# Feeding the Hoof – Biochemical Basics and Examples for Optimization

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## 2. World Conference for Holistic Hoofcare, November 13.-15., 2006 in Tübingen/Germany

At the beginning of the pasture period, many horse owners observe a clearly improved hoof growth. Articles in horse magazines frequently speculate about the influence of feeding on the quality of the hoof horn and hoof health, and feed producers offer special products for hoof improvement and even for founder prevention. This lecture offers a summary of the necessary building materials and possibilities for improving horn formation by feed optimization.

## *Keratin formation*

Hoof horn is formed by formation of keratin proteins in the cells of the epidermis. The keratinizing cells in the avascular epidermis are supplied with nutrients, macro minerals, trace elements and vitamins by diffusion from the highly vascular dermis underneath. Irrespective of feeding, blood circulation (hoof mechanism) and thus movement are thus the basic requirements for a good nourishment of the cells.

Besides in the hoof horn, keratin filaments are found in hair, nails and feathers of the vertebrates. The keratin proteins consist of amino acids - especially cystein, histidin and methionin play a crucial role - and are cross-linked by disulphide bridges. With the amount of disulphide bridges, the horn stiffness increases.

The mechanical characteristics differentiate soft and hard keratin. The protein composition varies accordingly. Soft keratin - e.g. in the skin - has a sulfur content (from cystein and methionin) of approximately 1% and a lipid content of approx. 4%. Hard keratin - e.g. in hard horn - consists of up to 5% sulfur (high amount of cystein) and has a low lipid content.

Complex biochemical procedures take place during the keratinization process. The following mineral materials, trace elements and vitamins are necessary:

*Calcium* is needed for the activation of the enzyme transglutaminase during cornification. A lack of calcium leads to the formation of dyskeratotic horn.

*Zinc* is the most frequent intracellular trace element and a component of more than 200 enzyme systems. Zn-Metalloenzymes are catalytically involved in the cornification. An important role of so-called Zn-fingerproteins during the formation of keratin filaments is being discussed. A strong lack of zinc becomes apparent e.g. through disturbed cornification, hair loss and dermatitis as well as degeneration of connective tissue.

*Copper* is likewise involved as cofactor of many enzymes, especially also for cell respiration. Besides, copper activate the enzyme thioloxidase, which is responsible for the formation of the disulphide bridges between the cystein residues of the keratin filaments. In combination with sulphur, copper is thus important for the horn stiffness. A pronounced lack of copper becomes visible as uneven white marks in the coat of the horse. The coat is usually dull, the immune system impaired and susceptibility for worms higher. In the hoof, a lack of copper may become apparent as susceptibility of the white line for bacterial and fungal infections (WLD), as well as predispose for founder.

*Selenium* protects cells from oxidative damage. Already a relatively small surplus may however displace sulfur during the protein formation and decrease the strength of the protein structure. High selenium overdosing may cause a loss of the entire hoof capsule.

*Biotin* - a B-vitamin that is produced by bacteria in the large intestines - is involved as cofactor in enzymes in different metabolic processes also during keratinization. In particular, Biotin is important for the formation of complex lipid molecules in the intercellular binding horn („cement substance“), thus for the horn coherence.

*Vitamins A and E* are also important for hoof structure.

## Glucose metabolism

Both, the cells of the dermis and the epidermis respond experimentally to insulin. Insulin increases the uptake of glucose and thus energy production and cell metabolism. Problems in the glucose metabolism of the cells impair the nutrient supply of the corium. A possible consequence is founder. Insulin resistant horses – that are animals where the cells not respond well to insulin, and thus insulin and glucose levels in the blood are increased - respond feeding errors with excessive tenderness - despite of a well shaped hoof.

With a predisposition to insulin resistance, the essential trace element ***chromium*** and ***vitamin*** $B_3$, which go into the glucose tolerance factor (GTF), can improve the glucose metabolism of the cells. GTF can be supplied by feeding brewery yeast. *Tryptophan*, an amino acid which is abundant in oats, is a precursor for Vitamin $B_3$. Corn and barley are poor in tryptophan. In the case of oats-free feeding and no other sources of Vitamin $B_3$, a lack may occur. With insulin-resistant horses, an adequate ***magnesium*** supply is particularly important as well. Magnesium is involved in the activation of many enzymes and thus in almost all metabolic processes.

Very important is as a matter of course, a feeding based on *cellulose-rich* hay and a reduced content of non-structure carbohydrates (*sugars* and *starch*) that is meeting - but not much exceeding - the energy demand, the assurance of sufficient *water* intake and *movement*.

## Supply of macro minerals and trace elements

The mineral and trace element content in forage (hay) depends strongly on geochemistry, the plant composition and on soil biology. Horses are frequently fed hay from the same region perennially, in extreme cases this hay is made on the pasture. Shortfalls or imbalances in the supply cannot equalize. A hay analysis can determine the content of minerals and the most important trace elements, as well as raw protein and non-structural carbohydrates.

