Feeding Management of Broodmares

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Introduction

An optimal broodmare feeding program will consider the maintenance of the mare, the growth and development of the fetal foal, and the production of milk. The impact of a broodmare feeding program can be substantial on not only the health of the mare, but also the development of the foal and the future equine athlete.

The nutritional requirements of the broodmare vary depending on her physiological state, thus when considering their nutritional and feeding needs, mares are usually divided into several categories. Traditionally, industry professionals divided a mare's gestation into two distinct nutritional periods: (1) from the time a mare was pronounced in foal to about eight months (first and second trimesters), and (2) nine months to approximately eleven months or birth (late gestation). In common practice, dietary requirements for mares in the first and second trimesters were assumed to be similar to any mature horse at maintenance. Moreover, because fetal growth is most rapid during the last trimester, an increase in certain nutrients such as energy and protein was traditionally recommended during the last three months of pregnancy (NRC, 1989). However, recent review of the research has indicated that certain vital nutrients should be increased prior to late gestation (NRC, 2007). There are now five main categories of broodmare, with specific nutrient requirements divided up even further within each class.

The main categories of broodmares are maiden mare; barren and early pregnant, nonlactating mare (0-4 months of gestation); mare in mid-pregnancy (5-8 months of gestation); mare in late pregnancy (9-11 months of gestation); and lactating mare (early and late, and likely pregnant as well).

For each class of mare, the required nutrients are the same, but intakes of these nutrients differ depending on the mare's physiological state.

Nutrient Needs of Broodmares

Energy Balance and Body Condition

Correct energy balance in mares is vital to a successful breeding program. During pregnancy, energy is required for maintenance of the dam, development of the fetal foal and placental tissue, and mammary development. In the nonpregnant mare, energy requirements are similar to a mature, nonexercised horse.

Fetal growth is very slow in the early months of pregnancy. At seven months of gestation, a fetal foal is less than 2% of the mare's body weight, and only 10 to 15% of birth weight (Frape, 1998). The majority of fetal growth occurs in the final months of gestation and thus its nutrient requirements are significantly greater. Due to the nonlinear growth curve of the fetal foal, the pregnant mare's energy requirements are also nonlinear. Up to the fourth month of gestation, pregnant mares have energy requirements similar to nonpregnant mares, but these requirements increase month-by-month from 5 months of pregnancy.

Lactating mares require energy for maintenance of body condition and milk production. Milk production is estimated at between 3 and 4% of body weight during the first 2 to 3 months of lactation and this declines in a linear fashion to 2% body weight after 5 months (Pagan, 2005; NRC 2007).

There are breed and individual differences in milk production. Energy requirements of the mare increase significantly with the onset of lactation, with requirements in early lactation nearly doubling those of midpregnancy (NRC, 2007).

In addition to milk production requirements, lactating mares require more energy for maintenance of body condition than nonpregnant mares because of the increased movement associated with protecting and tending to a foal and the increased energy needed by the gastrointestinal tract to digest the larger meals required to support lactation.

Body Condition

One of the most important aspects of broodmare nutrition is ensuring the mare is kept out of negative energy balance and preventing significant loss of body condition. Mares have an optimum body condition and are most efficient when kept at or near that condition. Establishment of the ideal condition comes from a combination of visually appraising the mare's condition and recording her body weight over time. The body condition scoring system of 1 to 9 is used in many countries to assess body condition in all classes of horse (Henneke et al., 1984), although a 0 to 5 system is used in other countries (Carroll and Huntington, 1988).

Mares may differ in shape and weight and be similar in condition. The mare should be moderately fleshy but not fat (BCS 5 to 7). If mares are below a BCS 5, they generally exhibit later onset of estrus in the spring, require more services per conception, and have a lower pregnancy rate (Lawrence, 2011). Mares in optimum condition should have adequate fat over the ribs, behind the shoulder, and along the topline. Ribs should be covered and not easily seen but should be readily palpated. Once optimum condition is achieved, it should be maintained as a minimal acceptable condition. There are times in the year when maintaining this condition requires a lot of feed and other times when little feed is required.

If the mare is provided sufficient energy, she will consume enough to attain the desired body condition, i.e., to store body fat during gestation for utilization in late pregnancy and lactation. When pregnant mares are allowed to self-regulate energy intake with good-quality forage sufficient in dietary energy and protein content to meet the mares' requirements, they will consume enough to store body fat for later utilization when energy needs increase. This was well demonstrated in one study in which mares, when allowed free access to alfalfa hay and haylage, ate enough to increase their body fat from 10.6% at 65 days to 14.2% at 215 days of gestation, where it stayed to 275 days; it then decreased to 12.5% and to the same body condition score as when they were bred by 305 days (Powell et al., 1989).

If grain is fed, it is important not to let the mare get too fat (i.e., to a body condition score of greater than 7). Although even severe obesity doesn't appear to affect the pregnant mare, the duration of pregnancy, placental weight or passage, or foaling, it may decrease the mare's milk production and as a result reduce her foal's growth rate (Kubiak et al., 1989). The lack of effect of obesity on parturition in mares is in contrast to what is frequently postulated and stated. Obesity can lead to labor complications and dystocia in women and heifers, but not mares or mature cows (Arnett et al., 1971; Ruge and Andersen, 1985). It has been reported that none of 900 mares that were fleshy or heavier at foaling had any difficulty foaling or any reduction in reproductive efficiency as a result of excess body fat (Kubiak et al., 1989). However, the broodmare should not be kept above moderate or moderately fleshy body condition year-round, as doing so is detrimental.

There is anecdotal evidence that fat late-pregnant mares have a greater incidence of foals with angular limb deformities (ALD). In an Australian case report, a very high incidence of ALD was related to excessive energy intake in a group of thin mares, which led them to be fat at the time of foaling (Mason, 1981). It has been speculated that this relates to excessive internal fat in the mare leading to compression of movement of the foal in utero, but this seems an unlikely reason. Hormonal changes related to obesity such as insulin resistance may be more relevant explanations.

If the mare is excessively overweight (i.e., has a body condition score greater than 7), a weight-reduction program should be instituted. This should be done during the period from 2 weeks before weaning until the last trimester of pregnancy, but not prior to breeding, during the first trimester of pregnancy, or in early lactation. Weight loss during these periods may decrease reproductive efficiency and milk production. Exercise is important for all horses and obese mares appear to move around paddocks less than mares of moderate weight. This tends to perpetuate the obesity as energy utilization for exercise is reduced. Breeders should provide late-pregnant mares with adequate opportunities for free-choice exercise. Hills are desirable as they increase the intensity of exercise but are not always available on horse farms. In some situations, fat pregnant or barren mares would benefit from forced exercise on automatic walkers. While exercise is desirable, a study by Sparks et al. (1999) showed that restriction of movement during pregnancy did not change the birth weights of foals when compared to mares allowed free exercise.

