Recent progress in the assessment of mineral requirements of goats

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Abstract

For a long time, mineral requirements of goats have been extrapolated from those of cattle and sheep. To date advances in goat nutritional research allow more specific mineral recommendations. Endogenous losses of calcium and phosphorus might be more related to dry matter intake than to the bodyweight. True absorption coefficient of P is probably higher for goats (70–75%) than for other ruminant species. Calcium and phosphorus requirements for pregnancy are higher because of the frequency of multiple foetuses. The requirements for growth are lower than for calves. Nevertheless, calcium and phosphorus content of goat milk (1.3 g Ca/l, and 0.9 g P/l, respectively) are very close to those of cow milk. A special attention must be given to sulphur according to fibre production needs. Several results indicate that goats are less sensitive to copper toxicity than sheep and cattle and can tolerate higher levels of Cu in their diets. Goats can also tolerate Mo levels 10 times higher than sheep. The goat sensitivity to iodine deficiency seems to be higher. Particular attention must be given to selenium and copper status of pregnant goats and/or new-born kids because of risk of white muscle disease or swayback.

Keywords: Goat; Mineral nutrition; Requirements

1. Introduction

For a long time, mineral requirements of goats have been considered as a halfway between those of cattle and sheep. During the 10 last years, advances in mineral nutrition of goats have occurred and allow more specific recommendations for this ruminant species for macro-elements and trace elements.

Before beginning, it should be stressed that nutritional requirements can be rather variable. The deficiency threshold value corresponds to the minimum requirement of a given nutrient. Intake levels below this value will result in pathological conditions. The apparent minimal requirement is higher than the deficiency threshold value. It represents an intake that avoids possible decreases in production levels during a given period; the length of the period under consideration is generally short. This intake level is often used in practice, but seems too restrictive as it does not take into account the mineral reserves. An intake level that is insufficient will not have any short term effects on animal production, its effects will be over the long term. The optimal requirement corresponds to an intake level that assures a zero balance in adult animals, and is sufficiently positive for growing animals. Finally, the recommended dietary allowance is even higher than

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the optimal level because it includes a safety margin, which takes into consideration the large inter-individual variations that exist.

The aim of the present paper is to review the recent goat mineral nutrition studies with the intention of proposing a more suitable mineral dietary recommendations for this species. Normally macro- and micro-elements are discussed separately, particularly as each employs different methodologies in order to determine the requirement levels.

2. Macro-element requirements

Macro-element requirements are evaluated by the factorial method. This method establishes the net physiological requirement levels for an animal (maintenance, growth, gestation and production). It also estimates the proportion of the intake that is actually available to meet these needs or true absorption coefficient (TAC).

2.1. Net physiological requirements

2.1.1. Maintenance requirement

The net physiological requirement for maintenance is often assimilated with the endogenous faecal and urinary losses (the latter are often negligible for Ca and P in ruminants). It is convenient to consider this aspect from a relative standpoint. The endogenous faecal loss of P actually corresponds to an irreducible fraction that may represent the actual net maintenance requirement and also an excretory component that permits the organism to eliminate the P absorbed in excess. This explains the quasi-linear relationship between the endogenous faecal loss and the level of P intake in sheep (Grace, 1981; Braithwaite, 1985; Scott et al., 1985, 1995; Ternouth, 1989). It is now well established that the maintenance requirement is more closely related to the quantity of dry matter intake (DMI) than to the body weight (BW) of the animals (Braithwaite, 1983; Field et al., 1985; Pfeffer, 1989; Ternouth, 1989).

The equation that predicts the P maintenance requirements ($P_M$) for sheep and cows ($P_M = (0.693 \cdot DMI \ kg/day - 0.06) \cdot 1.6$) for forage diets is initially adopted for goats (AFRC, 1991, 1997; FAG, 1994). An indirect approach based on 138 balance trials (Pfeffer, 1989) leads to a lower estimation of the $P_M$ in goat: $0.081 + 0.88 \ DMI$. This latter equation confirmed by Deitert and Pfeffer (1993) seems to be suitable for the P maintenance calculations in goats. This lower strict maintenance requirement of P for goats could be explained by a better P recycling through the saliva as it was shown for urea (Tisserand and Alrhamoun, 1998). This hypothesis could be supported by a higher P concentration in the saliva in goats than in other ruminant species (Kessler, 1981).

There is no recent work on maintenance requirements for the other macro-elements, the data retained for sheep should still be used for goats (AFRC, 1991, 1997; Kessler, 1991) calcium: 0.623 DMI + 0.228, magnesium: 3.5 mg/kg LW, potassium 50 mg/kg LW and sodium 15 mg/kg LW.

