TIED UP WITH ELECTROLYTES - OR NOT?

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Background information

A. DEFINITIONS

1. Electrolytes are substances which exist as positively or negatively charged particles in aqueous solution.

   The elements that form part of the ash produced by combustion of food material/ body tissues, etc. at high temperatures (from which impurities have been removed) are known as minerals or inorganic elements.

   Therefore, not all electrolytes are minerals, e.g. the proteins, organic acids.

2. Minerals can be classified in a number of ways, but practically and most usefully as either Macro-, Micro-, or Trace Elements (according to amounts required and amounts present in animal tissues) or Essential, Probably Essential or Function Unclear.

The essential elements include calcium, sodium, potassium, magnesium (cations - positively charged i.e. Ca^{2+}, Na^{+}, K^{+}, Mg^{2+} respectively) and chloride plus phosphate (anions -negatively charged ie Cl^{-}, PO_4^{3-} respectively). These are also known as macrominerals as they are required in several gram quantities by animals per day. These six elements will be discussed in more detail below.

B. FUNCTIONS AND STORES

The main functions of the various minerals include:

1. Muscle and nerve function.
2. Formation of skeletal tissue.
3. Maintenance of homeostasis of internal fluids.
4. Maintenance of cell membrane equilibrium.

5. Activation of biochemical reactions by action on enzyme systems.
6. Direct or indirect effects on the function of the endocrine glands.
7. Effect on the symbiotic microflora of the gastrointestinal tract (GIT).

Calcium makes up about 35% of bone structure and the skeleton represents 99% of total body stores. Approximately 85% of total body phosphorus is present in the bones and teeth. Bone contains about 60-70% of the body stores of magnesium with the remaining 30-35% found in body fluids and soft tissues. 50-75% of the body's sodium is contained in the ECF. Most of the rest is found in bone. 85% of the total body store of potassium is intracellular.

C. INTERACTIONS

Due the relative ease by which minerals tend to form bonds, they are much more liable to interact than are other nutrient substances. Minerals may interact with:

1. Each other
2. Other nutrient factors
3. Non-nutritive factors

These interactions may be:

1. Synergistic
2. Antagonistic

The interactions may occur:

1. In the feed
2. In the GIT
3. During tissue and cell metabolism

Few of the possible interactions have been thoroughly investigated in the horse and in practice only a few of the possible interactive effects require practical measures to avoid adverse consequences.

D. METHODS TO STUDY ABSORPTION AND RETENTION OF MINERALS

The three most common ways used are:

1. Material balance

   i.e.: M feed - M faeces = absorption

   M feed - (M faeces + M urine) = retention

where M is the concentration of a particular mineral, but these are only relative figures as the faeces not only contain the non-assimilated minerals from the dietary intake, but also the so-called endogenous component (and any unassimilated “extra” mineral from soil or other contamination.)

The endogenous component reflects the amount of each element that comes into the GIT from the animal’s body rather than via the diet (i.e. expelled into the GIT either in the various digestive juices or directly across the intestinal wall or via unavoidable losses due to sloughed GIT cells.)

Ways of overcoming the interference of endogenous losses have been investigated; for example, the apparent digestibilities for a range of nutrient intakes have been determined and plotted against the corresponding level of intake. The slope of the regression line can then be taken to represent the estimated true digestibility for that nutrient.

2. Use of inert substances

This method is based on the use of poorly assimilatable substances which are uniformly distributed in the feed. Chromium is often used, but not considered by everyone to be ideal.

Calculation:

% absorption = 100 x (1 - ([M:label] in faeces or chyme/[M:label] in the feed)).

