**Guides to be translated to German:**

**The cation-anion balance of the ration**

All animals need a number of minerals in their rations for their body to function. Thanks to one hundred years of nutrition research, we know a lot about their requirement for individual minerals - whether it is sodium (salt), potassium or iodine. We know for example that it is rare for a horse to lack potassium, since plant foods are rich in this mineral. However, the amount of sodium in roughages is small in relation to the horse's requirements. This explains why we must give salt supplements, but not potassium supplements. Sodium and potassium are positive ions (cations), i.e. they have a positive electric charge, and will always be accompanied by an equivalent number of negative ions (anions), since a feed as a whole is without electrical charge. Similarly, when urine is excreted, it has no electrical charge, and must contain equivalent amounts of negative and positive ions to achieve this. Therefore, the dietary surplus of potassium and sodium is excreted together with negative ions such as chloride, sulphate which are also derived from the feed.



As already noted, the total amounts of these minerals in the ration are important for covering the bodily needs of the horse. In addition, the balance between sodium, potassium, chloride and sulphur (sulphate) in the ration has a special effect in determining the acid-base status of the body. This balance is called the “cation-anion balance” and is calculated as the sum of the positive ions minus the sum of the negative ions. The balance may be positive or negative depending on the amounts of sodium, potassium, chloride and sulphur in the ration.
Rations with a negative value for the cation-anion balance will create an acidic environment in the body. Rations with a positive cation-anion balance will counteract this acidification. All of this has led recently to increased interest in the area of cation-anion balance. In particular, sports-horses, eaters of large amounts of concentrates, are best served with a ration that has a mild alkalinizing effect. Feed producers can regulate the cation-anion balance of a feed through the addition of various salt supplements.

As important as the absolute amounts of sodium, potassium, chloride and sulphate, in the diet, is the balance (i.e. the difference) between the concentrations of these ions. Rations with a negative value for the cation-anion balance will create an acidic environment in the body. Rations with a positive cation-anion balance will counteract this acidification. All of this has led recently to increased interest in the area of cation-anion balance. In particular, sports-horses, eaters of large amounts of concentrates, are best served with a ration that has a mild alkalinizing effect. Feed producers can regulate the cation-anion balance of a feed through the addition of various salt supplements.

Complicated physiological processes underly the effects on the organism of the cation-anion feed balance. For those interested in learning more, we have attempted below to explain some of the background theory.

**The Cation-Anion balance of the ration**

The acid-base balance of the horse's body is affected by the contents of electrolytes (especially potassium, sodium, chloride and sulphate or sulpur) in the food eaten. If there is an imbalance between the content of sodium and potassium, which are positive ions, and the content of chloride and sulfate ions, which are negatively charged, the body compensates through the secretion of hydrogen ions (acid) or hydrogencarbonate ions (base) in the urine. As a result of this, the urine pH value comes to deviate substantially from the blood pH value. Changes in urine pH take place throughout the day as a central part of the body's acid-base regulation system.

By analyzing the content of these electrolytes in the ration, we can calculate the effect of the ration on the horse's acid-base balance. The balance (i.e. the difference) between the content of positive and negative ions is called the cation-anion balance, usually abbreviated to DCAB or CAB. The cation-anion balance is not a nutrient, but a number, calculated on the basis of the levels of sodium, potassium, chloride and sulphur (sulphate) in the ration. DCAB can be calculated for a single feed, or for a days ration, and is expressed in milli-equivalents (mEq).

If DCAB is positive, the ration or feed contains an excess of potassium and sodium relative to chloride and sulfate. Such a ration will provoke an alkaline reaction in the body and hence the urine, as we commonly find with herbivores including horses. If DCAB is negative, the animal replaces the relative deficiency of sodium and potassium in its diet with acid (H+), and the urine becomes acidic. Carnivores such as dogs usually have a diet with negative DCAB and consequently they secrete acidic urine.

Sport horses are exposed to significant acid loads during vigorous physical activity. It is believed that rations with a beneficial cation-anion balance can help to buffer such acid loads, and thereby temporarily relieve their impact on the body. It is now increasingly common to provide information about the cation-anion balance of feeds, and to compose concentrates for sport horses in such a way that the total ration has a DCAB value of +200 to +300 mEq or higher. In PC-Horse you can keep an eye on the DCAB value of the ration and the individual meal. However, although there is no clear-cut advice on optimal DCAB values ??for horse rations available in the literature, there is general agreement that it is not desirable for rations to have negative DCAB values. Rations with negative DCAB will, if used for a long time, have detrimental effects, such as loss of calcium from the skeleton.