Several examples of ration calculations are shown on basis of different hay compositions. Since hay constitutes the predominant mass of the fodder, it is hard to compensate severe lacks or imbalances in minerals and trace elements with natural feeds (branches, fruit etc.). These fresh, natural feeds play however a large role with the supply of vitamins and other vital materials.

Because of a lower quantity of fodder due to reduced energy needs, a non-working horse in maintenance metabolism often needs an individual and region-specific supplementation (frequently zinc, copper and magnesium), in order to cover the need for the formation of vital enzymes and vitamins and thus supply metabolism sufficiently.

In contrast, a horse in training receives clearly more and usually quantitatively sufficiently minerals and trace elements. Often, only the ratio between the elements needs to be examined, in order to prevent the blocking of individual trace elements by strong imbalances. Covering the higher energy requirements by feeding large amounts of strongly enriched „sweet feed“ may supply too much and negatively affect the organism.

## *Balancing minerals*

When supplementing minerals and trace elements, various interactions need to be considered (see Fig. 1). For example, uptake of the trace elements copper and zinc - that are important for the hoof - interacts in the body. A favourable Cu:Zn-ratio in mineral supplements is thus extremely important.

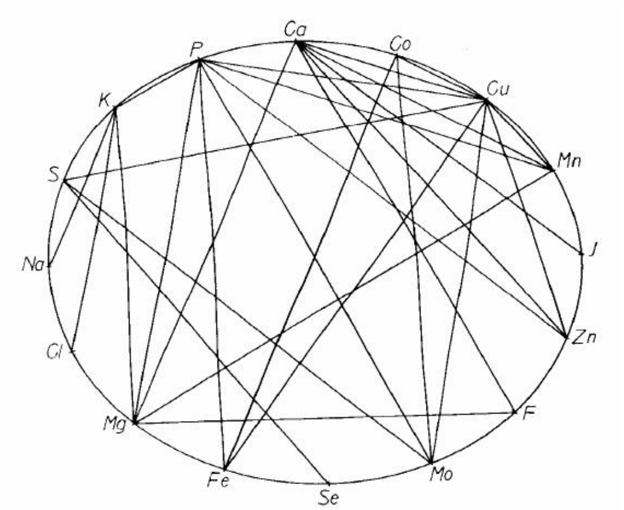


*FIG. 1: MINERAL - AND TRACE ELEMENT INTERACTIONS ACCORDING TO WIESNER (1970)*

The Ca:P-ratio of the ration should be kept within close borders (1:1 to 3:1). A high calcium content impairs the uptake of magnesium as well as the trace elements copper, zinc, manganese and iodine. Particularly hay in the limestone alps displays frequently a very high calcium content. Here, the mineral supplement should contain less calcium. In contrast, many regions suffer from a lack of calcium and magnesium, in particular granite soils such as Finland, Sweden and the Czech plate (northern Upper Austria). There, the mineral supplement needs a completely different composition.

A high content of phosphor as phytate in bran, grain and soy impairs the uptake of the trace elements copper, manganese, zinc, molybdenum, iron as well as magnesium by complexation. In extreme cases, the body may be depleted of zinc when feeding large amounts, e.g. of wheat bran.

As mentioned, a sufficient supply of sulphur and copper is important for the stiffness of the hoof horn. Too much sulphur however (e.g. by feeding excessive quantities raw protein, MSM or fertilization with ammonium sulphate) impairs the uptake of copper and selenium. In many regions, hay contains only 4-6 ppm copper and cannot supply the need. Also grain is generally poor in copper. Copper is also frequently impeded by high contents of iron or molybdenum.

When supplementing copper, the interaction between copper, molybdenum and chromium needs to be kept in mind. Molybdenum is needed for the metabolism by sulphur containing amino acids, chromium is important for the glucose tolerance factor.

## *Ultra trace elements*

In the past years, more and more elements have been recognized as essential for biochemical processes in the body. The list grows constantly. From boron via chromium, vanadium, lithium, germanium, nickel, tin up to arsenic. When supplementing the main essential trace elements described above, it is to be considered that these ultra trace elements, whose functions in the body are not yet completely clarified, can be impaired. Out of this reason, a highly excessive supply of minerals and trace elements should be avoided. Also it gives no further improvements once the need is well met, but instead loads the organism.

## *Further feeding errors*

When the coffin bone connection stays bad without signs of metabolic syndrome (insulin resistance), the feeding is to be examined in every detail for poisonous plants (white clover, marsh horsetail, sweet pea, common tare, buttercup, acorns etc.) and mould.

White clover produces cyanides as self-protection, which can endanger the oxygen supply of the corium and cause founder, or in small quantities slow deterioration of the coffin bone connection. Also some grass species potentially produce cyanides. The cyanide content increases when the plant is stressed, is thus particularly high on overgrazed pastures. Contrary to the fructane content, the cyanide content increases at night and during rainy periods!

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