The effect of low body condition on reproductive performance is well documented. Mares that are thin at time of breeding (i.e., with a body condition score below 4) will have normal-weight foals but low reproductive efficiency and increased early embryonic losses if they do become pregnant (Henneke et al., 1984). The only safe time to adjust a mare's body weight by diet is between weaning and up to 7 months of gestation. Increasing energy intake prior to breeding (flushing) is beneficial for the thin mare but not for the mare at or above moderate body condition. The mare that is losing weight, regardless of her body weight with respect to her optimum, has reduced reproductive efficiency (Henneke et al., 1984; Morris et al., 1987; Weedman et al., 1993). Weight loss by the pregnant mare doesn't appear to affect the foal's birth weight but may decrease the mare's colostrum and milk production, thus decreasing the foal's passive immunity and growth rate (Banach and Evans, 1981). Henneke at al. (1984) also found that mild energy restriction leading to condition loss in late pregnant mares did not influence gestation length or birth weight; however, Hines et al. (1987) found this was associated with longer gestations. On the other hand, severe weight loss (up to 20%) associated with an outbreak of strangles in Thoroughbred maiden mares in midpregnancy had a number of consequences compared to uninfected mares. It led to significantly lower placental area and efficiency, reduced birth weight, and reduced length in their foals. There were correlations between the degree of weight loss, placental changes, and length of the foals (Wilsher and Allen, 2006).

Milk yield and composition can be affected by breed, stage of lactation, parity, age, body condition score, and nutrition. In addition to excess obesity and weight loss, excess thinness at foaling may decrease the mare's milk production (Banach and Evans, 1981; Gibbs et al., 1982; Jordan, 1982; Gill et al., 1985). If the thin foaling mare is allowed sufficient feed to gain weight following foaling, she will increase her milk production to a level similar to that of heavier mares by 1 month of lactation (Doreau and Boulot, 1987). Lactation alone requires nearly a doubling in energy intake. This, added to the amount needed for weight gain, greatly increases the amount the mare must consume. The birth weight of the foal, however, appears to be little affected by its dam's weight gain or loss during pregnancy, or her body weight at foaling, whether she is obese or thin (Jordan, 1982; Kubiak et al., 1989; Anonymous 1993; Wilscher and Allen, 2006). However, very thin mares have been noted to have reduced milk production and foal growth rate (Pagan et al., 1984; Gill et al., 1985; Doreau and Boulot, 1987), so keeping mares in good condition is desirable.

How much weight should a mare gain in pregnancy? Optimal weight gain in pregnancy has not been determined in the mare, but anecdotal evidence from an Australian Thoroughbred farm suggests that mares foaling later in the season and gaining 80 kg in the last 60 days of pregnancy had heavier foals than those foaling earlier and gaining less weight (Baker, personal communication). This work has shown that early foaling mares gained an average of 40 kg in the last 2 months while later-foaling mares gained an average of 80 kg. The lower weight gain in the early-foaling mares was associated with changes in pasture quantity and quality and weather conditions during late winter compared with spring. It was also associated with lower birth weights, faster growth, and a higher incidence of valgus deformities of the knee. When management practices were changed to increase the weight gain, this incidence of angular limb deformities in foals born in August and early September was reduced. This change in management practices involved feeding greater amounts of a balanced concentrate feed so the mare would have received more energy, protein, and minerals. In contrast to these findings, Lui et al. (1984) have reviewed work from the United States and concluded that mares in good condition do not need to gain significant amounts of weight during late pregnancy in order to produce healthy foals. Other studies have found that mares can have foals of normal birth weight despite gaining little weight during the last 90 days of gestation (Powell et al., 1989; Kolwaski et al., 1990).

Maiden mares tend to have smaller foals than multiparous mares. Wilsher and Allen (2006) fed maiden mares a high- or moderate-grain intake during pregnancy so that the high-grain group gained 140 kg vs. 100 kg in pregnancy and became fat, with a significant difference in gain in body condition score as well. However, there was no difference in placental measurements, foal birth weight, or growth of the foal after birth.

In lactating mares, body weight and condition score of the mares had a strong effect on foal growth (Pagan et al., 2009). In a study of over 4,000 Thoroughbred mares and their foals, foal body weight was positively correlated to mare body weight, foal average daily gain (ADG) was positively associated with mare ADG, and foal fatness (indicated by body condition score or BCS) was positively related to mare BCS during the first 5 months of life. In the study, mares that foaled in winter (Jan/Feb) exhibited weight loss in early lactation, which suggested that their energy intake was insufficient to meet their requirements. Moderate energy restriction or excess during lactation was not associated with changes in the ADG of foals, but milk output was not measured (Pagan et al., 1984). Energy restriction during lactation may lead to weight loss in mares and reduced reproductive efficiency, but this will not necessarily lead to reduced growth in foals. The impact of a negative energy balance and weight loss may depend upon the fat reserves held by the mare at the time so that thin mares have lower reserves of fat and protein to support milk production.

Protein

Protein is the most important nutrient for a successful breeding program. Inadequate dietary protein or energy intake in nonpregnant mares may prevent ovulation, or, if ovulation and fertilization occur, may result in early embryonic death and reduced foal size (Bengtsson and Knudsen 1963; Van Niekirk 1965; Van Niekirk and Van Heerden, 1972). Inadequate dietary protein, even with sufficient energy or feed intake for body weight maintenance, decreases reproductive efficiency, perhaps primarily due to a failure to ovulate (Van Niekirk and Van Heerden, 1972).

Protein requirements for mares follow a similar pattern to energy requirement. For nonpregnant mares and mares up to 4 months of pregnancy, protein requirements are the same as a nonexercised, mature horse. From 5 months of gestation to foaling, protein requirements increase each month (Table 1) (NRC, 2007). By the end of the seventh month of pregnancy, the Thoroughbred fetus has accumulated about 8 kg of protein as it grows to a birth weight of approximately 50 kg (protein accumulated and birth weight will vary depending on breed), but during the last month of pregnancy alone, the fetus will accumulate over 2.5 kg of protein (Pagan, 2005). Protein requirements also increase into lactation. A 600-kg mare in early lactation will produce 18 to 20 kg of milk per day (NRC, 2007) and because milk is 20 to 25% protein on a dry matter basis, dietary protein must be increased from gestational levels (Pagan and Hintz, 1986).