**Biotin**

Biotin plays a part in many metabolic reactions in the body, including the metabolism of fatty acids and amino acids, and during the production of glucose. Biotin is also important for normal cell replication.

Biotin is found in many feeds and feed components. Examples of biotin content are: Alfalfa hay 0.2 mg/kg DM, Oats 0.1 to 0.4 mg/kg DM, Barley 0.13 to 0.17 mg/kg DM.

Biotin is one of the water soluble B-vitamins. For a horse, the exact requirement for biotin is not yet determined. Therefore, PC-Horse cannot warn of deficiency or of surplus of biotin in the ration. Normally, sufficient biotin to cover the horses' needs is produced by the microbes in the intestinal tract. Biotin is reported to have a positive effect on normal hoof growth and in the repair of damaged hooves. For such conditions, typical recommendations say that relatively large amounts of biotin (10-30 mg/day) must be provided for periods of 7-9 months.

Many animal feeds and mineral- and vitamin mixtures have added biotin. There are also special supplements with particularly high levels of biotin on the market.

**Too little Clor (Cl)**

 Chloride deficiency may occur, commonly in combination with sodium deficiency, during hard exercise and in hot environments, where sweating is extensive. Otherwise forages will contain sufficient chloride to balance bodily losses.

**Solutions**: Provide salt licks and extra salt whenever sweating is extensive

**Too much Chloride.**

Not an actual condition.

**Potassium**

Normal forage (grass, hay, silage) is rich in potassium. Even though the potassium requirements of horses are known, we have chosen not to include potassium requirements in PC-Horse, because the roughage in the ration will, under normal practical conditions, provide a large excess of potassium. During extreme physical activity (endurance riding and other high intensity competitions) it is recommended to use electrolyte (mineral) mixes with potassium to replace sweat losses. Molasses from sugar cane is also a good source of potassium.

In plant cells potassium (K+) is found together with various organic anions (ions with negative electrical charge). A dietary surplus of potassium must be excreted with urine and feces, and is accompanied by anions, such as bicarbonate or chloride. A high excretion of bicarbonate leads to an alkaline urine, which is typical for herbivore animals (plant eaters). The potassium content of the feed is part of the cation-anion balance (DCAB) which PC-Horse calculates for a feed or a complete ration.

**Too little Sulfur (S)**

Sulfur is a chemical element. In the body, sulfur is part of the amino acids cysteine and methionine. These amino acids are referred to as sulfur-containing amino acids, and they are represented in practically all proteins that makes up the body. Sulfur is among others also part of the B-vitamins thiamine (vitamin B1) and biotin, the natural anticoagulant heparin, and chondroitin sulfate, an important constituent of cartilage in all joint surfaces.

Horses cover their requirements for sulfur through intake of organic, sulfur-containing feed molecules, mainly the amino acids methionine and cysteine.

When the ration has sufficient amounts of protein, preferably from several sources, sulfur deficiency will not occur.

**Too little fat**

The most common rations for horses contain little fat. Amongst forages such as hay and haylage, the fat content is usually 10-15 grams of digestible fat per kg of dry material. In barley the content of fat is approximately 20 grams and in oats 50 grams per kg.

Fat in the form of vegetable oils can be an important energy supplement for the horse, particularly for horses that have problems with the regulation of their blood sugar (glucose) levels, and whose ration therefore should be one with minimal amounts of cereals. Fat is therefore recommended for horses that have a history of laminitis or have problems with "tying up" symptoms and muscle degeneration.

**Too much fat**

The horse digests fat well, when consumed in moderate quantities. If we give vegetable oil in the ration, we expect that it is unproblematic to give up to 0.10 kg per 100 kg of body weight. This means that we could give 0.5 litres per day to a horse of 500 kg. The oil should be divided into at least two meals. The horse is not particularly fond of vegetable oil. You will therefore have to mix the oil with feeds that the horse will eat readily, such as grain or concentrates.

Fat is rich in energy, and usually contains around three times as much energy as conventional feed mixtures. This means that 0.3 kg of oil has about the same energy value as 1 kg of concentrates.