3. Radioactive indicators

Preferable to introduce two radioisotopes at the same time, one intravenously and the other *per os*. The percentage of the mineral absorbed is calculated from the ratio between the content of the radioisotope introduced per os to the content of the intravenously introduced radioisotope in the urine. NB (Expensive)

E. CA, P, MG, NA, K, CL GIT ABSORPTION.

Calcium

- Bound in plants with protein and organic acid anions.
- Most of the calcium compounds ingested (apart from oxalates) are converted by the gastric juices (HCl) to CaCl which is almost completely dissociated into ions.
- Ionic calcium is the principal form that is absorbed from the duodenum (and possibly the stomach). There is apparently active transport of calcium as well as passive or facilitated diffusion. The possible role of the Vitamin D responsive calcium binding protein in the horse is not clear, although it has been identified in the duodenum of the horse.
- When anions which bind or precipitate calcium are present in excess, they may interfere with the absorption of calcium ie: oxalates, phytates, phosphates and possibly sulphates.
- As the soluble calcium compounds pass along the GIT, many of them are converted back into the low solubility phosphates and carbonates and into almost insoluble compounds with the higher fatty acids (palmitic, stearic and oleic acids) .
- The bile salts form complex compounds with calcium salts of unsaturated fatty acids. These micelles (3-10 mm diameter) are highly dispersed in an aqueous medium and enhance the dissolution and absorption of some calcium salts.
- Most of the active Ca absorption occurs in the duodenum: as the ingesta passes along the GIT the mechanism of micellar transfer becomes more prominent.
- Post absorption passed via the portal vein to the liver where complexes break down and new compounds form (often with proteins). Like other cations, it remains some time in the liver so that the rate of release into the blood is relatively uniform.
- High intakes of calcium, at least in other species, have been shown to influence zinc, magnesium, iron, sulphur and fluorine utilization.
- Individual variation in the ability to absorb calcium has been suggested.

Magnesium

- Forms part of chlorophyll. Some bound as proteinates, carbonates or phosphates. Magnesium fertilizers tend to result in increased concentration of the mobile Mg fractions in plants whereas potassium fertilizers tend to cause the opposite.

- Mg is partly converted into its ionized form by HCl. It is predominantly absorbed in the upper part of the small intestine by ordinary and facilitated diffusion. An active transport mechanism is believed to exist.
- As the dissociated Mg ions pass through the GIT, they are converted to the poorly soluble carbonates, phosphates and the insoluble Mg salts of the fatty acids.
- In other species at least excess fat, calcium, sulphate, phosphates (especially when potassium is in excess), phytic acid and oxalates are believed to decrease absorption.

Phosphorus

- Enters as the mono-, di-, or tri- substituted inorganic phosphates plus the organic compounds: phytates, phospholipids and phosphoproteins.
- Acid gastric juice dissolves the soluble and also some of the insoluble phosphates. Digestive juice phosphatases (especially alkaline phosphatase) split phosphoric acid from organic compounds. Phytates (especially calcium and magnesium) are not well digested but some hydrolysis due to the action of bacterial phytases.
- Soluble phosphates coming from the stomach and those formed in the intestine are readily absorbed (mainly end of small intestine and large intestine, in particular dorsal large colon and the small colon).
- ? an active mechanism present. The secondary and tertiary calcium phosphates are partly absorbed after reacting with fatty acids and forming diffusing chelates.
- At least in other species, excessive iron, aluminum, lead, magnesium and calcium impair absorption of phosphorus due to formation of insoluble phosphates. In the horse, there is little evidence that moderate excesses of dietary calcium have any deleterious effects on phosphorus utilization providing intake is adequate, although it is suggested that an excessive dietary concentration of phosphorus with a low dietary Ca:P ratio of less than 1 will depress calcium absorption.
- Important as a buffer for the volatile fatty acids produced by microfloral fermentation.

Potassium

- Commonly found as carbonates, chlorides and with organic acids.
- Tend to be readily soluble and readily extracted from feed stuffs.
- Absorption mainly by diffusion throughout the GIT but mainly in the proximal small intestine.

- May be very important in the caecum/LI (as per the rumen to buffer the fluids and maintain moisture levels so as to produce an optimum medium for bacterial fermentation) and has been as is considered to be indispensable for normal microbial activities.

