a foal too slowly results in the risk of it being too small at a particular age or never obtaining optimal mature body size. Growing a foal too quickly results in the risk of developmental orthopedic disease (DOD) such as epiphysitis, angular limb deformities, and osteochondritis dissecans (OCD) (Pagan, 2005a).

It has been widely recommended to maintain a steady growth rate in young horses by regularly weighing and measuring horses during at least the first 18 months of life (Pagan, 2005a; NRC, 2007) and adjusting nutrition as necessary.

Pattern of Equine Growth

In general, horses are 10% of their mature weight at birth (Frape, 1998; Lawrence, 2005), but pony foals can be as much as 13% of mature weight and draft foals as little as 7% (Martin-Rosset, 2005). Heavier foals tend to be heavier throughout life (Brown-Douglas et al., 2005), and thus are favored by breeders in industries where size sells.

During the first year of life the foal grows rapidly, achieving 43% of mature body weight at 6 months of age and 83% of height. By 12 months of age, 61% of mature weight has been attained and at 24 months, horses are 96% of mature weight (Brown-Douglas et al., 2011).

Regardless of breed or country of birth, with optimal nutrition, horses show a similar pattern of growth between birth and two years of age. Rapid growth rates are observed in the first few months of life while the foal is still with its mother. Daily weight gain will decline at a constant rate from about four months of age to reach a low at 10 to 11 months of age, coinciding with the time of reduced pasture growth and availability in the winter (Pagan et al., 1996; Brown-Douglas et al., 2005; Martin-Rosset, 2005). Growth rates are observed to increase in the first spring of a horse's life, which is possibly a function of increased pasture nutrition and onset of puberty (Brown-Douglas et al., 2009).

Nutrient Requirements for Growth

Energy, protein (amino acids), macrominerals, trace minerals, and vitamins are essential for growth in the young equine, with daily requirements varying depending on growth rate and size of the individual.

Energy

Energy is required for maintenance, tissue deposition, and in the case of the older growing horse, exercise. However, there is no single nutrient identified as energy. Energy is derived from nonstructural carbohydrates (starches and sugars), structural carbohydrates (cellulose, hemicellulose, etc.), fatty acids, and carbon chains of proteins (NRC, 2007).

The desired average daily gain (ADG) will depend on commercial endpoint and management system but will dictate energy requirements. As it is important to maintain a steady growth rate, breeders are advised to plan the long-range management of their foal in advance and regularly weigh their young stock (Pagan, 2005a). Estimated energy requirement for growth in the NRC (2007) takes into consideration maintenance, age, and body weight as well as daily rate of grain, and is summarized for various ages in Table 1.

Excessive energy intake can result in rapid growth and increased fat deposition, which increases the incidence of some types of DOD. Young horses fed 130% of their energy requirement had a higher incidence of dyschondroplasia joint lesions than control horses (Savage et al., 1993a), and Thoroughbreds with OCD lesions were heavier than the average population as weanlings (Pagan, 1998).

Measurement of body weight can help with tracking growth rates of horses, but assessment of body condition score or fatness is helpful in assessing energy status. Condition scoring uses subjective measurement determined by feel and sight observation of the horse 's muscle tone and fat deposits to determine the overall score of a horse. In the most commonly accepted condition scoring system, scores are given ranging from 1 to 9 (Henneke et al., 1983) or, in a modified version, from 0 to 5 (Carroll and Huntington, 1988), and horses are judged to be poor, very thin, moderately thin, moderate, moderately fleshy, fleshy, fat, and extremely fat. An ideal condition score for young growing horses is deemed to be 4.5 to 5.5, as excessive body condition can be a precursor to DOD (Pagan, 1998). Energy intakes can be adjusted based on body condition score so that young horses are prevented from becoming too heavy.

Protein

Protein accounts for 80% of the fat- and moisture-free composition of the body and thus is important for growth. Protein is made up of chains of amino acids and the young growing horse has a high requirement for amino acids needed to build muscle and bone. Lysine is the first limiting amino acid in growing horses, with requirements outlined in Table 1, while threonine is the second most limiting amino acid.