**Fibre**

The horse is a grass-eating (herbivore) animal and its digestive system is adapted to rations consisting mainly of roughage, i.e. grasses and herbs, either fresh or as hay or haylage. Roughages are rich in fibre and the horse needs this fibre for both energy and as a structural component which ensures proper functioning of the digestive system. In simple terms, we can divide the horse's digestive system into two parts. In the stomach and small intestine, which comes first, we find enzymes that digest starch, sugars, proteins and fat. Further along, in the caecum and colon, a rich population of microbes (i.e. protozoa, bacteria and yeast) helps to break down the fibre component into short-chain fatty acids that can be absorbed and utilized for energy. In horses on forage-rich diets, a significant part of the energy needs are met by the acids produced from fibre. Although the cellulose in the fibre-fraction is composed of glucose molecules, microbial digestion transfers the glucose to short (volatile) fatty acids – which subsequently are absorbed. As a consequence, the products of fibre digestion do not affect the horse's blood sugar concentration and insulin secretion.

Fibre-rich diets require a long time for chewing. They keep the horse occupied and increase the time needed to consume a meal. This is important for the horse's comfort and well-being, and leads to increased saliva production, which in turn helps reduce the risk of gastric ulcers.

A horse ration must contain a certain amount of roughage and in PC-Horse we place that requirement at 1.5 kg per 100 kg body weight. When using haylage, with its higher water content, it is necessary to adjust the amount fed to reach the requirement for roughage dry matter. This is done easily through the formula:

hay (in kg x 85)
----------------------------------------------- = kg of haylage
dry matter content, % in haylage

Example: A horse weighing 500 kg has a requirement of 7.5 kg hay per day. How much haylage with 60% dry matter must be given in order to be equivalent to 7.5 kg of hay:

7.5 kg hay x 85
-------------------- = 10.6 kg haylage
60

The fibre content of forages will vary widely between plant species, and also from one stage of botanical development to another. When plants are harvested early in their growth, the fibre content is not high, but the nutritional value of the fibre is at its highest. A later harvest will have a higher fibre content, but at the same time increased amounts of lignin will cause a decrease in the nutritional value of the fibre. We must therefore consider carefully what are the forage qualities that will suit different types of horses the best.

In PC-Horse, we calculate the amount of fibre in the ration based on an analysis of the crude fibre content. In regular hay or haylage there is about 300 grams of crude fibre per kg dry matter (DM). It will be somewhat lower for early cuts and higher for the late cuts.

PC-Horse sets the lower limit for crude fibre in the daily ration to 3 grams per kg body weight daily, and the horse should preferably receive more than this. This minimum limit is roughly equivalent to the amount of forage mentioned earlier.

There are several methods available for the analysis of fibre in roughages. All recommendations given in PC-Horse are based on crude fibre analysis, and this is the only method that should be used when including analysis of fibre in the program. If selecting NDF (non-detergent fibre), a fibre analysis which is commonly used for cattle, you will get twice as high numbers as when using the crude fibre analysis.

**Starch**

If you have been warned about too much starch in a meal, you should distribute the concentrates and grains in the ration throughout the planned meals, and introduce more meals if necessary. You can also try to replace some of the concentrates with roughage (hay, haylage, beet pulp) of good quality. You can read below more about starch and how this feed component is digested.

**Starch in the horse's ration**
Starch is a carbohydrate found in plant seeds and roots, such as grains or potatoes, and is an energy reserve for the plant. For comparison, animals use fat as their energy reserve. Starch is the most energy-rich part of the grain. The content of starch in oats and barley is about 500 g per kg (50% of the weight), and there is slightly more starch in barley than in oats.

**Digestion of starch in the horse**
We want as much as possible of the starch to be digested and absorbed in the small intestine. Starch which is not digested in the small intestine will be passed on into the caecum, which is very large in the horse. Here, starch may create imbalances in the microbial flora and lead to a fall in pH and a reduced digestion of fibre.

The chemical and physical structure of starch varies between grain species. The starch in oats is more easily digested than starch from barley and maize. This has practical significance for the horse because the horse can digest more oat starch in the small intestine than starches from other cereal species. When barley and maize are treated with pressure and heat, as is common in the commercial production of feed mixtures, the starch becomes more easily digestible, and behaves more like oat starch in the digestive tract.
Glucose is produced when starch is cleaved by several enzymes in the small intestine, and is then absorbed into the blood. A meal of cereals will in just a few hours give the horse elevated blood glucose (blood sugar) concentrations. Blood levels of glucose are regulated by the hormone insulin. Increased secretion of insulin takes place after a meal, and the hormone promotes the storage of glucose in the form of glycogen in liver and muscles. Glycogen is an important energy store for the horse, and is mobilized quickly when needed, for example during strenuous exercise and competitions.