2.1.2. Growth requirement

Several investigations (Pfeffer and Keunecke, 1986; Pfeffer, 1989; Pfeffer et al., 1995) now allow specific recommendations for growing goats. The Ca and P accretion seems to be slightly lower than those in sheep. Through these experiments, a good relationship has been found between empty body weight (EBW) and the P content of empty body mass ($P_{EBM}$):

$$P_{EBM} = 0.44 + 6.89 \ \text{EBW}$$

this corresponds to 5.8 g of P/kg of LW gain, corresponding value for calcium was 9.4 g. Nevertheless, these values must be considered with care because of the wide range of variation according to the dietary level of P intake (Pfeffer et al., 1996). On the other hand, no difference was found according to the diet especially with milk fed kids up to 30 kg (Pfeffer and Rodehutscord, 1998). Values for other minerals may be assessed as 0.4 for Mg, 1.6 for Na and 2.4 for K (Kessler, 1991).

2.1.3. Net pregnancy requirement

Such requirement would correspond to the mineralisation of the foetus and the gravid uterus and primarily concern Ca and P. It must only be take into account during the last two months of gestation. This requirement mainly results from the number of foetuses. At birth, the averages of empty body
mineral composition are 11.5 Ca, 6.6 P, 0.3 Mg, 2.1 K and 1.7 Na (Lüdke, 1971; Pfeffer and Keunecke, 1986; Kessler, 1991; Pfeffer and Rodehutscord, 1998). According to the size of the litter, these values correspond to a net transfer from the goat to the kid(s) of more or less 40–90 g of Ca and 25–50 g of P.

2.1.4. Net lactation requirement

This requirement is much easier to determine than the ones previously discussed because it can be determined directly from the milk’s mineral composition, which can vary depending on stage of lactation (Table 1), breed or sanitary conditions (mastitis). The goat milk mineral composition during the middle of lactation of all breeds pooled has been reviewed recently (Guéguen, 1997); the values are given in Table 2.

2.2. True absorption

The true absorption coefficient or TAC (INRA, 1989) is the percentage of dietary intake truly absorbed. The intestinal absorption depends on the absorptive capacity of the intestine and also on the potential absorbability of the mineral in feed. TAC of P seems to be higher for goats than for cows or ewes; nevertheless, the value of 90% obtained by Koddebusch (1988) appears to be somewhat high, and only possibly obtained with deficient animals. The true absorption coefficient of P is probably between the value of 75% (Pfeffer, 1989) and 65% (Kessler, 1991). From our own observations (unpublished data) from 65 individual balance trials with lactating goats (BW 60 kg, milk yield 4.5 kg/day) the mean apparent absorption coefficient of P was 44.5%. From these data the theoretical calculated TAC (on the basis of endogenous loss according to Pfeffer, 1989 equation) was 70.7%. For the calculation of P requirements in goats a TAC of 70% can be retained.

Published TAC values of Ca for goats show a wide range of variation. The value of 30% is generally adopted (INRA, 1988; Kessler, 1991; FAG, 1994) except by AFRC, 1997 (55%). In the goat, the level of Ca intake (Maraval et al., 1984) markedly affects the efficiency of intestinal absorption. Our own data (unpublished) show an important depression of Ca absorption with high levels of Ca in the diet (Table 3). That underlines that the TAC value of 30% must only be used with normal calcium supply.

There are no published results on true absorption of magnesium in goats available. Apparent absorption studies show great variations. For example Kessler (1981) reported a range of 18–57%. With semi-synthetic diets we obtained quite high values of apparent absorption of Mg ranking from 41 to 57% with inorganic sources of Mg for in growing lamb (Meschy, 1998) as well as for lactating goats (unpublished). As demonstrated for cattle high potassium intake depresses Mg absorption in goats, but starch, not glucose or cellulose, supplementation fully counteracts the inhibitory effect of potassium on magnesium absorption (Schonewile et al., 1997). The TAC value of 20% derived from specific studies

| Table 1 |
| Effect of stage of the lactation upon Ca and P content (mean±SEM) of Saanen and Alpine breeds milk (unpublished data) |
| Stage of the lactation | n | Calcium (g/l) | Phosphorus (g/l) |
| Early | 28 | 1.40±0.04 | 1.05±0.02 |
| Middle | 27 | 1.26±0.04 | 0.95±0.03 |
| Late | 26 | 1.15±0.04 | 0.89±0.02 |

| Table 2 |
| Mean mineral composition of goat’s milk (Guéguen, 1997) |
| Macro elements | (g/l) | Trace elements | (mg/l) |
| Calcium | 1.26 | Zinc | 3.8 |
| Phosphorus | 0.97 | Iron | 0.46 |
| Potassium | 1.9 | Copper | 0.22 |
| Sodium | 0.38 | Manganese | 0.06 |
| Magnesium | 0.11 | Iodine | 0.07 |
| Chlorine | 1.1 | Selenium | 0.02 |

| Table 3 |
| Effect of Ca level of intake upon Ca availability in goats (mean±SEM, unpublished data) |
| n | Intake (% requirement) | AAC (%) | TACc (%) |
| Exp. 1 | 65 | 160 | 17.85±0.96 | 23.23±1.02 |
| Exp. 2 | 33 | 106 | 28.22±0.97 | 38.83±0.94 |

AAC, apparent absorption coefficient; TACc, true absorption coefficient calculated (from AFRC, 1991).
in goats proposed by Kessler (1991) and adopted by FAG (1994) seems to be adequate for Mg requirement calculations in goats.