The quality of the protein consumed by the broodmare is an important consideration. The amino acid most likely to be deficient in the mare's diet is lysine. Ensuring adequate amounts of vital amino acids such as lysine is more important than just meeting crude protein requirements (Lawrence, 2011). Foal growth rate and milk crude protein both increased in Thoroughbred mares supplemented with soybean meal 2 weeks prior and 7 weeks after foaling (Glade and Luba, 1990). The addition of 500 g of soybean meal prior to foaling and 750 g after foaling was matched by a reduction in concentrate intake so that the DE intake remained the same in both groups. The crude protein content of milk was significantly increased in the first 5 weeks of lactation, and the foals of soybean-supplemented mares grew 10% taller in the first 7 weeks of life. The control group of mares in this study was fed a 16% (as fed) crude protein concentrate and was supplied with crude protein and lysine in excess of NRC requirements both before and after foaling. However, several studies have also shown that variations in protein and amino acid intake had no impact on the composition of mare's milk. The lysine requirement for pregnant mares is estimated to be 4.3% of crude protein requirement (NRC, 2007).

Arginine is an essential amino acid for horses and is metabolized into several substrates including nitric oxide. Research in women has shown that arginine supplementation increased blood flow to the uterus. Recent work in horses showed that 100 g per day fed to light-horse mares for 21 days before foaling led to increased blood flow to the previously pregnant horn and reduced uterine fluid accumulation after foaling (Kelley et al., 2011). Arginine supplementation may be useful in mares prone to chronic intrauterine fluid accumulation.

Protein or energy deprivation in pregnancy and lactation will result in the mare drawing upon stored reserves to maintain intrauterine growth rate of a fetus and foal birth weight (Lawrence et al., 1992; Van Niekirk and Van Niekirk, 1997), and milk production and growth rate after foaling. The impact of protein and energy restriction may depend upon the reserves the mare has to draw on. Doreau and Boulot (1987) found that thin mares had lower milk production than fat mares. Pagan et al. (1984) found that there was no difference in the growth rate of pony foals on mares that were fed either 70% or 130% of their energy and protein requirements. Mares either lost or gained weight, but foal growth rate did not change. However, when mares were in poor body condition (BCS 2) and had fewer reserves to draw on for energy and protein required for milk production, growth rate of the foal was reduced. The same group of workers found that feeding excess energy to pony mares led to reduced fat and protein content in the milk, which may reduce foal growth rate.

Gill et al. (1985) restricted mares to 70% of protein needs during pregnancy and lactation, and found that birth weights were not affected, but that growth rate of the foal to 90 days was reduced in restricted group compared to mares fed normal diets during both pregnancy and lactation or those restricted during pregnancy but not lactation. These diets were not isocaloric. This effect of protein deprivation on the growth rate of foals was presumed to have occurred via an effect on milk production. Martin et al. (1992) fed mares a protein-deficient diet that led to reduced milk production and lower growth in their foals.

Prolactin is a hormone that is important in parturition and milk secretion in the mare. Recent work has shown that energy restriction and low body condition can reduce prolactin secretion and this could be an important consideration in lactating mares. Dry mares kept in poor to moderate condition produced less prolactin than mares kept in fat condition (Gentry et al., 2002), and geldings kept on a high-forage diet that only supplied 70% of energy needs produced lower prolactin levels following stimulation with thyroid releasing hormone (Powell et al., 2003).

Table 1. Recommended minimum daily requirements for a 500-kg Thoroughbred broodmare in good body condition (adapted from NRC, 2007).

	Body weight (kg)	DE (MJ/day)	CP (g/d)	Lys (g/d)	Ca (g/d)	P (g/d)	Cu (mg/d)	Zn (mg/d)
Early gestation	500	69.8	630	27.1	20.0	14.0	100	400
5 months gestation	504	71.5	685	29.5	20.0	14.0	100	400
7 months gestation	515	74.8	729	31.3	28.0	20.0	100	400
9 months gestation	534	80.3	797	34.3	36.0	26.3	125	400
11 months gestation	566	89.5	893	38.4	36.0	26.3	125	400
1 month lactation	500	132.5	1535	84.8	59.1	38.3	125	500
3 months lactation	500	127.9	1468	80.3	55.9	36.0	125	500
5 months lactation	500	118.3	1330	71.2	39.5	24.7	125	500

Minerals

Important macrominerals in the diet of pregnant and lactating mares are calcium, phosphorus, and magnesium, which are needed for the rapid growth of bone in the fetus in late gestation and the foal prior to weaning. At birth, the foal is 10% of mature weight and only has 17% of its maximal bone mineral content. By 6 months of age, the foal has reached 85% of its height and has 68% of its bone mineral content (Hintz et al., 1979; Lawrence, 2005). Up until this time many foals would not be weaned, and if the mare had not received supplementary feed, all of these minerals would have been supplied by the placental circulation, milk, and grass.

Optimal daily calcium requirements for pregnant mares have not be established, though the NRC recommends increasing calcium intake from 20 g/day in early pregnancy to 28 g/day at 7 months and 36 g/day in the final 3 months of gestation (NRC, 2007). Lactating mares have a calcium requirement three times that of dry mares, and it is estimated that the milk of mares contains about 1.2 g of calcium per kg of fluid milk during early lactation (first three months) and 0.8 g of calcium per kg of fluid milk during late lactation (Schryver et al., 1986; Grace et al., 1999). Wide variation in calcium intake by the mare have been shown to have no effect on concentration in milk in a number of studies (Lewis, 1995) as the mare draws on calcium reserves in the skeleton to sustain calcium secretion in the milk. This can lead to increased serum parathyroid hormone levels and demineralization in the mare (Martin et al., 1991). Lewis (1995) cited an unrefereed study in which milk calcium concentration was 40% lower in mares receiving 33% of dietary calcium needs, but levels were not increased above normal values in mares getting 250% of their daily requirement. Glade (1993) reported that mares fed the NRC-recommended levels of calcium gradually lost bone density during the first 12 weeks of lactation, but bone density started increasing at that time and was fully restored at 24 weeks post-parturition. However, mares fed 20% less calcium than recommended had not recovered bone density at 40 weeks after parturition even though the foals were weaned at 20 weeks.

Phosphorus requirements also increase in late pregnancy and lactation in line with calcium. It is reported that phosphorus deficiencies were quite common in late pregnancy while calcium deficiencies occurred in lactation (Donoghue et al., 1990). Phosphorus deposition in the fetus was estimated to be 9.4 g/day for a 500-kg mare during the last three months of gestation (Drepper et al., 1982), thus a 500-kg mare would require about 30 g of phosphorus per day. The phosphorus content of liquid milk in early lactation was 0.75 g/kg and decreased to 0.50 g/kg during late lactation (NRC, 1989). This leads to a 30% increase in phosphorus needs in early lactation. Data from digestion studies at Kentucky Equine Research (KER) have shown that phosphorus digestibility is unaffected by calcium content and calcium-to-phosphorus ratio but was negatively correlated with fiber content in the diet (Pagan, 1998a,b).