Horses are sensitive to variations in blood sugar. Some horses, especially ponies, may have trouble regulating blood sugar (a form of insulin resistance). Some horses may also become excited if the blood sugar concentration rises quickly (heating). It is therefore important, when planning feeding, to consider the amount of starch each horse will receive at every meal.

**Recommendation**
Because of its properties, starch is both an important source of energy in the horse's ration, and also a feed component that can cause adverse reactions in the digestive system. As mentioned earlier, we do not want too much undigested starch to arrive at the caecum. At the same time, we do not want the starch to be too easy to digest, since this will give rise to excessive increases in blood glucose levels. It is therefore important to have a good grasp of how a starch-rich ration affects your horse, and how you can achieve a digestion profile for the starch that balances the two effects mentioned above. With PC-Horse you have the means to ensure that the amount of starch contained in each meal is within the recommended limits.

In normal healthy horses, we recommend that a single meal should not contain more than 1,5 grams of starch per kg body weight. This means that a horse weighing 500 kg should not get more than about 750 grams of starch per meal. Since cereals and grain mixtures contain 400-500 grams of starch per kg, you should not give more than about 1,5 kg of grain or concentrate mix per meal. If your horse has a high energy requirement and receives a high proportion of grains and concentrates in its diet, we recommend increasing the number of meals per day, or changing the distribution of feed between meals if you become aware that the amount of starch per meal is too high.

In PC-Horse, you can distribute the horse's overall ration over individual meals. You will then be given a clear warning when the amount of starch in one or more of your meals exceeds the recommended limits. For horses that have trouble regulating blood sugar, or easily develop symptoms of "tying up", it will be beneficial to provide less starch per meal than the recommended 1,5 g/kg body weight. As an alternative you can feed vegetable oil (see below), thus reducing the amount of grain or concentrate mix in the ration, without depriving the horse of too much energy.

**Sugar**

Sugars in feeds are analyzed using several methods. The most common is referred to as “total sugar”, and measures simple sugars such as glucose, fructose and sucrose.

In regular hay, the sugar content is about 100 grams per kg, but with a considerable variation. In haylage, part of the original sugar is broken down during fermentation, and the sugar content is usually lower. In grains and concentrates, the sugar content is low (the normal sugar content of oats and barley is only about 18 to 20 grams per kg.). Rations containing added molasses will, however, have a higher content of sugar.

The amount of sugar found in hay and haylage seldom causes problems in horses. The uptake of roughage is spread over many hours of the day. Sugar absorption is therefore taking place over an extended period of time in the small intestine, and does not lead to large fluctuations in blood glucose concentrations.

Horses that have problems with blood sugar regulation or are insulin resistant may still benefit from forage that is low in sugar.

**Fructanes**

Fructanes are complex molecules (polysaccharides) which grasses store as an energy source. The horse lacks enzymes to digest fructanes in the small intestine, and these carbohydrates will therefore not be digested in the same way as starch and simple sugars. Fructanes are instead transported to the caecum, where they are broken down by microbes. If the ration contains large quantities of fructanes, it can cause, in the same way as too much starch, an imbalance in microbial fermentation and adverse conditions in the caecum. In the case of some horses, this may lead to laminitis. It is therefore important that horses are introduced gradually to a lush, rich pasture.

The level of fructanes in grasses varies with weather conditions and grass species. In cold periods, the fructane content can be higher than in warm periods. On hot sunny summer days, there is little to worry about. In the early summer and autumn, during periods of cold nights and mornings the fructane content of the grass can be very high. It is therefore wise to give extra attention to the horse's reactions to grazing in cool periods, especially early and late in the grazing season.

Since the fructane content of grasses varies so much, specific analyses of fructanes are not commonly used. However, since there are significant differences in the amount of fructanes amongst grass species and varieties, those who grow their own horse feeds also have the option to seed grasses selected for their moderate fructane content.

**Too little Folic acid**

Deficiencies not shown, since requirements are not well defined.

**Solutions**: Extra supplies

**Too much Folic acid**

Over feeding does not occur under normal feeding conditions.

**Solutions**: None

**Too little energy**

The energy provided by your diet is not sufficient. A low energy intake can results in loss of bodyweight and condition, reduce growth rates in young animals and result in poor performance for competitive and racing horses.

**Solutions**:
Increase the energy content of your diet through increasing use of feeds and oils with a higher digestible energy value. When increasing feed it is important to still maintain adequate fibre intake and to give consideration to the amount of starch given per meal.

Feeds are normally higher in energy than forages with an energy value typically ranging from 10 MJDE (mega joules digestible energy) up to 14 MJDE per kilogram as fed. Dried forages are naturally variable and typically range from 7-9 MJDE on a dry matter basis. The most energy dense nutrient is oils or fats which contain approximately 35 MJDE per kilogram.