The amino acid profiles vary depending on the protein source. In the foal, milk protein is superior to soybean meal, but for the nonsuckling foal, weanling, yearling, and mature horse, soybean meal is the protein source of choice.

Protein requirements for growing horses are based on digestible energy (DE) requirements (Ott and Asquith, 1986) as restrictions of both will reduce growth rates. The crude protein (CP) to energy relationship for weanlings is CP (g/day) = 50 g/Mcal DE, and for yearlings it is CP (g/day) = 45 g/Mcal DE. Lysine requirements are also provided on an energy basis. The lysine requirement for weanlings is 2.1 g/Mcal DE per day, and the yearling requirement is 1.9 g/Mcal DE per day.

There is still inaccurate advice floating around the industry that excessive dietary protein can cause DOD. This has been proven incorrect in many studies (Schryver et al., 1987; Thompson et al., 1988; Savage et al., 1993a), and it is concluded that deficiencies in dietary protein are more likely to negatively affect bone metabolism. Weanling foals fed 126% of the NRC protein requirement had no greater incidence than foals fed at NRC-recommended levels (Savage et al., 1993a).

Minerals

The most critical minerals for growing horses are calcium, phosphorus, copper, and zinc, which are primary precursors for bone and cartilage development. Mineral deficiency and/or excess of these minerals may lead to developmental orthopedic disease (Gunson et al., 1982; Pearce et al., 1988; Bridges and Moffitt, 1990; Knight et al., 1990; Hurtig et al., 1993; Savage et al., 1993b; Firth et al., 1999; Pagan, 2005b).

Calcium and Phosphorus

The importance of calcium and phosphorus in the mineralization of bone is well known. The ratio of calcium to phosphorus in the bone is 2:1, and it is recommended that horses be fed diets containing calcium and phosphorus ratios between 2.5:1 and 1:1. The ideal ratio of calcium to phosphorus in the ration of young horses is 1.5:1 and should never fall below 1:1 or exceed 2.5:1. Jordan et al. (1975) fed ratios of 6:1 to pony mares over a four-year period and found narrowing of the cortical area and less bone per unit area of bone.

Too much calcium may also affect phosphorus status, particularly if the level of phosphorus in the ration is marginal. In addition, high levels of phosphorus will inhibit the absorption of calcium and will lead to a deficiency, even if the amount of calcium present is normally adequate. Forage diets with high calcium levels should be supplemented with phosphorus.

Inverted calcium to phosphorus ratios are not uncommon when high-grain diets are fed with little or poor-quality forages. Nutritional secondary hyperparathyroidism can result from excessive phosphorus intakes in the presence of low calcium. This disease can cause shifting lameness and, in advanced cases, enlargement of the upper and lower jaws (NRC, 2007).

Calcium and phosphorus requirements for growing horses are outlined in Table 1.

Copper, Zinc, and Manganese

Copper requirements in growing horses have been debated for many years; however, it is important that copper is provided to the pregnant mare to adequately supply the growing fetal foal with copper for bone and cartilage development. Copper is a component of several copper-dependent enzymes that are involved with collagen and elastin formation in growing horses (NRC, 2007). New Zealand researchers studied the effect of copper supplementation on the incidence of developmental orthopedic disease in Thoroughbred foals (Pearce et al., 1998). Pregnant Thoroughbred mares were divided into either copper-supplemented or control groups. Live foals born to each group of mares were also divided into copper-supplemented or control groups. Copper supplementation of mares was associated with a significant reduction in the physitis (inflammation of the bone growth plates) scores of the foals at 150 days of age. Foals from mares that received no supplementation had a mean physitis score of 6, whereas foals out of supplemented mares had a mean score of 3.7. A lower score means less physitis. Copper supplementation of foals had no effect on physitis scores. A significantly lower incidence of articular cartilage lesions occurred in foals from supplemented mares. However, copper supplementation of the foals had no significant effect on articular and physeal cartilage lesions, further emphasising the importance of pregnant mare nutrition. It was also observed that foals born with low liver copper concentrations had worsening OCD scores between 5 and 11 months compared with foals born with high liver copper concentrations (Van Weeren et al., 2003).