As with calcium and phosphorus, body composition data from the laboratory of Dr. Helmut Meyer were utilized to estimate NRC magnesium requirements of mares. Deposition of magnesium was calculated to be 0.3 mg/kg of body weight of the mare, and it was calculated that a 500-kg late-pregnant mare would need about 10 to 12 g of magnesium per day. It was estimated that the magnesium concentration of milk averages 90 mg/kg during early lactation and a 500-kg mare would need about 15 g of magnesium during early lactation. It is possible that we should be concerned about calcium/magnesium ratio in the diet of mares, as well as young horses, but there is no data to validate any suggested ratios (Drepper et al., 1982). Data from digestion studies conducted at Kentucky Equine Research have shown a positive correlation between calcium content and magnesium digestibility and a negative correlation with phosphorus content (Pagan, 1998a,b).

Trace Minerals

Trace mineral supplementation is very important during the last few months of pregnancy because the fetal foal 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 occurs because the trace mineral content of mare's milk is relatively low and does not meet the requirement of the suckling foal (Meyer, 1994).

Copper is essential for proper functioning of enzymes involved in the synthesis and maintenance of elastic connective tissue and detoxification of superoxide. Copper has received a great deal of attention in breeding horses because of its role in the pathogenesis of developmental orthopedic disease (DOD). NRC requirements estimate 100 mg/day copper to 550-kg pregnant mares up to 8 months of gestation and 125 mg/day until foaling (2007).

New Zealand researchers (Pearce et al., 1998a) studied the effect of copper supplementation on the incidence of DOD in Thoroughbred foals. Pregnant Thoroughbred mares (n=24) 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. The four treatment groups were: (1) mares supplemented with copper, but their foals were not supplemented; (2) both mares and foals were supplemented with copper; (3) mares were not supplemented, but their foals received supplementation; and (4) neither mares nor foals received supplementation.

Supplemented mares received 0.5 mg copper/kg body weight daily (~250 mg) while copper-supplemented foals received 0.2 mg copper/kg body weight from 21 to 49 days of age and 0.5 mg copper/kg body weight (~100 mg) from 50 days to 150 days. Mares were supplemented for the final 13 to 25 weeks of gestation, and all mares and foals received concurrent selenium and zinc supplementation. At 150 days of age, the foals were sacrificed and an exhaustive postmortem examination was performed. The number of articular and physeal cartilage lesions was noted for each treatment group along with a physitis score that was determined from radiographs of the distal metacarpus.

Copper supplementation of mares was associated with a significant reduction in the radiographic physitis scores of the foals at 150 days of age. Foals from mares that received no supplementation had a mean physitis score of 6, while foals out of supplemented mares had a mean score of 3.7. A lower score indicates less physitis. When only foals (but not mares) were supplemented with copper, no significant effect on physitis scores was noted. There was a significantly lower incidence of articular cartilage lesions in foals from mares supplemented with copper. However, no significant effects on lesions occurred in foals supplemented with copper.

This research (Pearce et al., 1998a,b) would suggest that oral supplementation of the pregnant mare is more important than supplementation of the foal or copper administered by injection to the mare in late pregnancy, which did not influence foal copper status (Gee et al., 2000). Oral copper supplementation of mares in late gestation altered the copper balance in these horses and resulted in an increase in the foal's liver copper stores at birth. Increased liver copper stores of the neonate may be important for ensuring healthy development of the skeleton during the period of maximum postnatal growth. Van Weeren et al. (2003) examined the copper status of foals at birth and the incidence of radiographic signs of OCD in Warmblood foals genetically prone to OCD, that were examined at 5 and 11 months of age. Radiographic score was not related to liver copper concentration at birth, but foals with high liver copper levels had improvements in the severity of OCD changes in the stifle from 5 months to 11 months. Foals with low liver copper levels at birth had more severe signs of OCD at 11months than 5 months, indicating that copper is perhaps less involved as a cause of OCD and more important in repair of lesions.

These studies certainly provide evidence that copper supplementation of mares and their foals can play an important role in skeletal development. Copper is not, however, the only factor involved in the pathogenesis of DOD, and it has been questioned whether the lesions produced by copper deficiency are the same as those most often seen in the field (Pagan, 2000). Copper deficiencies may either be primary in origin because of a lack of copper intake or induced (secondary) due to interactions with other substances in the ration. Zinc and molybdenum have often been implicated as minerals that can interfere with copper absorption in horses, but several studies have suggested that neither zinc nor molybdenum (Pagan, 2000) affects copper utilization when fed at levels found in practical diets. Pagan (1998b) found significant negative correlations between true copper digestibility and the concentration of both crude protein and calcium in 30 different diets. These interactions may be particularly relevant when horses are fed predominantly legume forage or given several calcium supplements.

Zinc is present as a component of many enzymes and the biochemical role of zinc relates largely to the functions of these enzymes. Pagan (1998b) evaluated interactions between zinc digestibility and a number of nutrients in 30 different diets. The only nutrient that was significantly correlated to zinc digestibility was magnesium. None of the trace minerals, including iron, affected zinc digestibility. There are no studies examining the intake of zinc in the diets of mares and bone development in their offspring.

Manganese deficiency has not been observed in horses. From research in other animals, manganese is known to be involved in several metabolic processes, including cartilage formation. Unfortunately, little research on this mineral has been conducted with horses.

Many studies have shown that because milk is a poor source of trace minerals for the foal, there is no correlation between the amount of copper, iron, and zinc in the mare's diet and levels in the milk or blood levels in the newborn foal. However, regardless of dietary intake, age of the mare had a significant impact on the concentration of zinc and copper in the colostrum (Asai et al., 1995).

In contrast, iodine and selenium concentrations in milk are correlated with consumption by the mare. Iodine is an essential nutrient for reproduction and normal physiological function in the horse. Thyroxine (T4) contains iodine and this hormone, along with triiodothyronine (T3), has powerful effects on the overall health of the horse. These hormones influence nearly every process in the body, from heat regulation and feed utilization to proper bone growth and maturation. Iodine deficiency may result in goiter as the thyroid becomes enlarged in an attempt to produce adequate levels of thyroxine. In the horse, goiters often occur in the foal at birth. Goiter in the foal may result from a deficiency in iodine in the mare's ration during pregnancy or it may be caused by a goitrogenic substance. Symptoms of iodine deficiency may be a stillborn foal or a very weak foal that cannot stand and nurse. The foal may also have a rough haircoat, contracted tendons, angular limb deformities, or other abnormal bone development. There can be dramatic seasonal variation in the iodine intake for grazing animals with low intakes recorded during spring when many mares are in the final stages of pregnancy (Caple, 1991).