If the horse has a good body condition at present and maintains this on the current diet it is important to check that the correct level of exercise has been chosen.

**Too much energy**

The energy provided by your diet is above what is required. Excess energy intake will increase bodyweight which if leading to obesity will increase risk of health problems including laminitis. Excess energy is equally detrimental for young growing horses where a sudden growth rate will increase the risk of developmental orthopaedic disease. A steady and consistent growth rate is the best practice and monitoring average daily gain (ADG) of bodyweight is advised. Excess energy is also a concern for competition or racing horses where an athletic bodyweight is required to maximise performance and reduce excess weight bearing on limbs.

**Solutions**:
Decrease the energy content of your diet. This may mean reducing the amount of feed and oils given as these have a higher energy value. Feeds are normally higher in energy than forages with an energy value typically ranging from 10 MJDE (mega joules digestible energy) up to 14 MJDE per kilogram as fed. Dried forages are naturally variable and typically range from 7-9 MJDE on a dry matter basis. The most energy dense nutrient is oils or fats which contain approximately 35 MJDE per kilogram.

If reducing the feed creates an unbalanced diet that is insufficient for vitamins and minerals consider using a feed balancer or supplement to provide the necessary nutrients. Balancers and supplements are low in energy and ideal for helping to manage energy intake.

Maintaining adequate fibre intake is important when reducing energy intake. Consider restricting pasture access through shorter periods of turnout or using well grazed paddocks and substituting the diet with lower value dried forages.

If the horse has a good body condition at present and maintains this on the current diet it is important to check that the correct level of exercise has been chosen.

**Too little Protein**

The diet does not provide enough protein. A low protein intake has many effects for horses. For young growing horses body growth and muscle development will be affected negatively. For broodmares low protein is connected with early embryonic resorption, low foaling weights and poor milk quality. For performance horses insufficient protein effects recovery and development of muscle. Low protein may affect all horses through a reduced appetite, weakened hooves and dull coat.

**Recommendation**: Increase the protein content of the diet through use of higher protein feeds and supplements such as soyabean meal. Consider higher protein forages such as alfalfa or earlier cut haylages. Analysing your forage for protein is important as it provides a significant contribution to the daily diet.

**Too much Protein**

The diet contains too much protein. Excess protein is unnecessary and cannot be stored by the body and so must be excreted. High levels of protein can negatively affect performance and development.

**Recommendation**: Reduce protein content in the diet. Consider using lower protein feeds and if necessary reduce pasture access during spring and autumn periods if grazing is rich and readily available.

**Too little Lysine**

If the ration contains enough protein, but too little lysine, the quality of the protein may be poor. A good protein quality is of particular importance for young growing horses and for lactating mares.

Deficiency of lysine in the diet impairs growth and development.

**Recommendation**: Good sources of lysine are commercial feeds where lysine has been supplemented. Soyabean meal is also high in lysine and can be fed as a supplement to the diet. Pasture is a good source of lysine but varies over the year with a high content in the spring and low content in the winter.

**Too much Lysine**

The diet contains too much lysine. This is not directly harmful to the horse but is unnecessary and places stress on the liver. Reduce the lysine content by considering lower protein feeds. Lysine is only effective when fed in combination with all other 20 amino acids therefore supplementing on its own is not beneficial

**Recommendation** Select feeds with lower protein content. Save money and reduce the stress on the liver of your horse.

**Too little Calcium**

Calcium and phosphorous build the mineral crystals which are responsible for the hardness and compressive strength of the skeleton. Calcium is also required for a normal function of muscle and nerve cells, and for the glands in the body.

Calcium deficiency in young horses will lead to abnormalities and metabolic diseases of the bones, including rickets and loose bone fragments in joints.

**Recommendation**: Good sources of calcium are mineral supplements (including calcium carbonate and dicalcium phosphate), alfalfa hay and most commercial feeds (look for mixes with 6-12 g/kg of calcium). Grass hays may
vary from 1.5 to 5 g/kg. It is recommended to insist on a feed analysis for calcium when buying large quantities of hay, especially when it is to be fed to young growing horses.

**Too much Calcium**

May result in abnormal development of the skeleton in young growing horses. Excess calcium can also reduce uptake of zinc and should be avoided.

**Recommendation**: Reduce the amounts of calcium containing vitamin/mineral mixtures. Study the contribution of the different feeds in the ration to the total calcium intake.