Cymbaluk and Smart (1993) reviewed the literature on copper and its relationship to equine bone disease. They suggested that copper requirement may vary among breeds, but recommended that ponies and draft horses be fed 10 mg/kg ration and that horses prone to copper deficiency be fed a total of 20 to 25 mg/kg diet. They also reported a high tolerance to excess copper supplementation in the horse. The authors warned against a complicated copper deficiency caused by excessive zinc in the diet competing for the same transportation mechanism as copper. The key to proper copper and zinc nutrition seems to be an optimum ratio of 1:3-4 (copper to zinc).

Copper (Cu) requirements for the growing horse are approximately 0.25 mg Cu/kg body weight (NRC, 2007) and outlined in Table 1. Commonly, commercial feeds for growing horses are formulated with a copper concentration between 40 and 60 mg/kg feed.

Zinc (Zn) is important for the synthesis of many enzymes involved in protein and carbohydrate metabolism (NRC, 2007), and thus is vital for growing horses. Zinc deficiency in foals causes reduced growth and is reported when rates of 5 mg of Zn/kg diet are fed (Harrington et al., 1973), whereas tolerance to excess zinc is accepted in horses, with maximum tolerable levels around 500 mg Zn/kg ration (NRC, 2007). Current published recommendation for growing horses is 40 mg Zn/kg ration (NRC, 2007); however, most commercial feeds are formulated to provide 100-200 mg Zn/kg feed. Zinc requirements for growing horses at different ages are outlined in Table 1.

Manganese (Mn) is necessary for the synthesis of chondroitin sulfate during cartilage formation in the growing animal, with deficiency linked to abnormal cartilage formation and bone malformation (NRC, 2007). The recommended concentration for growing horses is 40 mg Mn/kg ration, but commercial feeds are commonly formulated to provide 50 to 150 mg Mn/kg feed.

Vitamins

Vitamins are an important class of nutrients required for growth, some of which must be provided nutritionally, while others can be synthesized by the healthy individual. Vitamins A and E are essential and must be provided in the diet, while vitamins C and D as well as the B vitamin niacin are produced by the horse. In the healthy horse, the rest of the B vitamins and vitamin K are produced by microbes in the horse's cecum and large intestine (Lewis, 1995). Many of these vitamins have key roles in the regulation of calcium and phosphorus and in proper skeletal development.

Vitamin A has a distinct role in equine growth with both deficiency and toxicity of vitamin A adversely affecting growth, body weight, and rate of gain in young growing ponies (Donoghue et al., 1981). Suboptimal growth may have reflected impaired cell proliferation and differentiation. In the growing horse, vitamin A supports the proper functioning of osteoclasts during bone remodelling. There is limited information on absolute vitamin A requirements for growing horses, but for horses grazing sufficient quantities of green pastures, vitamin A requirement can be met entirely by the carotenes in the forage (Greiwe-Crandell et al., 1995). In some regions, vitamin A supplementation is particularly important because of the short growing season of grasses. Weanling foals supplemented with 40,000 IU of vitamin A per day (~160 IU/kg body weight per day) along with hay and oats had improved serum levels during winter and spring, but supplementation had no effect during the summer when the horses were on pasture (Mäenpää et al., 1988). Toxicity levels for vitamin A are estimated to be around 1000 IU/kg body weight per day (NRC, 2007), with excess vitamin A being implicated in DOD in growing horses (Donoghue et al., 1981; Kronfeld et al., 1990).

Vitamin D is important in the maintenance of calcium homeostasis in the blood (McDowell, 1989), which is vital for normal mineralization of bone as well as for a host of other body functions. In some horse-production systems, young horses are often kept out of the sunlight to prevent dulling of the coat and to allow for ease of management. For horses not exposed to sunlight or artificial light with an emission spectrum of 280-315 nm, the requirement for dietary vitamin D is 800 IU of vitamin D/kg of diet dry matter (NRC, 2007). Vitamin D should not be given in an effort to treat developmental orthopedic disease (DOD) by increasing calcium and phosphorus absorption and bone mineralization. DOD has not been shown to be caused by vitamin D deficiency and supplementation with vitamin D will not make up for diets that are not properly fortified with calcium and phosphorus. Oversupplementation of vitamin D to horses is toxic and results in extensive mineralization of cardiovascular and other soft tissues (Harrington and Page, 1983).