Sodium and chloride

- Sodium is not considered to be essential for plants.
- The sodium salts of animal/vegetable feeds and mineral supplements are readily absorbed.
- Na absorption possibly predominantly active. Cl possibly a combination of movement along electric and concentration gradients once the minimum threshold of concentration attained. Predominant site of Cl absorption is the distal small intestine.
- Large amounts of water and, in particular, Na and Cl enter the SI via the saliva, stomach juices, pancreatic juice and bile. Only about 50% water, 35% Na and 80% Cl will be absorbed by the end of the SI. Therefore, a large ileocaecal flow of water and Na (and to a lesser extent, Cl) takes place. Most of the water and Na/Cl which enters the large intestine will be absorbed.

Summary

Along the entire length of the GIT, intensive excretion of minerals takes place at the same time as absorption. The intensity of the various processes will vary at different sites.

F. PRINCIPAL NATURAL SOURCES

Ca:	leafy forages, particularly legumes
P:	cereal grains and their by-products
Mg:	legume forages, sugar beet pulp and sugar beet molasses
K:	leafy forages, sugar beet molasses and milk products
Na and Cl:	common salt, milk products and sugar beet molasses

G. HOMEOSTASIS IMPOSSIBLE TO GO INTO DETAIL BUT MAIN POINTS ARE AS FOLLOWS.

Calcium and phosphorus

A number of hormones affect calcium status, principally parathyroid, calcitonin and vitamin D but also the adrenal corticosteroids, estrogens, thyroid hormones and glucagon.

PTH principally acts when blood Ca levels fall in order to increase blood Ca concentrations and at the same time decrease the P levels. Acts via effects on the urinary excretion of P and Ca and the rate of skeletal remodeling and bone resorption.

Calcitonin interacts primarily on bone and kidney and to a lesser extent, the intestine. Calcitonin acts to lower blood calcium concentration. Vitamin D's role in the horse is not extremely clear but it acts, at least in other species, to increase Ca and P absorption from the intestine, but also has an effect on the bone where small amounts are believed to be necessary to allow the osteolytic cells to respond to PTH.

The renal excretion of calcium has been reported to be directly related to the amount of absorbed calcium, the phosphorus level of the diet and the anion-cation balance of the diet (it has been shown that in the horse, high sodium diets do not affect calcium urinary excretion). The major route of excretion for calcium is via the kidney.

Magnesium

Homeostasis occurs mainly via a balance between absorption from the GIT and excretion via the kidney.

No primary hormonal control but influenced by adrenal and thyroid hormones plus PTH. Mg has a similar effect on PTH as Ca but not equipotent.

Hypermagnasaemia or very severe hypomagnasaemia may result in a decrease in PTH whilst moderate hypomagnasemia may cause an increase in PTH. PTH causes an increase in plasma Mg by increasing intestinal absorption, increasing renal tubular resorption and increasing bone resorption. But PTH needs Mg ions for activation of adenylate cyclase in bone and kidney.

Aldosterone increases result in lowering of the plasma Mg and an increase in urinary Mg excretion (and vice versa) although Mg has no effect on aldosterone levels. (In other species, low dietary levels of Na which produce increased levels of aldosterone result in increased Mg excretion and a negative Mg balance.) Increased thyroid activity results in a decrease in plasma Mg.

Sodium, potassium, chloride

The major excretory pathway for these three electrolytes in the resting animal is via the kidney. The homeostasis of these electrolytes is largely controlled by the hormone aldosterone (plus the renin-angotensin system).

The amount of Na excreted in the urine is determined by the ratio between urinary filtration and resorption. This ratio in turn depends on Na/water levels in diet and so on.

Effect of age and other factors

The efficiency of absorption of the various minerals can be affected by age and dietary intake level eg. calcium efficiency increases as dietary intake decreases. Calcium absorption has been said to decrease with age. Phosphorus absorption may be decreased with age although older animals may be able to decrease urinary losses better. Increasing magnesium intake may significantly increase magnesium absorption and retention.