While iodine deficiency is the primary cause of goiter in foals, excessive levels of iodine may also cause this condition. The maximal tolerable dietary concentration of iodine has been estimated to be 5 mg/kg (ppm) of dry matter (NRC, 2007), equivalent to 50 mg of iodine/day for a horse consuming 10 kg of dry matter daily. The horses most sensitive to high iodine levels are foals from mares that are supplemented with high levels of iodine. Iodine is concentrated across the placenta and in milk so that the fetus and nursing foal receive much higher concentrations than are present in the mare's ration. Therefore, goiter may be present in newborn foals while sparing the mother. A dietary intake of 83 mg iodine/day is the lowest level reported to have caused goiter in a horse more mature than a suckling foal (Drew et al., 1975).

Baker and Lindsey (1968) reported that foals with goiter were born on three farms that were feeding mares high levels of iodine. The incidence of goiter was proportional to the level of iodine fed and was 3% on one farm feeding 48 to 55 mg iodine/day, 10% on a farm feeding 36 to 69 mg iodine day and 50% on another farm feeding 288 to 432 mg iodine/day. A nearby farm that did not have any affected foals fed iodine at a rate of 6.3 to 7 mg iodine/day. Drew et al. (1975) reported that on one stud farm in England four foals were born with greatly enlarged thyroids and leg weaknesses. One mare also had an enlarged thyroid. Feed analysis showed that the mares had received 83 mg iodine/day from a proprietary feed during pregnancy. The year before, the mares received a supplement that supplied about 12 mg iodine/day, and there was no problem with goiter on the farm.

It appears from these reports that around 50 mg of dietary iodine is required in the daily rations of mares to produce any incidence of goiter in their foals. Toxic dietary iodine concentrations may result from adding excessive supplemental iodine, such as from ethylenediamindihydroiodide (EDDI), to concentrates or from using feedstuffs high in iodine. A common feedstuff that may contain excess iodine is kelp (*Laminariales*), a specific family of seaweeds that may contain as much as 1,850 ppm iodine (NRC, 1989). Unfortunately, people have a tendency to classify all seaweeds as kelp. There are numerous other specific seaweeds that contain considerably less iodine than kelp (Pagan, 2000). The iodine content of seaweed meal and kelp products should be examined prior to feeding to pregnant mares and intake must be carefully controlled.

Selenium plays an important role in the maintenance of membrane integrity, growth, reproduction, and immune response. A deficiency of selenium in neonatal foals may produce white muscle disease, a myopathy that results in weakness, impaired locomotion, difficulty in suckling and swallowing, respiratory distress, and impaired cardiac function (Dill and Rebhun, 1985). This relates to deficient intake of selenium by the pregnant mare. Many areas of the world have very low selenium levels in soil and forages, and selenium content is not routinely measured in forage analysis. However, the selenium status of a horse can be assessed by measurement of whole blood or plasma selenium levels or by the selenium-dependent enzyme glutathione peroxidise. The NRC (2007) lists a selenium requirement of 0.1 mg/kg diet to prevent classic selenium deficiency signs, but research has shown benefits in supplying pregnant mares with 3 mg/day or 0.3 mg/kg of diet. Janicki et al. (2001) found greater antibody levels in foals of mares receiving the higher level of selenium. This same study showed that mares receiving 3 mg as selenium yeast had higher plasma levels of selenium in serum, colostrum, and milk than those mares fed inorganic selenium.

Vitamins

Vitamin A is best known for its role in vision but also has functions in reproduction, differentiation of epithelial cells, immune function, embryogenesis, and growth. Vitamin A is found in abundant quantities in fresh, green forages in the form of carotenes, which are converted to vitamin A by enzymes in the intestinal mucosa. Once forage is cut, there is rapid oxidation of carotenes (up to 85% within the first 24 hours and then about 7% per month during storage), which results in hay being practically devoid of carotenes after extended storage (McDowell, 1989). Horses on hay-only diets had depletion of vitamin A liver stores over a relatively short period of time (Fonnesbeck and Symons, 1967; Greiwe-Crandell et al., 1995).

Vitamin A has a distinct role in growth of the horse. Both deficiency and toxicity of vitamin A adversely affected growth, body weight, and rate of gain in young, growing ponies (Donoghue et al., 1981). This retardation of growth may have reflected impaired cell proliferation and differentiation. Bone remodeling is modulated by vitamin A in the growing animal. Vitamin A aids in bone remodeling by ensuring proper functioning of osteoclasts, the bone cells responsible for resorption of bone. Without sufficient vitamin A, excessive deposition of periosteal bone occurs. The appearance of bones in vitamin A deficiency is actually shorter and thicker than normal (Fell and Mellanby, 1950). This is in part caused by the dysfunction of osteoclasts but also by a reduction in the degradation of glycosaminoglycans and the synthesis of proteoglycans also caused by deficiency (Dingle et al., 1972). It is possible that some of the systemic effects of vitamin A on growth, as well as the poor growth usually associated with vitamin A deficiency, are related to its effects on growth hormone secretion. Vitamin A takes different functional forms once it is working in the body, one of which is retinoic acid. Retinoic acid has been found to affect growth hormone regulation (Sporn et al.,1994). Retinoic acid can synergize with either thyroid hormone or glucocorticoids to enhance the transcriptional activity of the growth hormone gene, and subsequently of growth hormone secretion from cells (Bedo et al., 1989). Retinoic acid is also essential for embroyonic development during pregnancy

For horses grazing sufficient quantities of green pastures, their vitamin A requirement can be met entirely by the carotenes in the forage (Greiwe-Crandell et al., 1997a). In high latitude areas, vitamin A supplementation is particularly important because of the short growing season of grasses. Depletion of vitamin A reserves in pregnant mares was found within two months of a diet of hay and vitamin A-free concentrate. Subsequent supplementation of vitamin A palmitate at two times the NRC recommended level was not adequate to completely replete stores of vitamin A in mares with no access to pasture (Greiwe-Crandell et al., 1997a). Other studies have found a seasonal decline in vitamin A status in pregnant mares. Mares with access to green pastures had adequate liver stores of vitamin A regardless of vitamin A supplementation. Additional vitamin A palmitate did not induce any excesses of vitamin A in liver or serum (Greiwe-Crandell et al., 1997a). Further investigation on ß-carotene found carotenes in grass readily available as a source of vitamin A, but synthetic ß-carotene was not readily absorbed. Use of synthetic ß-carotene as a sole source of vitamin A could not meet vitamin A requirements of horses and is not recommended (Greiwe-Crandell et al., 1997b). Vitamin A has been found to be of critical importance to the late-pregnant mare. Studies by Greiwe-Crandell (unpublished) showed that if mares are maintained on hay alone with no green pasture and no vitamin A supplementation, the subsequent growth rates of their foals is significantly reduced up until 12 months of age compared to foals of mares with adequate vitamin A intake.