Vitamin E, a biological antioxidant, is not directly linked to growth, but its roles in immune response and nerve and muscle function as well as its powerful antioxidant properties make it vital to the health of the young growing horse (Duren and Crandell, 1998). Together with selenium, vitamin E acts to maintain normal muscle function, aid in the prevention of muscular disease, and provide antioxidant protection to body tissue, particularly cell membranes, enzymes, and other intracellular substances, from oxidation induced damage (McDowell, 1989). Vitamin E is found in fresh green forage, and horses consuming adequate amounts of green forage have not been found to have vitamin E deficiency. The vitamin E requirement for growing horses is reported to be 80 IU/kg DM, assuming 2.5% body weight DM consumed. This is equivalent to 2 IU/kg body weight (NRC, 2007).

Vitamin C is important in the growing horse because it plays an important role in collagen synthesis and repair. Vitamin C is also necessary in energy production and hormone and amino acid synthesis. Vitamin C is also needed for production of the amino acid tyrosine. Vitamin C deficiency is not normally observed in horses because they can synthesize ascorbic acid from glucose in the liver. Production of vitamin C in the liver can be limited, and in some circumstances, the supply may not be adequate to meet the requirement of the horse. Supplementation of vitamin C may be beneficial during dietary deficiencies of energy (in particular glucose and glucose substrates), protein, vitamin E, selenium, and iron, and in times of rapid growth (McDowell, 1989).

Vitamin K is necessary for the proper clotting of blood, a process that uses calcium. Another calcium-related function of vitamin K is its role in bone and cartilage metabolism. If vitamin K is in short supply in the horse's body, it is first used to guarantee that the clotting factor is supplied. For this reason, it is thought that any deficiencies may short-change use in bone metabolism (Duren and Crandell, 1998). Vitamin K is found in high levels in forages, with cereal grains containing very little vitamin K. Vitamin K is also produced by intestinal bacteria in a healthy hindgut. Equine dietary vitamin K requirements have not been determined (NRC, 2007), but there is some suggestion that vitamin K supplementation might be helpful for young horses that do not have access to fresh pasture or have less than adequate hindgut health.

Table 1. Daily nutrient requirements of the growing horse with mature body weight of 500 kg (adapted from NRC, 2007, and Brown-Douglas and Pagan, 2009).

	4 months	6 months	12 months	18 months	24 months
Average wt (kg)*	200	250	350	450	490
ADG (kg/d)*	1.0	0.8	0.6	0.5	0.2
DE (Mcal)	13.3	15.5	18.8	19.2	18.7
CP (g)	669	676	846	799	770
Lysine (g)	28.8	29.1	36.4	34.4	33.1
Ca (g)	39.1	38.6	37.7	37.0	36.7
P (g)	21.7	21.5	20.9	20.6	20.6
Cu (mg)	42.1	54.0	80.3	96.9	96.9
Zn (mg)	168.5	215.9	321.2	387.5	429.2

Feeding Management for Young Growing Horses

There are many possible feeding practices to meet nutrient requirements and achieve successful growth. The best way to evaluate the success of a feeding and conditioning program for young horses is through assessment of body weight, height, and condition. Regular monitoring of weight allows farm managers to maintain a steady growth rate while preventing the animal from becoming too heavy.

Each horse should be fed as an individual. This will ensure that the correct amount of nutrients is consumed. Often individual feeding is not practical, especially for horses in groups out on pasture. In these situations, dividing up groups of young horses based on age and body size is wise. Ideally groups should be divided into nursing foals and their dams, weanlings, yearlings, long yearlings, and two-year-olds. If groups are greater than 20 horses, dividing into additional groups based on size and temperament is helpful to prevent bullying for food. In addition, it is wise to separate fillies and colts after weaning as both genders can reach puberty in the spring of their first year.