Dietary cation-anion balance

As Na and K are often absorbed from the GIT in exchange for a proton and Cl is absorbed in exchange for a bicarbonate ion, the relative balance of these cations and anions in the diet can affect acid-base balance and the metabolism of other electrolytes.

Dietary cation-anion balance (DCAB) is defined as meq(Na + K)-Cl/kg dietary DM.

Many equine diets with a high percentage of grain or corn based concentrate may be highly anionic with a low DCAB.

- Low DCAB associated with low urine and blood pH.
- Urinary excretion of Ca and Cl said to significantly increase with decreasing DCAB.
- Mixed effects reported on Na, Mg, P and K excretion. More work needed.
- Faecal, urine and blood pH found to decrease when a high starch diet was fed with increased urinary clearance of Ca and P unrelated to changes in DCAB.

H. REQUIREMENTS

Need to take into account unavoidable losses, and availability from feedstuffs plus any requirements for growth, exercise, lactation, etc. plus individual differences. Many assumptions still have to be made in order to arrive at a “guide figure.”

Maintenance requirements

Table 1. BASED ON A VARIETY OF PAPERS (AS REPORTED IN HARRIS, *et al.*, 1995).

Element	*Unavoidable Losses (mg/kg BW/day)*[a]	*Availability %*[b]	*Maintenance*	
			mg/kg BW/day	*g/500 kg*
Ca[c]	30	60 (36-82)*	50	25
P	12	40 (30-55)*	30	15
Mg	5	35(-61)	15	7.5
Na	18 (15-20)*	90 (45-90)*	20	10
K	40	80	50	25
Cl	5-10	100	80	40

* range in literature
[a] With a low sodium or potassium intake, the Na/K losses said to be substantially reduced to less than 10 for Na and around 5 for K. The same is not believed to be true for Cl.
[b] The availability will vary with type of feed, presence of interfering substances, the individual animal and the amount supplied.
[c] After a prolonged period of inactivity, calcium and phosphorus supply should be increased about 20% above recommended figures to compensate for the losses from the skeleton during inactivity.

Table 2. BASED ON *IN VIVO* WORK BY PAGAN (1994).

Element	*Unavoidable losses g/day*	*Availability**	*Maintenance g/500 kg*
Ca	17.4	74.7	23.3
P	4.7	25.2	18.5
Mg	2.2	51.8	4.2

*very similar values

Requirements for exercise.

The total requirement of electrolytes for the exercising horse depends largely on the amount of sweat produced and its composition.

Sweat losses

Electrolytes are continually lost from the body via the kidney, gut and from the skin in sweat. Sweat electrolyte losses are therefore an important factor to consider in mineral nutrition of the exercising horse, which can lose large amounts of sweat.

The amount of sweat produced depends on the environmental conditions, nature of the work (this in turn will depend on the rider's ability and the terrain), and the animal's fitness. Under favorable climate conditions, sweat loss can be in the order of 7-8 liters per hour in long distance rides. In hot, humid conditions where sweating is partially ineffective, production can be as high as 10-15 litres/hour. This means an endurance horse may lose 25-30 litres or more if conditions are unfavorable. Under average conditions a race horse performing at high speeds even for a short period of time can lose between 1-5 litres. Sweat production seems to only decrease after extreme water loss. When the sweat loss is low, much of the loss can be made up by absorption of water contained in the large intestine and no disastrous effects are seen. But if water losses are between 3-4% of body weight, a decrease in circulatory volume as well as a loss of skin elasticity occurs. This will occur after about 3 hours of exercise with moderate sweating, but much sooner at rates of 10-15 litres/hour.

Sweat composition

There is some controversy over sweat composition due primarily to difficulties in collection. Newer methods are currently being explored which may answer some of these concerns.