 **Too low Calcium/Phosphorous ratio**

The ration contains a surplus of phosphorous relative to calcium, although the absolute amounts of calcium may be acceptable. Diseases in the skeleton may develop if feeding of a ration with an unbalanced Ca/P ratio continues for prolonged periods.

**Recommendation**: Use feeds with a high calcium content like alfalfa and calcium carbonate. Reduce the feeding of phosphorous rich feeds like wheat bran and grains. Be sure that the total contents of calcium and phosphorous are
within the recommended range. "No red lines please!"

**Too high Calcium/Phosphorous ratio**

The ration contains a surplus of calcium relative to phosphorous, although the absolute amounts of calcium may be acceptable. Diseases in the skeleton may develop if a ration with an unbalanced Ca/P ratio is given for prolonged periods.

**Recommendation**: Provide less of feeds with a high calcium content like alfalfa and calcium carbonate. Increase the proportion of phosphorous rich feeds like wheat bran and grains in the diet. Be sure that the total contents of calcium and phosphorous are within the recommended range.

**Too little Phosphorus**

Phosphorous is required for mineralization of the skeleton, and for the energy metabolism in all cells in the body.

**Recommendation**: Phosphorous-rich feeds include wheat, oats, barley and commercial concentrate mixtures (5-8 g/kg). Grass hay contains 1-2 g phosphorous per kg.

**Too much Phosphorus**

Excess phosphorus reduces calcium absorption and can lead to abnormal skeleton development in young growing horses. Too much phosphorus can also interfere with iron uptake and should be avoided.

**Recommendation**: Reduce the amounts of vitamin/mineral mixtures with a high phosphorous content and feeds like wheat bran. Study the contribution of the different feeds in the ration to the total intake of phosphorous.

**Too little Magnesium**

Magnesium is an activator for many cell enzymes and is required for normal function in nerve and muscle cells. Lack of magnesium may lead to convulsions.

**Solutions**: Most concentrate mixtures for horses are supplemented with magnesium and will be valuable supplements to your ration.

**Too much Magnesium**

Moderate over feeding of magnesium will not lead to detrimental effects.

**Solutions**: You should nevertheless try to feed your horse according to the requirements.

**Too little Sodium**

Requirement for sodium (Na) or common salt (NaCl) varies greatly according to the temperature and the working intensity of the horse.

PC-Horse estimates the requirements during winter (October - April) to be 60% of summer requirements.

Breeding mares and growing horses should always have access to a salt or mineral lick with a high salt content.

Horses which are trained or exercised heavily may have problems with regulation of salt intake. Such animals should therefore be given a controlled amount of salt every day.

Recommended amounts of salt for horses which are trained are 5-6 gram per 100 kg body weight in winter, and 6-10 gram during summer, when they sweat more.

**Too much Sodium**

Requirement for sodium (Na) or common salt (NaCl) varies greatly according to the temperature and the working intensity of the horse.

A moderate intake above requirement is not harmful and is ordinarily excreted. Excessive salt intake however can cause digestive disturbances and in extreme cases colic, particularily if water supplies are restricted.

**Too little Iron**

Iron (Fe) is required for production of red blood cells and is part of important enzymes which are required for metabolism in all cells.

Iron deficiency leads to anaemia and poor stamina.

**Solutions**: Ordinary roughages and concentrate mixtures normally provide enough iron to cover the requirements. Extra supplements of iron can be provided by concentrate and mineral mixtures.

**Too much Iron**

Iron (Fe) surplus may lead to reduced concentrations of zinc in the blood and liver. Large amounts of iron may be harmful for young horses.

**Solutions**: Control the use of iron supplements. Be especially careful if the horse receives iron injections or is fed pure iron supplements in addition to the feeds included in your formulated ration.

**Too little Manganese**

Manganese (Mn) is important for the utilization of carbohydrates and fats in the body, and for cartilage formation. Manganese deficiency is thought to be connected with poor bone development.

**Solutions**: Common vitamin/mineral mixtures and commercial concentrates for horses contain manganese. Good quality grass hay is usually a good source for manganese (40 - 140 mg/kg).

**Too much Manganese**

A surplus of manganese may impair the absorption of iron (and calcium).

**Solutions**: Reduce amounts of concentrates and mineral mixtures with manganese in ration.

**Too little Cobalt**

Cobalt (Co) is required for production of vitamin B12. The majority of forages provide adequate cobalt.

**Solutions**: Cobalt is not always added to feeds or supplements, instead additional B12 is provided. Consider feeding rations or supplements with a high B12 value.