Sources of Nutrients for Growing Horses

Contribution of forage

Forage makes a significant contribution to the diet of young growing horses. As with all horses, it is recommended that young horses are offered at least 1% of their body weight in forage DM per day, but young horses are able to eat 1.5 to 2% of their body weight in forage DM per day, which will supply a considerable amount of their required energy and nutrients for growth. The types and amount of forages (hay and pasture) available will dictate the grain choice. The difference in nutritional value of grass versus legume forages is considerable, with legume forages (alfalfa, clover, etc.) generally having more energy, protein, and calcium compared with grass forages. In addition, the age or maturity of forage will also dictate its nutrient contribution to the diet, with young, leafy, vegetative forages usually having greater nutritive value than older, mature, stalkier forages.

Most breeding farms, regardless of country, will attempt to utilize available pasture in their feeding program. Many temperate countries, including New Zealand, Ireland, United Kingdom, and France, will grow grass year-round, and depending on pasture conditions and space, horses are housed outside year-round. Other countries require irrigation for pasture growth or will supply horses with conserved forages (hay/haylage) during summer and winter months. Horses raised in these countries will also require the use of barns or stabling for parts of the year.

Fortified Grains – Concentrates and Full Feeds

In many cases, the energy and sometimes protein requirements of young growing horses can be met by forage alone, although this will depend on the quality and amount of forage offered. However, mineral requirements for growth are unlikely to be met by forages, and thus additional supplementation is required. For easy-keeping young horses on good-quality forage, the use of a highly concentrated, low-intake balancer (usually 500 g to 2 kg per day depending on formulation) is often all that is required to meet nutrient requirements. These balancers tend to be between 20 and 30% protein, 2 to 5% calcium, and fortified to provide 100 to 250 mg/kg Cu and 300 to 600 mg/kg Zn depending on their formulation, recommended intake, and what forages they are designed to complement.

However, most growing horses will require additional energy and protein over and above the forage contribution. In an attempt to add energy to a horse's diet, many breeders will supply cereal grains (oats, barley, corn). Although straight cereal grain may add sufficient energy, the ration of a growing horse should be properly fortified because commonly fed cereal grains and forages contain insufficient quantities of several important minerals. As an example, a ration of grass hay and oats would supply only about 40% and 70% of a weanling's calcium and phosphorus requirement, respectively, and less than 40% of its requirement for copper and zinc. It is important to provide a balanced ration as the ratio of certain minerals (calcium to phosphorus; copper to zinc) is extremely important. Feed companies formulate specific feeds for growing and breeding horses taking their nutrient requirements into account. Fully fortified commercial grain mixes or pellets for young growing horses are generally higher in protein than feeds designed for mature horses and contain greater amounts of minerals for bone and cartilage development. Many feed companies produce breeding or stud feeds suitable for all horses on the breeding farm including pregnant and lactating mares, weanlings, yearlings, and stallions. These feeds tend to be formulated to contain between 14 and 16% protein, 0.8 to 1.2% calcium, 40 to 170 mg Cu, and 100 to 200 mg Zn per kg and are usually fed at a rate of between 2 and 5 kg per day depending on the age and physiological state of the breeding horse.

Credible feed companies will consider local forages when formulating feeds for horses in their area and will add or withhold nutrients depending on the forage available. This is why is it wise to choose locally manufactured feed from a reputable producer that regularly tests local forages and balances feed formulations to match.

Supplements

Generally if the young growing horse's diet is built around good-quality forage (1.5% body weight in forage DM per day) and a specially formulated breeding feed to meet energy, protein, and nutrient requirements, there should be no need for additional supplementation unless there are known deficiencies or specific problems to be targeted. The only exception is salt (NaCl), which should be offered free choice in the form of a white salt block. Other nutrients that may require supplementation should be considered only after forage and feed analysis has shown an imbalance or deficiency. Supplementation may also be necessary when clinical signs of a deficiency are present, such as poor hoof or coat condition (additional protein, biotin, and some trace minerals may be required) or excessive sweating (additional electrolytes may be required). Other supplements that don't target nutrient status are termed nutraceuticals and include joint supplements, buffers, and digestive aids, which can all be considered for the young horse but are often not necessary.