Sweat however is believed to contain low concentrations of calcium, magnesium and phosphate but relatively high concentrations of sodium, potassium and chloride. Some workers have suggested that the potassium and chloride concentration decreases after the first hour. A decrease in magnesium concentration has also been shown to occur. Whatever the exact sweat composition turns out to be, a heavily sweating horse may rapidly develop a negative water and electrolyte balance as sweat is accompanied by an obligatory loss of electrolytes. The exhausted horse syndrome is believed to reflect a combination of fluid and electrolyte losses, depletion of energy stores and extremes of environmental conditions. Affected animals appear severely depressed, dehydrated, unwilling to eat or drink, with elevated temperatures, pulses and respiration rates. Laminitis and synchronous diaphragmatic flutter may be found. Metabolic acidosis with a paradoxical aciduria, hypokalemia, hyponatraemia and hypochloraemia with elevated CK, AST and LDH activities tend to be found (Carlson 1987). Horses can die from this condition.

Estimated/approximate sweat composition

Na	3.1 g/l
K	1.6 g/l
Cl	5.5 g/l
Ca	0.12 g/l
Mg	0.05 g/l
P	<10 mg/l

Focus on Na requirements for the exercising horse

Endogenous losses given as 15-20 mg/kg BW/day in a non-sweating horse.
Availability reported as varying from 45-90%.

Therefore requirements for a mature 500 kg non-exercising horse as fed would vary from 8-22 grams of sodium a day.

For a sweating horse doing moderate work with sweat loss of around 10 liters, the theoretical required Na intake would vary from 42 - 91 g/day. Very few horses would be fed or eat or need 91 g Na (approx. 8 oz. of NaCl)!!

Some factors to be considered

a. Content of the gastrointestinal tract may provide an important reservoir for sodium during hard work.

b. Electrolyte losses that occur with heavy sweating do not need to be restored all at once.

c. We need to know availabilities for exercising horses - currently unknown.

d. Need to have a better knowledge of sweat composition.

Practical evaluation of electrolyte status (Harris 1988, Harris and Gray 1992)

Whole body electrolyte content may be a reliable and accurate estimate of whole body status, but it is not practical. There are difficulties with methods involving whole body calcium composition, bone biopsies, mineral content of hair and random analysis of saliva samples. Sweat collection can be problematical and significant alterations in sweat electrolyte content may not be seen until severe electrolyte depletion has occurred. Faecal electrolyte content may not reliably reflect dietary intake or body status. Muscle electrolyte content is not practical for regular monitoring and does not seem to be very sensitive to mild alterations in electrolyte intake. Serum or plasma concentrations cannot be used reliably to indicate electrolyte imbalances due to efficient homeostatic mechanisms which maintain normal blood concentrations despite body depletion. Normal daily requirements for a horse are affected by a number of factors including age, body weight, exercise and environmental conditions. Dietary analysis alone may not reflect the electrolyte status of the horse because the availability varies, especially between individual animals and there are many interactions.

ESTIMATION OF EXCHANGEABLE CATION LOSS

Based on work by Carlson, an estimation of exchangeable cation loss following exercise can be obtained if pre and post exercise plasma Na concentrations and body weights are known and the following formulas applied.

A. water deficit (WD) = weight loss x 0.9

B. pre-exercise total body water (TBWPre) = 66% of pre-exercise body weight

C. post exercise total body water (TBWPo) = TBWPre - WD

D. plasma sodium concentration (Na)p x TBW = exchangeable cations (Na and K) therefore:

Pre(Na)p x TBWpre = A meg
Post(Na)p x TBWpo = B meg

Total deficit of exchangeable cations = A - B = C mg.

Assume that 70% of the total exchangeable cation loss is Na and 30% is K

Then Na loss is 70% x C = D
K loss is 30% x C = E

eg : if
Pre (Na)p = 138
Post (Na)p = 142
Pre BW = 613
Wt. loss= 27
WD= 243
TBWpre= 405
TBWpost= 381

Then exchangeable cations pre (A) = 55890
post (B) = 54102 mmol

Na loss (D) = 1252 mmol
K loss (E) = 536 mmol
But many assumptions are made and not all proven.