There are suggestions that an interaction between adequate vitamin A and E enhanced reproductive status and fertility in mares (Stowe, 1967), and vitamin A deficiency in swine has been shown to increase early embryonic death (McDowell, 1989). Under dry conditions (summer or winter), the intake of vitamin A from pasture declines dramatically and added vitamin A from a feed or supplement may be needed. At this time, it is likely that mares will be fed concentrates. Most, but not all, prepared feeds and supplements will contain enough added vitamin A to supply a daily intake of 6000 IU/kg body weight for breeding mares. Supplementary hay, provided it is fresh and has retained its vitamin A content, will also help add vitamin A to the diet. However, vitamin A toxicity has been implicated in bone fragility and developmental orthopedic disease (Donoghue et at., 1981; NRC, 2007). The presumed upper safe level is 16,000 IU/kg DM and elevated plasma vitamin A levels greater than 40-60 ug/dl are thought to be diagnostic of toxicity (Lewis, 1995), but clinical cases are rare.

Vitamin D is known as the sunshine vitamin because it is made on the skin from 7-dehydrocholesterol by a reaction catalyzed by ultraviolet (UV) light. The function of vitamin D is maintenance of calcium homeostasis in the blood (McDowell, 1989). Circulating calcium is used for normal mineralization of bone as well as for a host of other body functions. Parathyroid hormone (PTH) and calcitonin function with vitamin D to control blood calcium and phosphorus concentrations. When blood calcium is low, the parathyroid is stimulated to release PTH. PTH travels to the kidney and stimulates conversion of 25-OH vitamin D to form the active vitamin (1,25 OH vitamin D). Active vitamin D then stimulates intestinal calcium uptake, bone mineral release, and resorption of calcium by the kidney, all in an effort to restore blood calcium levels (Linder, 1991). Calcitonin regulates high serum calcium by depressing gut absorption, halting bone demineralization, and slowing resorbed in the kidney.

Since vitamin D is readily synthesized and absorbed from the skin, is it necessary to supplement vitamin D in the diet? In modern horse production systems, show horses are often kept out of the sunlight to prevent dulling of the hair coat. For horses not exposed to sunlight or artificial light with an emission spectrum of 280-315 nm, the NRC (2007) has established a requirement for dietary vitamin D. Pregnant and lactating mares (550 kg) require 3300 IU vitamin D per day.

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 is an important biological antioxidant for all classes of horses. Although vitamin A and E status was thought to influence mare fertility (Stowe, 1967), the control diet contained very low intakes of vitamin E and other studies have not found any fertility benefit in supplementing vitamin E. As with vitamin A, if adequate amounts of fresh pasture are available to the broodmare, then her vitamin E requirements are likely to be met. Vitamin E deficiency has been implicated in white muscle disease in foals, but it is thought that the primary deficiency is selenium (NRC, 2007). Recent research has indicated a benefit of vitamin E supplementation in pregnant mares related to increased colostral antibody levels. Hoffman et al. (1999) found mares fed 160 IU/kg DM had higher IgG levels in the colostrum than mares fed the NRC (2007) recommended intake of 80 IU/kg. Their foals tended to have higher serum IgG than foals of control mares. Mares supplemented with 2500 IU/d natural vitamin E in the last month of pregnancy in addition to a fortified broodmare feed providing 170-320 IU vitamin E/day had increased total milk vitamin E levels, and elevated IgG and IgM on the second and third days postpartum, compared with control mares fed only the broodmare feed (Bondo and Jensen, 2011).

Vitamin K was the last fat-soluble vitamin to be discovered (McDowell, 1989). For many years, vitamin K has been known for its blood-clotting function. Recently, the carboxyglutamyl residues have been found in other proteins associated with a variety of tissues. Most notable is osteocalcin, a protein involved in bone metabolism. Osteocalcin is responsible for binding to hydroxyapatite and facilitating bone mineralization. Undercarboxylated osteocalcin does not bind hydroxyapatite with the same affinity as carboxylated osteocalcin (Knapen et al., 1989). If vitamin K is in short supply, one would expect to find irregularities in blood clotting along with undercarboxylated osteocalcin. However, it is suspected that osteocalcin is more sensitive to low vitamin K activity than are the blood-clotting proteins (Duren and Crandell, 1998). Therefore, it seems possible that intakes may be inadequate for optimal bone development, while being adequate for the blood-clotting mechanism. If vitamin K has a positive effect on net bone formation, it might be expected that vitamin K antagonists (e.g., dicoumarol from moldy sweet clover hay) have an opposite effect. Pastoureau et al. (1993) reported that lambs treated with vitamin K antagonists (warfarin) had strongly decreased bone formation indicated by a 30% lower bone mass in three months compared to controls. A deficiency in vitamin K would be expected also to have negative consequences for bone health.

The NRC (2007) has not established requirements for vitamin K intakes in equine diets. Natural sources of vitamin K are phylloquinone (K-1), found in green leafy plants, and menaquinone (K-2), which is produced by bacteria in the digestive system. Levels of K-1 in grass drop when it is wilted, deprived of sun, or made into hay. Menadione (K-3) is the synthetic form used in feed supplements and premixes, and it has recently been shown to be the most effective form of supplement, in terms of increased levels of the vitamin K analogue that has the greatest influence on bone formation (Terachi et al., 2011).

Feeding Management of Broodmares
Forages: Pasture, Hay and Chaff

Although horse evolved as grazing animals, the growth rate and reproductive efficiency of horses demanded by breeders means that many horses cannot be reared on pasture alone. However, the contribution of pasture, chaff, and hay is maximized as horses thrive when fed a simple forage-based diet. Supplementation with concentrates or supplements is therefore necessary to correct various nutrient deficiencies in forage.

To calculate accurately the contribution that forage makes to the horse's overall feeding program, forage intake as well as composition must be known. Chaff intake can be calculated by weighing a dipper or using average figures. Hay intake can be determined by simply recording the total weight of hay offered minus any hay wasted or refused. This does not take into account the differences in composition between hay that is eaten and that is not consumed but is accurate enough to do a good evaluation in the field.