Broodmare Nutrition During Pregnancy and Lactation

Correct nutrition of the broodmare is vital for successful growth and development of the foal, and thus it is impossible not to mention the broodmare during a discussion on equine growth. Broodmare nutrient requirements increase significantly after seven months of gestation due to the increase in fetal size. During the last four months of gestation, the fetal and nonfetal tissues accumulate 77 grams of protein, 7.5 grams of calcium, and 4 grams of phosphorus per day (Pagan, 2005b). In addition to protein and macrominerals, trace mineral supplementation is also very important during the last trimester of pregnancy because the fetus stores iron, zinc, copper, and manganese in its liver for use during the first few months after it is born (Meyer and Ahlswede, 1976). This physiological process is necessary because the trace mineral content of mare's milk is relatively low and does not meet the requirement of the suckling foal (Meyer, 1994).

The energy requirements of mares increase significantly during lactation. During the first three months of lactation, daily milk production averages approximately 3% of the mare's body weight, and during months 4 to 6 it averages 2% of mare's body weight (Pagan, 2005b; NRC, 2007). During early and midlactation, the energy requirement is approximately double that of the mare during early pregnancy, while protein needs are doubled and lysine, calcium, and phosphorus requirements are thought to be over 300% higher (NRC, 2007).

Feeding the Foal

Foals grow rapidly during the first few months of life, quadrupling their bodyweight by five months of age (Pagan et al., 1996; Lawrence, 2005; Brown-Douglas and Pagan, 2009). Foals derive their energy, protein, and minerals to support this rapid growth from a combination of mare's milk, pasture, supplemental grain, and mineral stores in the foal's body. If the broodmare has received a correctly fortified feed during late pregnancy and is producing adequate milk, in most cases it is unnecessary to supplement the foal with grain until it reaches 90 days of age. If mares are fed their ration in feed bins accessible by the foal, it is an accepted practice that the foal consumes some of the mare's ration in the first few months. The amount of solid feed eaten is usually closely associated with the amount of milk being consumed. The more milk, the less solid feed the foal will eat.

Some farms will introduce a correctly fortified creep feed from 90 days of age and gradually increase the amount offered so that the foal's daily grain intake is 1 lb (0.5 kg) feed per month of age (Pagan, 2005b). An alternative practice is to introduce creep feeding from several days of age, allowing access to unlimited feed in specifically designed creep feeders until the foals are consuming 4 to 5 lb (about 2 kg) daily. Once the foals are eating 4 to 5 lb daily, the amount of creep feed fed should be limited so that they are receiving a maximum of 1 lb (0.5 kg) per month of age. If the amount fed isn't limited, some foals will eat excessive amounts, resulting in a rapid growth rate increasing the risk and severity of DOD. Both practices require regular monitoring of body weight to ensure foals are maintaining a good, even growth rate.

It is sometimes difficult to ensure the foal receives all its allocated creep feed. If the mare is fed in a stall, she can be tied and a separate feeder provided for the foal. Alternatively, a board can be placed across one corner of the stall so the foal can walk under the board to access the feed, but the mare cannot. If mares and foals are on pasture and the foals are fed in a group, it is important to observe feeding to ensure all foals can access the feeder and receive their daily amount. Dominant foals may consume more than their share, and if this isn't prevented by having adequate feeding space available, it may be necessary to feed slower-eating foals separately from the faster-eating foals. The amount of creep feed needed should be put in the creep feeder in equal amounts at least twice daily after removing any moldy or wet feed that may remain in the feeder.

If the older foal isn't receiving adequate milk from its dam, it may be weaned early and fed as a weanling separate from the mare. Conversely, if the foal is gaining too much weight on a high-producing mare, their milk intake needs to be reduced. To decrease the amount of milk consumed, either reduce the mare's feed (DE) intake to decrease her milk production, muzzle the foal for several hours per day or, if the foal is more than two months old, it is acceptable to wean the foal.

It is important that the foal is accustomed to eating supplementary feed before weaning. If foals are only offered grain post-weaning, it is likely that a compensatory growth spurt will occur. This growth spurt greatly increases the risk of developmental orthopedic disease (DOD) occurrence and severity. If the foal has been on a good feeding program, this growth spurt, and subsequently the risk of DOD, is reduced. It is important to remember that nutrition mistakes made during a foal's early growth can lead to developmental problems that limit performance later in life.