FRACTIONAL ELECTROLYTE EXCRETION TEST

Electrolyte homeostasis is mediated primarily by the kidney. Simple measurements of urinary electrolyte concentrations are unreliable due to variations in urine volume and 24 hour urine collections rely on the accurate collection, timing and measurement of urine volumes. A more practical alternative, which removes the need for accurate urine volume measurements, compares the excretion of an electrolyte to that of a control substance. The control substance ideally has an excretion rate which reflects the glomerular filtration rate and is not secreted or re-absorbed by the renal tubules. Inulin is an ideal compound that fulfills these criteria. However, the measurement of the exogenous inulin clearance is not practical. Measurement of the exogenous creatinine clearance is a more applicable alternative, although less ideal. The renal excretion of an electrolyte can then be compared with the creatinine excretion or clearance. The ratio of these two excretion values has been referred to as the urinary fractional excretion of an electrolyte (X) CrCl i.e. the FE X (fractional excretion index) or the % creatinine clearance ration %CrCl X i.e:

$$\frac{\text{clearance of an electrolyte (X) x 100}}{\text{clearance of creatinine (Cr)}}$$

$$\frac{\frac{(X)_u}{(X)_p} \times \text{volume of urine time period kg body weight}}{\frac{(Cr)_u}{(Cr)_p} \times \text{volume of urine time period kg body weight}} = \frac{(X)_u}{(X)_p} \times \frac{(Cr)_p}{(Cr)_u} \times 100 = FEX$$

u = urinary concentration p = plasma concentration

PRACTICAL ISSUES TO BE CONSIDERED

1. Freely-voided urine samples are preferred - often not possible to obtain these. a) Use a urine collection harness (Harris 1988b)

   b) First thing in the morning, take horse out of the stable (if stabled) and walk slowly around at the horse's pace whilst stable is mucked out so returns to clean straw or shavings, etc.

   c) In females only, catheterized samples may be acceptable, but the fillies/ mares should first be bled and then given a short brisk trot before urine sample is collected. Post-exercise samples are not reliable.

2. No significant differences in the FE values for Na, K, PO^4 or Cl results have been found with samples collected at the start, middle or end of a urine stream. Differences in calcium content have however been found and it is adviseable to collect all of a voided urine sample.

3. There may be a delay in the analysis of samples at a laboratory. Very little alteration in urinary or plasma concentration of Na, K or Cl occurs with storage at 18, 4 or -20 C. However, there are considerable changes in the Ca, PO^4 and Cr concentrations, particularly when samples are stored at 18 C although the extent of changes varies between samples. In urine, this may be linked to the pH and degree of bacterial contamination. Plasma and urine samples should therefore be transported in capped, sterile containers and although short term storage in the refrigerator may be adequate, longer storage should be at -20 C. Samples should ideally be analyzed as soon as possible for Ca, Cr and PO^4 i.e. within 4 days.

4. Samples should not be collected for the determination of base line electrolyte status during or soon after an episode of the equine rhabdomyolysis syndrome (ERS) because circulatory disturbances and increased plasma myoglobin concentrations may affect renal function and result in unrepresentative FE values.

5. Before analysis all urines should be checked and those with:

   a. pH of 6 or below

   b. positive for glucose

   c. more than 0.3g protein per litre

   d. positive for blood or myoglobin/haemoglobin should not be considered normal.

6. If a sample has a Cr concentration of < 9,000 mmol/L (AHT Laboratories, Newmarket) need to check that:

   a. no contamination of the sample has occurred

   b. excessive salt has not been given to cause polydipsea

   c. no signs of polydipsea/polyuria

   (It has been suggested that Cr may be significantly lowered when sugar beet pulp is fed.) Usually, if such a value is found, one needs to repeat the test. The test should not be interpreted as an indication of electrolyte status if the sample has a low urinary creatinine concentration. But, problems arise in young animals less than 18 months old which often have low urinary creatinine concentrations.

7. Urinary Ca determinations should be carried out using a flame atomic absorption spectrophotometer because colormetric methods used for serum/plasma have been shown to be unsuitable. Samples must be very well mixed.