The 1989 NRC gives estimates of forage and concentrate intakes based on the body weight of the animal and as a percentage of the total diet (Table 2). These figures can be used to establish reasonable concentrate and forage intakes for different classes of horses. Pasture intake is more difficult to estimate. Pasture intake will vary depending on the season, species and quality of pasture grazed, and the total amount of time that horses are allowed to graze. Another factor that has not been thoroughly studied is the effect that supplementary grain feeding has on pasture intake. Is pasture intake limited physically by the amount of time that a horse has to graze, the dry matter needs of a particular horse, or does the animal's total energy requirement dictate intake?

Table 2. Expected feed consumption by horses.

Horse	% of Body Weight		% of Diet	
	Forage	Concentrate	Forage	Concentrate
Mares				
Maintenance Early pregnancy	1.5 - 2.0	0 - 0.5	100	0
Late pregnancy	1.0 - 1.5	0.5 - 1.0	70	30
Early lactation	1.0 - 2.0	1.0 - 2.0	50	50
Late lactation	1.0 - 2.0	0.5 - 1.5	65	35
Young horses				
Weanling	0.5 - 1.0	1.5 - 3.0	30	70
Yearling	1.0 - 1.5	1.0 - 2.0	40	60

There have been several studies that have evaluated pasture intake (Table 3). Actual pasture intakes may be 4 to 7 times the dry matter intake, as some green pastures can be only 15-25% dry matter.

Table 3. Estimates of pasture dry matter intake by horses.

Class of Horse	Pasture	Intake/hr (lb)	Duration (hr)
Mature horse	fescue	3.30	3
Mature horse	alfalfa	3.63	3
Two-year-old	fescue	0.91	24
Two-year-old	orchardgrass	0.85	24

In Australia, Martin et al. (1989) studied pasture intake of mares and found that late-pregnant mares consumed pasture at the rate of 1.6% BW (DM) while lactating mares ate 2.3% BW (DM). Provision of 2 kg/d of a concentrate pellet resulted in reduced pasture intake. There is no doubt lactating mares can eat large amounts of pasture as mares of certain breeds can produce enough milk for rapid growth in their foal while on pasture alone. These mares are producing 3 to 4% of their body weight in milk and are probably consuming a similar quantity of pasture dry matter. Obviously, the quality and quantity of pasture available has a significant bearing on the consumption level and the ability of the mare to produce enough milk on pasture alone.

Pasture analysis is important to pinpoint nutrient deficiencies that need to be met to balance the diet and to determine appropriate levels of mineral supplementation. Most pastures have higher calcium than phosphorus levels, a situation that matches the requirements of the horse. Of particular relevance to skeletal development is the low calcium and high phosphorus levels combined with very low availability of calcium in high oxalate pastures such as kikuyu and other tropical species. Reversals of the normal calcium:phosphorus ratio can occur on a temporary basis in certain pasture types in late winter and early spring. The level of copper and zinc supplementation needed in late pregnancy can be determined best by pasture analysis at the relevant time of year.

The Barren and Early-Pregnant, Nonlactating Mare

Barren and early-pregnant, nonlactating mares have the same nutrient requirements as mature horses at maintenance. The most common mistake made in feeding broodmares is overfeeding the early pregnant mare. About 80% of the growth of the foal in the pregnant mare occurs in the last 4 months of pregnancy. The goal for early-pregnant mares should be to maintain body condition. If good-quality pasture or hay is available, the normal mare should need no supplementary feed other than a trace-mineralized supplement and a salt block. Warmblood mares and other easy keepers do not need concentrates in most situations, as their efficient metabolism allows them to consume lower amounts of energy for maintenance. Obviously, if pasture is limited or if hay is in short supply, pellets, grain, or sweet feed may be used to effectively meet the mare's energy needs.

Another factor is weather. If mares are exposed to winter rain and cold, supplementary energy may be required. Intakes vary but should not generally exceed 3 kg concentrates per day for the average mare. Higher intakes may be needed if a gain in condition is desired and mares should be grouped accordingly. The mare should not put on too much weight in early pregnancy.

The Mare in Midgestation

As the mare enters the fifth month of pregnancy, her energy and protein needs increase. To support development and maintenance of nonfetal tissues, the NRC (2007) recommends that protein and energy requirements be raised 5 to 8% above maintenance during midgestation for an averagesized (500-kg) mare. Unlike protein and energy, the requirement for additional minerals seems to appear later in the gestation, at approximately seven months. This can be attributed to the fact that nonfetal tissues require mostly protein and energy for accretion and subsequent maintenance and very few minerals.

Forage should form the basis of the pregnant mare's feeding program. Good-quality pasture and/or hay consumed at 1-1.5% of body weight are ideal. Energy and nutrients can be topped up with a specially fortified breeding feed, or if the mare is an easy keeper, then a protein, vitamin, and mineral balancer will meet additional requirements.

The Mare in Late Pregnancy

As the mare enters the eighth month of pregnancy, her nutrient needs increase significantly because of the demands of rapidly increasing fetal growth. The first foal of a mare is often smaller than subsequent foals, and one factor may be feed intake. French research has identified that first-foaling mares ate 10% less feed than multiparous mares and the foals were 10% lighter (Doreau et al., 1991). This difference in nutrient intake may be addressed by paying special attention to feeding of the late-pregnant mare that is foaling for the first time. Older mares also benefit from the same individual attention.

The late-pregnant mare needs more energy, protein, minerals, and vitamins than the early-pregnant mare (Table 1). If the diet does not supply adequate nutrients for fetal growth, the mare can utilize her own reserves to an extent, but it would appear that these diets can also cause an increase in the incidence of developmental orthopedic disease. Some of these disorders may not present until after weaning but the feeding of the mare in late pregnancy can have a major impact on the wastage rate and the development in young horses. One of the critical areas relates to trace mineral nutrition as content of trace minerals in mare's milk is relatively low and does not meet the requirement of the suckling foal (Meyer, 1994). Thus, trace mineral supplementation during the last three months of gestation is important because the fetus stores iron, zinc, copper, and manganese in its liver for use during the first few months after it is born to cope with the deprivation that occurs while it is on a milk-based diet (Meyer and Ahlswede, 1976).