Feeding the Weanling

Weaning age comes down to management preference, with foals commonly being weaned from four to eight months of age. However, the best age to wean appears to be as soon as the foal's nutrient needs are no longer provided primarily by the mare's milk and, therefore, must be provided by solid feed intake. For most normal well-fed mares and foals eating the mare's grain mix, or a grain mix separate from the mare, this is at about four months of age. Earlier weaning appears to have no detrimental effect on the foal and offers a number of advantages including less feed needed for the mare, allowing her longer to prepare for her next foal.

The weaning process can have a significant influence on growth rate and several studies report a check in ADG immediately following weaning regardless of age (Warren et al., 1997; Brown-Douglas et al., 2005). Weaning can be managed to produce as little stress on the foals as possible and anecdotal evidence suggests that staggered weaning, when the mares of the oldest foals in a group are removed one by one over time, is the least stressful on the foals.

Proper nutrient intake is vital during the weanling stage as the skeleton is most vulnerable to disease. Nutrition plays an important role in the pathogenesis of developmental orthopedic disease in horses as deficiencies, excesses, and imbalances of nutrients affect the incidence and severity of DOD such as physitis, angular limb deformity, wobbler syndrome, and OCD (Savage et al., 1993a,b; McIllwraith, 2001; Jeffcott, 2005; Pagan, 2005b). The most common feeding errors attributed to developmental orthopedic disease are excessive grain intake, feeding an inappropriate grain for the forage being fed, and inadequate fortification of grain. These three scenarios are easily rectified by feeding an appropriate grain mix formulated for the young growing horse and feeding it at the correct intake. Young horses already suffering from developmental orthopedic disease should have their energy intakes reduced while maintaining correct levels of protein, vitamins, and minerals.

In addition to excessive energy, the source of calories for young horses is also important. Foals that experience a large and sustained increase in circulating glucose or insulin in response to a carbohydrate (grain) meal may be predisposed to OCD (Brown-Douglas et al., 2011). Research conducted by Kentucky Equine Research (KER) suggests that hyperinsulinemia may influence the incidence of surgically significant OCD in Thoroughbred weanlings (Pagan et al., 2001). In a large field trial, a high glucose and insulin response after a concentrate meal was associated with an increased incidence of OCD. Plasma glucose and insulin two hours post-feeding were significantly higher in weanlings with OCD than in unaffected foals. The ratios between insulin and glucose were not significantly different, but the incidence of OCD was significantly higher in foals whose glucose and insulin values were greater than one standard deviation above the mean for the entire population (both OCD and unaffected) in the study. Glycemic responses measured in the weanlings were highly correlated with each feed's glycemic index (GI), suggesting that the GI of a farm's feed may play a role in the pathogenesis of OCD. Hyperinsulinemia may affect chondrocyte maturation, leading to altered matrix metabolism and faulty mineralization or altered cartilage growth by influencing other hormones such as thyroxine (Jeffcott and Henson, 1998). Based on the results of this study, it is now commonly recommended to feed young horses concentrates that produce low glycemic responses such as feeds in which a proportion of the energy is supplied by fat and fermentable fiber sources (beet pulp and soy hulls).

Feeding the Yearling

Often growth and feeding management of the yearling will depend on its chosen career and whether or not it is being prepared for sale. Yearlings that gain and maintain body weight easily are termed easy keepers and should be prevented from becoming fat by being fed a low-intake, low-calorie source of essential protein, vitamins, and minerals. Conversely, yearlings that are large-framed with much growth potential can consume normal amounts of fortified feed. DOD, specifically OCD, is less of a concern in yearlings than with weanlings as most types of DOD are unlikely to arise after 12 months of age. Lesions that become clinically relevant after this age have typically been formed at a younger age; nevertheless, correct nutrient balance is important in the growing yearling (Pagan, 2005b).