**Too much Cobalt**

Whilst there are no know toxic effects of a moderate excess on cobalt this situation should be avoided.

**Solutions**: Consider reducing the level of supplementation in your diet.

**Too little Iodine**

Iodine (I) is required for the formation of thyroid hormones (thyroxine) which control the metabolic rate of all animals. Iodine deficiency leads to goiter and reduces metabolic rate.

Foals born to mares with iodine deficiency or a deficient supply of iodine may be weak or stillborn.

**Solutions**: Good sources of iodine are seaweed, fishmeal, commercial concentrates (where iodized salts are commonly used) and common mineral mixes.

**Too much Iodine**

Over feeding of iodine (I) may cause fetal damage or lead to weakly or stillborn foals.

**Solutions**: Reduce the feeding of mineral mixtures with iodine, avoid iodized salt and avoid supplements which contain marine algae (seaweed).

**Too little Vitamin A**

Vitamin A is required for normal vision, for the skin and other epithelia, and bone formation.

Vitamin A deficiency may lead to poor vision at dusk and during darkness, runny eyes, weak and scaly skin, loss of appetite, reduced growth rate, poor conception rates and general weakness.

**Solutions**: Concentrates and most vitamin/mineral mixtures for horses contain ample amounts of vitamin A. Cod liver oil, carrots, green grasses, haylage and well cured hay are all good sources of vitamin A. #Grasses and haylage also contain beta-carotene which forms vitamin A in the body.

**Too much Vitamin A**

Vitamin A if found in two forms: retinol and betacarotene. Betacarotene is a precursor for vitamin A and is present in grasses and other feeds which contain red or yellow pigments.

During normal feeding conditions the risk for toxicity from betacarotene is low, since it is not all absorbed from the diet.

Grasses, haylage and carrots are feeds which contain high amounts of betacarotene. When using such feeds you may experience red lines for Vitamin A.

If a major part of vitamin A in the diet comes from such betacarotene-rich feeds you can accept the ration even when the line showing vitamin A is red.

The center window on the help screen gives an analysis of the relative contribution of the different feeds to the total intake of vitamin A.

Prolonged over feeding of vitamin A will lead to intoxication resulting in weak or abnormally formed bones, hair loss and abnormal skin.

**Solutions**: Give supplements which contain less vitamin A. Substitute commercial (vitamin-fortified) concentrates with grain. Be careful of giving more than one vitamin/mineral mix as many will contain vitamin A.

Do not give cod liver oil if the ration already contains a lot of vitamin A.

**Too little Vitamin B1**

Vitamin B1 (Thiamine) is under normal healthy conditions produced in sufficient quantities by the large intestine of the horse. When stressed or when workloads are high B vitamin production can be reduced and supplementation is recommended. The ratio of grains to forage also influences B vitamin production with high grain and low forage diets negatively impacting on production. Always feed adequate forage.

**Solutions**: Concentrates and most vitamin/mineral mixtures for horses are supplemented with vitamin B1. Bakers yeast and brewers grain are good sources of B1.

**Too much Vitamin B1**

Moderate over feeding of vitamin B1 have no known negative effects.

**Solutions**: Reduce the use of vitamin/mineral mixes - save money!

**Too little Vitamin B12**

Vitamin B12 (Cyanocobalamin) is under normal healthy conditions produced in sufficient quantities by the large intestine of the horse.

To aid in its absorption Vitamin B12 needs a carrier protein produced by the stomach wall. Diseases of the gastric mucosa (gastroenteritis, parasitics infestations) may give secondary anaemias due to vitamin B12 deficiency.

**Solutions**: Provide feeds supplemeted with vitamin B12. (Also ensure that a correct worming programme is strictly observed).

**Too much Vitamin B12**

Over feeding of vitamin B12 (Cyanocobolamin) has no known side effects.

**Solutions**: Consider reducing intake of high B12 feeds and supplements.

**Too little Vitamin B2**

-Vitamin B2 (Riboflavine) is under normal healthy conditions produced in sufficient quantities by the large intestine of the horse. When stressed or when workloads are high B vitamin production can be reduced and supplementation is recommended. The ratio of grains to forage also influences B vitamin production with high grain and low forage diets negatively impacting on production. Always feed adequate forage.

**Solutions**: Concentrates and most vitamin/mineral mixtures for horses are supplemented with vitamin B2. Bakers yeast and brewers grain are good sources of B2.

**Too much Vitamin B2**

Moderate over feeding of vitamin B2 has no known negative effects.