TAC of K and Na has not been documented but the values of 90 and 80%, respectively, for goats as for other ruminants might be adequate (Guéguen et al., 1987).

### 3. Sulphur and trace-element requirements

For technical reasons, the factorial method is not generally used to determine either the sulphur or trace element requirements. A more global method such as the dose–response method is generally employed. This consists of evaluating the optimal concentration of a given component of the diet based on either global criteria (performances) or more specific ones as clinical signs of deficiency or enzymatic activities.

#### 3.1. Sulphur requirements

In ruminants, sulphur is mainly required to optimise rumen microbial activity (Stévani et al., 1992), but growth, lactation and fibre production also need specific sulphur supply. The optimal S diet concentrations (on a DM basis) reported in the literature are as follow: 2.2–2.5 g/kg (Durand and Komisarczuck, 1988) and 2.6 g/kg (Qi et al., 1992b) for microbial activity; 2.2 g/kg for growth (Qi et al., 1993); 2.6 g/kg for lactation and 2.7 g/kg for fibre production (Qi et al., 1992a, 1993). All these values are slightly higher than the requirements adopted for other ruminants (NRC, 1989).

#### 3.2. Trace mineral requirements

It is possible to define deficiency threshold values (the value above which the symptoms of a deficiency disappear) and a toxicity level also considered a ‘safety range’. Depending on the element in question, the range between these two values may be quite variable: for example, there is a factor of 100 between them for cobalt, while only a factor of 3–5 for copper and selenium.

The dietary recommendations for trace elements are values taken from somewhere within this range, including a safety margin to take individual differences into account. These values are given in the Table 4. Only elements that differ in goat nutrition will be discussed. Likewise, essentiality of a number of other trace elements (F, As, Li, Ni, V, Al, Br) has been demonstrated (studies of Anke, reported by Haenlein, 1998). This studies were conducted with very low levels of these elements which are often far from practical conditions, where natural diets and air and water contents allow generally sufficient supply.

#### Table 4

<table>
<thead>
<tr>
<th>Element</th>
<th>Recommended dietary level (mg/kg DM)</th>
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</thead>
<tbody>
<tr>
<td>Copper</td>
<td>8–10</td>
</tr>
<tr>
<td>Cobalt</td>
<td>0.1</td>
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<tr>
<td>Iodine</td>
<td>0.4–0.6</td>
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<tr>
<td>Manganese</td>
<td>40–50</td>
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<tr>
<td>Zinc</td>
<td>50</td>
</tr>
<tr>
<td>Selenium</td>
<td>0.1</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>0.1</td>
</tr>
</tbody>
</table>

As for other ruminants, the copper requirement of goats may be assessed at 8–10 mg per kg of DM of the diet (Kessler, 1991; AFRC, 1997). The goats, especially young animals seem to be less sensitive to copper toxicity than sheep are. This could be explained by a lower hepatic uptake by kids fed high Cu content diets (6–9 times less according to Zervas et al., 1989). On the other hand, hepatic storage of goats is ten times lower than in other ruminants (Anke and Szentmihalyi, 1986), which may lead to higher susceptibility of new-born kids for swayback or ataxia, especially in the case of multiple births.

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#### 3.2.2. Cobalt

The goats seem to be less sensitive to cobalt deficiency than other ruminants (Clark et al., 1987). In spite of this observation and because the Co toxicity level is quite high a 0.1 mg/kg DM value may be adopted for goats.

#### 3.2.3. Iodine

Iodine requirement of goats is higher than for other ruminants. Iodine levels considered as adequate
for dairy cow (0.3 mg/kg DM) diets if fed to goats were not sufficient to prevent goitre in kids (Lamand, 1981). According to Kessler (1991), the minimum recommended dietary level of I for goats is assessed at 0.4 mg/kg DM and must be increased up to 0.6 mg/kg DM for high yielding dairy goats.

### 3.2.4. Molybdenum

In ruminants, Mo excess is generally more documented than deficiency, particularly its effect on copper bioavailability. The goats are sensitive to Mo deficiency (growth depression, reproduction troubles) and the minimum dietary level is about 0.1 mg/kg DM (Kessler, 1991). On the other hand, the goats can tolerate much higher levels of Mo without showing toxicity symptoms in contrast to cattle and sheep (Falke and Anke, 1987).

### 4. Conclusion

With the research data available now, it becomes possible to have a more specific approach in mineral nutrition of goats at least for Ca, P, S and several trace elements. Nevertheless, more research is needed to assess in goats some aspects still extrapolated from cattle and especially from sheep. Calcium and phosphorus bone mobilisation at the onset of lactation is a good example.

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