Ongoing research suggests a relationship between the glycemic nature of feed and the incidence of skeletal problems in young horses. Diets high in starch and sugar (typical grain-based concentrates) produce a large blood glucose and insulin response after feeding and have been implicated in the etiology of DOD (Glade and Belling, 1986; Kronfeld et al., 1990). This, in addition to the work on hyperinsulinemia in weanlings (Pagan et al., 2001), indicates that it may be beneficial to replace a significant portion of the energy normally supplied by grain with fat and fermentable fiber to reduce the glycemic response to concentrate ration (Harris et al., 2005; Pagan, 2005b). Typically feeds designed for growing horses, whether they are weanlings or yearlings, will utilize a range of energy sources including highly digestible fibers, such as beet pulp and soy hulls, and oils for energy, reducing the proportion of starch in the diet.

Growth Management of the Yearling

Because larger, well-grown horses tend to be favored by buyers at yearling sales, young Thoroughbreds and Quarter Horses prepared for sale are grown rapidly to achieve maximal size (Brown-Douglas et al., 2007). To fuel this growth, these horses are often fed large amounts of supplementary grain. Extremely rapid growth by overfeeding energy has been implicated in DOD (Savage et al., 1993a). Periods of slow or decreased growth followed by growth spurts are also risky (Brown-Douglas et al., 2011).

In general, there are three different patterns of growth that breeders can use for their growing horses depending on when the horse is born and when or if it is sold at a sale (Pagan, 2005a). A pattern of slow early growth is more appropriate for foals that will not be sold as yearlings. Delaying rapid growth until after the window of vulnerability for bone and joint disease (<12 months of age) significantly reduces the risk of growth-related DOD (Hurtig and Pool, 1996). Foals that are early born and those that will be sold at later yearling sales could follow a moderate growth curve. This growth pattern is most commonly used for Thoroughbreds in Kentucky and results in a large, well-grown yearling with minimal joint problems (Pagan, 2005a). A rapid growth curve, in which weight gain is achieved over a short period of time, is used for later-born foals targeted at early yearling sales. This growth pattern is most likely to result in skeletal problems, but can result in more mature yearlings earlier in the season if properly managed. Rapid growth patterns can be successfully managed by spreading the growth over several months rather than trying to add the body weight gain during the traditional sales preparation period of 60 to 90 days before a sale (Brown-Douglas et al., 2011).

Country of birth and individual industry standards will also dictate growth patterns in young horses (Brown-Douglas and Pagan, 2009). Australasian Thoroughbred yearlings were heavier and taller than all other countries at 12 to 15 months of age. Climatic and pasture quality differences in late winter and early spring contribute to this situation, while the other factor is scheduling of yearling sales earlier in the year. The first yearling sales occur in January when the oldest yearlings will be 17 months of age, whereas in the Northern Hemisphere the first sales are in September when the oldest yearlings could be 21 months of age. At 18 months of age, Australasian Thoroughbreds are significantly heavier than those from all other countries. This is most likely representative of the difference in management of yearlings prepared for sale. Australasian yearlings tend to be sold at sales in a well-rounded condition with higher condition scores compared with American and English yearlings which are presented as leaner, more athletic, and fit. During an 8- to 10-week yearling preparation, ADG of up to and over one kg per day are common as the market demands big horses carrying plenty of muscle and fat cover. This trend is beginning to change as breeders and buyers realize the potential musculoskeletal problems associated with overconditioned yearlings (Brown-Douglas and Pagan, 2009).

In addition, these observations may further be attributed to the management of growing horses for different racing industries under different growing conditions. In general, the North American racing industry has significantly more short-distance dirt races than the industries of England, Australia, and New Zealand, and as a result, North American Thoroughbreds are raised to be precocious sprinting horses ready to race at two years old with a comparatively large muscle mass and a refined bone structure. In contrast, the English racing industry holds turf races commonly of distances greater than one mile, and as a result England has traditionally produced slower-maturing Thoroughbreds with larger frames but comparatively less muscle bulk than sprinting horses. Australia and New Zealand produce turf horses with a premium on early maturity and two-year-old racing; however, these Southern Hemisphere horses are traditionally known for their size, which may be attributed to genetics, even though shuttle stallions have had a significant impact on evening out the genetic pool between hemispheres (Huntington et al., 2007).

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