**Solutions**: Consider reducing the intake of high B2 feeds and supplements.

**Too little Vitamin B6**

Vitamin B6 (Pyridoxine) is under normal healthy conditions produced in sufficient quantities by the large intestine of the horse. When stressed or when workloads are high B vitamin production can be reduced and supplementation is recommended. The ratio of grains to forage also influences B vitamin production with high grain and low forage diets negatively impacting on production. Always feed adequate forage.

**Solutions**: Concentrates and most vitamin/mineral mixtures for horses are supplemented with vitamin B6. Bakers yeast and brewers grain are good sources of B6.

**Too much Vitamin B6**

Moderate over feeding of vitamin B6 has no known negative effects.

**Solutions**: Consider reducing the intake of high B6 feeds and supplements.

**Too little Vitamin D**

Vitamin D is a precursor for hormones which regulate calcium metabolism in the body. Vitamin D deficiency leads to abnormal development of the skeleton (rickets), poorly mineralized bones and reduced appetite and muscle strength.

**Solutions**: Vitamin D is produced in the skin when horses are exposed to sunlight. Sun-cured hay, cod liver oil and most concentrate and vitamin/mineral mixes are good sources of vitamin D.

**Too much Vitamin D**

Over feeding for prolonged periods vitamin D will lead to intoxication characterized by abnormal bone development (hypermineralization), calcium deposition in blood vessels and heart and kidney, and other organs damage.

Stiff gait, loss of appetite and a generally poor condition may be symptoms. Blood samples show abnormally high calcium levels in plasma. Some plants contain vitamin D analogs which may lead to vitamin D toxicity.

**Solutions**: Provide less vitamin D rich vitamin/mineral mixtures. Substitute commercial (vitamin-fortified) concentrates with grain. Be careful of giving more than one vitamin/mineral mix as many will contain vitamin D.

Do not give cod liver oil if the ration already contains a lot of vitamin D.

**Too little Vitamin E**

Vitamin E acts as an antioxidant for lipids in cell membranes. Vitamin E has a samilar functions as selenium. Deficiency leads to muscle dystrophy (white muscle disease) and to uncoordinated movements and lameness.

**Solutions**: Concentrates and most vitamin/mineral mixtures for horses contain vitamin E. Special vitamin/mineral mixtures for vitamin E and selenium are marketed in most countries.

**Too much Vitamin E**

Moderate over feeding of vitamin E has no proven detrimental effect, in fact recommendations for vitamin E intake have increased over the last two decades.

Too much may however affect the utilization of other lipid soluble vitamins (A, D and K).

**Solutions**: Consider reducing use of high vitamin E feeds and supplements.

**Vitamin C**

Vitamin C is a biological antioxidant, but it also has other important functions in the organism.

Horses (like many other animals) seem to be able to derive vitamin C from glucose. The Vitamin C requirements of the horse are not defined as well as the other vitamins that are included in PC-Horse. Although the horse normally produces adequate amounts of vitamin C, it is customary to add the vitamin to concentrates and vitamin- and mineral mixes.

**Too little Zinc**

Zinc (Zn) is an integral part of several enzymes and also a stabilizer of protein hormones.

Zinc deficiency has been connected to skeletal diseases (i.e. osteochondrosis), and will reduce the mechanical strength of the skin and impair its resistance to infections.

**Solutions**: Provide common vitamin/mineral mixtures for horses which usually contain zinc.

**Too much Zinc**

A surplus of zinc (Zn) may lead to impaired utilization of copper and induce copper deficiency symptoms. Skeletal damage may occur.

**Solutions**: Reduce the feeding of concentrates and mineral mixtures with a high zinc content**.**

**Too little Niacin**

Deficiencies not shown, since requirements are not well defined.
Niacin is not included in PC-Horse at the moment.

**Solution**: Extra supplies.

**Too much Niacin**

Over feeding does not occur under normal conditions.

**Too little Selenium**

Selenium (Se) is an important part of the enzyme glutathion peroxydase which takes part in the protection of lipids in cell membranes.

Selenium deficiency may lead to muscle dysthrophy, newborn foals with poor ability to suckle, and many other pathological conditions.

Many areas in the world have selenium deficient soils where selenium supplementation is required for successful animal production.

**Solutions**: Selenium is added to most concentrate and mineral mixes for horses. Look for feeds with a high selenium content in your feed list.

**Too much Selenium**

Selenium is very poisonous, and excess intakes over prolonged periods will lead to intoxication and death.

**Solutions**: Reduce the feeding of concentrates and mineral mixtures with a high selenium content