8. Cannot use the FE test to monitor low phosphate intakes. (Raised % FE PO^4 values tend to represent a Ca:P imbalance.)

9. Decreased urinary Mg and Ca concentrations have been found shortly before and after feeding with maximum values 4-8 hours after feeding. (Myer, *et al*., 1989)

10. Watch out for low blood potassium values which will 'falsely' elevate the % FE values for K. These low levels seem to occur in animals rested for a period of time, around the time of hay ingestion, etc. Usually advisable to repeat before interpreting further. (Can use a more "acceptable" plasma level to provide an adjusted %FEK). High plasma values may occur with even slight haemolysis. *Collect blood sample pre-exercise/prefeeding ideally and remove plasma as soon as possible.

CALCIUM

It has been suggested that the precipitation of calcium as crystals or salts in the bladder means that urinary calcium concentrations may not reflect calcium status adequately because an unpredictable amount of this precipitate may be voided at any one time.

However, Meyer, *et al*., 1989 reported that a low calcium intake could be confirmed by analysis, although when the calcium intake was above requirement, the renal calcium excretion was not closely correlated with the calcium intake. Magnesium, which does not tend to precipitate out, may be used to give additional information on calcium status.

The anion-cation balance has been shown to affect calcium urinary excretion and may falsely affect the interpretation of the Fe Ca values.

PRACTICAL ADVICE

a. Do not interpret an FE test if the urinary pH is 6 or below.

b. High Ca/Mg excretion values are difficult to determine. If the diet is known and does not appear to be providing excessive Ca/Mg intakes, then anion-cation balance of the diet should be examined further.

c. Use the FE test more to detect low % FE Ca/Mg values rather than high values (low % FE Ca can be false due to sedimentation, etc.), but a low FE Ca with a concomitantly low % Fe Mg most probably indicates a Ca (and possible Mg) imbalance.

INTERPRETATION

Always have the dietary information available. The expected "reference" ranges for the % Fe values will vary with the diet.

There are diurnal variations in urinary electrolyte (and Cr) concentrations. 24 hour collections are more reliable (and have fairly consistent Cr excretion values) but not as practical. However although the single sample may not be accurate it may be sufficiently representative to enable certain metabolic abnormalitites to be detected.

Table 3.

Grain based[1]		*Typical compound cube and hay "balanced" diet reference range*[2]
	Ca	>7
	Mg	>15
0.02 - 1	Na	0.04 - 0.52
15 - 65	K	35 - 80
0.04 - 1.6	Cl	0.7 - 2.1
0 - 0.5	PO_4	0 - 0.2

[1] Traver, *et al.*, 1976 [2] Harris 1988, Harris and Snow 1991

USE IN THE EQUINE RHABDOMYOLYSIS SYNDROME (TYING-UP)

Animals without renal disease that have abnormal FE values whilst being fed a diet containing an adequate and balanced electrolyte content may have an individual absorption/utilization problem. Such abnormalities have been found in horses suffering from ERS. Restoration of the FE values to within the expected reference range for the type of diet fed may result in clinical improvement (Harris and Colles 1988, Harris and Snow 1991). Abnormal FE values in horses with rhabdomyolysis are complicated by the fact that many diets of horse are low or imbalanced with respect to their electrolyte and vitamin content. Ideally affected animals should be sampled while being fed their regular diet (on which they had suffered attacks) and then after a period on a diet balanced with respect to its electrolyte content. For practical and financial reasons, this may not be possible. A compromise therefore is to feed the animal a diet believed to provide an adequate and balanced diet for at least 2 weeks before collection of appropriate blood and urine samples. The appropriate supplementation could then be given and the level of supplementation altered accordingly following a monitoring. If an FE abnormality was not detected on this 'balanced diet', the animal could then be kept on the diet with the knowledge that the electrolyte intake would remain fairly constant and any further attacks would be unlikely to be related to electrolyte imbalances (as detected by the FE test). However because of the increased requirements of certain electrolytes with exercise, the test should be repeated when the horse is in full work on full feed.

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