During late pregnancy, mares are often overfed energy in an attempt to supply adequate protein and minerals to the developing foal, which can lead to obesity (Pagan, 2005). Obesity in broodmares, as with any type of horse, should be avoided to reduce issues such as equine metabolic syndrome, insulin resistance, and/or laminitis (Geor and Harris, 2009), and to reduce the potential for angular limb deformities in their foals. The mid- to late-pregnant mare may well be able to meet her energy needs from forage alone, especially if she is an easy keeper or grazing suitable pasture and hay; however, she will be unable to meet her other nutrient requirements in this manner. If an abundant supply of good-quality pasture is available, one may feed a mare 1 kg of a 20 to 30% protein concentrate pellet, which contains added minerals and vitamins, and will meet the mare's nutrient needs, with most of the energy coming from forage.

A more common manner of meeting the late pregnant mare's nutrient needs is to provide her with 3 to 5 kg/d of a 13 to 15% protein feed such as that described in Table 4, so the mare is required to meet a smaller percentage of her nutrient needs with forage. If abundant grass, hay, or both is available, the mare fed in this manner will probably gain weight. The protein content of the pasture or hay will determine the specific protein level required in the hard feed. A critical aspect of this phase of the nutritional management of the mare is to maintain body condition and perhaps even slightly increase fat stores.

If creating home-made mixes, horse owners should use soybean meal as the protein supplement of choice in late pregnancy or use a supplement pellet or a concentrate that has a high lysine content (Table 4). The hay of choice for the late-pregnant mare is good-quality grass or legume (alfalfa/ lucerne or clover) hay that has a high protein and lysine content.

Table 4. Key nutrient specifications of feeds for mares.

Nutrient	Balancer	Mare Feed
Feed Intake	1kg	3kg - 7kg
Protein (%)	20 - 25	13 - 15
Lysine (%)	1.5	0.7 – 0.75
DE (MJ/kg)	11	12.5
Calcium (%)	3.0	0.8
Phosphorus (%)	2.0	0.6
Magnesium (%)	1.0	0.25
Zinc (mg/kg)	400	120
Copper (mg/kg)	150	45

The Lactating Mare

The mare's energy and protein requirements increase significantly with the onset of lactation. With the exception of the racehorse in heavy training, the lactating mare has the highest nutrient requirements of any class of horse. 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).

Although the mare has never been selected on the basis of her ability to produce milk, she actually does a very good job of it. During the first 3 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 2005, NRC 2007). Mares are thought to produce 3 to 4% and over 2% of their body weight per day in milk in early and late lactation, respectively. This milk production represents a significant daily secretion of nutrients by the mare. The amount of secreted energy, protein, vitamins, and minerals leads to an increased dietary requirement for these nutrients. For this reason mares can lose a lot of weight during lactation unless the feeding management is good.

In most parts of the world, it is doubtful that the Thoroughbred or Standardbred mare can do an acceptable job of raising a foal, conceive, and maintain a new pregnancy on pasture alone, so supplementary feeding will be needed. However, in countries like New Zealand, temperate climates and good-quality, year-round pasture growth mean that many mares do not require feeding to supply energy and protein needs for lactation. Other breeds, such as Warmbloods, Quarter Horses, and ponies, will be likely to not need additional energy unless pastures are very poor.

Unlike the late-pregnant mare, energy intake is critical to the lactating mare. Therefore, a more appropriate feeding regime includes the use of a high-quality, energy-dense feed, such as the 13 to 15% protein feed previously discussed (Table 4). Assuming a minimal forage intake of 1.5% of body weight per day, practical ranges in feed intake are from 3 to 7 kg.

The extreme range seen in feed intakes of lactating mares points to the variability in the proportion of the mare's nutrient needs that is met by forage. As with the other classes of mares, one should carefully monitor the condition of individuals. If mares are too thin, increase their feed. If they are too fat, decrease it.

Once again, good-quality grass or legume hay is the forage of choice for the lactating mare. Legume hay has a higher protein, amino acid, and energy content than grass-based hay. If grass-based hay is fed in large quantities, then allowances need to be made in the formulation of the concentrate part of the diet. If the breeder is mixing his own feed, supplementary protein should be added to the grains. Oats will generally be the staple grain and supplementary protein can generally come from soybean meal, full-fat soybean meal, or lupins. Commercial balancer pellets that supply protein can also be used. There is a practical limit to the intake of soybean meal per day, and this is about 500 g. There are benefits in using pelleted concentrates or those which don't leave any fines in the feed bins. If mares are receiving more than 3 kg of concentrate feed per day, they should be fed twice a day, and this provides another opportunity for observation and early detection of illness or disease in foals. Pellets or cubes are an economical alternative for feeding lactating mares.

One of the determining factors in the decision to creep feed foals revolves around the nutrient content of the mare's feed. If you are using a suitable fortified feed to feed your mares, it may be preferable to provide enough feed so that the foal can eat with the mare. On the other hand, if pasture supplies are plentiful or if the supplement for the mare is just oats or unfortified grains, then a creep feed is more desirable. Foals and weanlings need more concentrated feeds than mares because they are growing rapidly and have restricted appetites.

Although the economics of feeding large quantities of fat to lactating mares does not justify its widespread use, adding fat to the diet from oil, sunflower seeds, or rice bran can assist in maintaining a positive energy balance in the lactating mare. The fat content of prepared feeds is on the label or oil can be added to the feed. Remember that two cups of oil supplies about the same amount of energy as 1.2 kg of oats and could be a valuable aid in feeding the mare that is producing a large quantity of milk and losing weight.

Lactating mares require large amounts of quality protein. The lactating mare needs twice as much protein as the dry mare, because mare's milk and contains 20 to 25% protein on a dry basis. Milk protein is high in lysine, and the mare requires high-quality protein in her diet to produce it. In fact, the quickest way to decrease milk production in a mare is to restrict her protein intake and this can cause a decrease in foal growth rate. Sometimes this strategy is useful with mares that milk too well and foals that are growing too fast; however, dietary restriction needs to be managed carefully in the mare that is being bred again that season. Mares that are in a negative energy balance will be less reproductively efficient, and you may lead to an improvement in the growth and legs of the current foal, but at the same time delay or prevent conception of next year's foal. It would be useful to find a simple method to reduce milk production without impacting reproduction.

Trace mineral fortification is not as important for lactating mares as for late-pregnant mares, because although milk contains low levels of these nutrients, research has shown that adding more to the lactating mare's diet does not increase the trace mineral content of the milk. Calcium and phosphorus are the minerals of prime concern at this stage.

Conclusion

In summary, the critical aspect of feeding the broodmare is maintaining the mare in good condition by meeting her energy needs while ensuring that her protein, vitamin, and mineral intakes are appropriate for each stage in the reproductive cycle.

Most breeders pay much more attention to feeding the young growing horse than the broodmare, yet an increased focus on the broodmare could boost fertility and produce healthy and athletic young horses.

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