ABSTRACT

This paper reviews the major (Calcium, Phosphorus, Potassium, Sodium, Chlorine, Sulphur, Magnesium) and the trace elements (Iron, Copper, Cobalt, Iodine, Zinc, Molybdenum, Selenium) that play an essential role in animal metabolism. For each one the authors indicate not only the function, but also the more recent advances in terms of daily requirements for dairy sheep.

Key words: Major elements, Trace elements, Dairy sheep.

RIASSUNTO

Il lavoro passa in rassegna i macro (Calcio, Fosforo, Potassio, Sodio, Cloro, Solfuro, Magnesio) e microelementi minerali (Ferro, Rame, Cobalto, Iodo, Manganese, Zinco, Molibdano, Selenio) che svolgono un ruolo essenziale nel metabolismo animale. Per ciascuno di essi gli autori indicano non solo la funzione svolta, ma anche le più recenti acquisizioni in materia di fabbisogni giornalieri per gli ovini da latte.

Parole chiave: Macroelementi, Microelementi, Ovini da latte.

Introduction

Many minerals make up the body composition of animals; they play many fundamental roles and many of them are essential to the normal vital functions of animals. The roles played by each inorganic component are not always completely known and in some cases it is not clear whether or not they are really essential. In fact, the privation of some minerals (even when found in each animal organism) does not result in any effect (Underwood, 1977). Depending on the amount of minerals found in the organism they are classified as either major elements (or macrominerals) or trace elements (or microminerals). In the animal body, major minerals constitute more than 100 mg/kg (Ca, P, Mg, Na, K, Cl, S), while microminerals or trace elements (Fe, Zn, Cu, Mb, Se, I, Mn, F, Co, Cr, Al, As, Si, V, Ni, Sn) are present in lower amounts (Underwood, 1977). The average content
of some minerals in the animal body is reported in Table 1 (ARC, 1980; Grace, 1983; Underwood, 1977) and that of ash and the main mineral elements in sheep milk is shown in Table 2 (NRC, 1985). Nearly 40 minerals play an essential role in the metabolic processes of animals; their functions are numerous and heterogeneous. They participate in the regulation of the osmotic pressure and in the acid-base balance of liquids within the body.

Minerals play fundamental roles in the permeability and polarisation of the cellular membrane and determine the transmission of the nervous impulses and the contraction of muscles. In many cases minerals are essential constituents of co-enzymes, factors or cofactors participating in chemical reactions in the organism. Moreover, some minerals have plastic functions in several organs and tissues: first of all, they are constituents of bones, representing half of their weight. The deficiency of many trace mineral elements can be obtained only under experimental conditions because they are required in such minute quantities, and are so widely distributed in foods, that deficiencies are unlikely or even impossible under normal practical conditions (Suttle, 1983c; Underwood, 1977). Moreover, some elements (copper, selenium, molybdenum, fluorine, vanadium, arsenic), although essential, when ingested in excessive quantities can become toxic (Table 3). Therefore, the supplementation of these elements must be carefully evaluated, taking into account the real food allowances (NRC, 1980). For many aspects the mineral requirements of ovines in different physiological situations are not completely clear as respects many elements (ARC, 1980; INRA, 1978, 1988; NRC, 1975, 1985). Studies on mineral requirements of sheep often refer to breeds which are specialised in meat production. Requirements may be different in dairy sheep, especially because of their long milking period. In addition, the con-

| Table 1. | Major elements and nutritionally important trace elements and their approximate concentration in the animal body. |
|----------|---------------------------------------------------------------------------------------------------------------|
| **Macrominerals** | **Microminerals** |
| Element (g/kg): | Element (mg/kg): |
| Calcium | 15 | Iron | 20-80 |
| Phosphorus | 10 | Zinc | 10-50 |
| Potassium | 2 | Copper | 1-5 |
| Sodium | 1.6 | Molybdenum | 1-4 |
| Chlorine | 1.1 | Selenium | 1-2 |
| Sulphur | 1.5 | Iodine | 0.3-0.6 |
| Magnesium | 0.4 | Manganese | 0.2-0.5 |
| Cobalt | 0.02-0.1 |

| Table 2. | Average content of ash and of the main minerals in sheep milk. |
|----------|------------------------------------------------------------------|
| Total ash g/100g | 0.85 |
| Macrominerals (g/100g): |  |
| Sodium | 0.04 |
| Potassium | 0.15 |
| Chlorine | 0.075 |
| Calcium | 0.20 |
| Phosphorus | 0.15 |
| Sulphur | 0.05 |
| Magnesium | 0.016 |
| Microminerals (mg/l): |  |
| Iron | 0.60 - 0.70 |
| Copper | 0.05 - 0.15 |
| Manganese | 0.06 |
| Aluminium | 1.70 |
| Zinc | 2.00 - 3.00 |

| Table 3. | Micromineral requirements of sheep and maximum tolerable levels in the diet. |
|----------|------------------------------------------------------------------|
| Element | Requirement (mg/kg DM) | Maximum tolerable level (mg/kg DM) |
| Iodine | 0.10-0.80 | 50 |
| Iron | 30-50 | 500 |
| Copper | 7-11 | 25 |
| Molybdenum | 0.5 | 10 |
| Cobalt | 0.1-0.2 | 10 |
| Manganese | 20-40 | 1000 |
| Zinc | 20-33 | 750 |
| Selenium | 0.1-0.2 | 2 |
| Fluorine | - | 60-150 |
tent of each mineral in milk can change as the lactation advances (Braithwaite, 1983a, 1983b). The range of macromineral requirements (mg/kg DM of diet), except for chlorine (which is always associated with sodium), is reported in Table 4 (NRC, 1985).

Table 4. Range of macromineral requirements in sheep.

| Element       | Requirement (mg/kg DM of diet) |
|---------------|--------------------------------|
| Sodium        | 0.09-0.18                      |
| Calcium       | 0.20-0.82                      |
| Phosphorus    | 0.16-0.38                      |
| Magnesium     | 0.12-0.18                      |
| Potassium     | 0.50-0.80                      |
| Sulphur       | 0.14-0.26                      |

Major elements

Calcium

Calcium is the most abundant mineral element in the animal body and it is fundamental for the activity of many enzyme systems, coagulation of blood, transmission of nerve impulses, contraction of muscles, flocculation of casein in the stomach and many others (ARC, 1980; INRA, 1978; 1988; NRC, 1975; 1985). About 99% of the total body calcium is localised in the skeleton and teeth as basic phosphate, $3\text{Ca}_2(\text{PO}_4)_2\cdot\text{Ca(OH)}_2$ in association with magnesium salts. Bone ash contains approximately 36% calcium, 17% phosphorus and 10% magnesium. Calcium (together with phosphorus) in bones is in a constant state of flux and is available to offset any deficiency due to the lack of intake and/or an increase in requirements (e.g. during some phases of the lactation). The turnover of calcium and phosphorus in bones is under the control of calcitonin and parathormone (Farningham, 1988). The absorption of calcium in the intestine increases with the requirements of the animals and when the content of the element decreases in the diet (Braithwaite, 1982). At maintenance level in adult animals the absorption of calcium is around 40%; in pregnant animals it is about 50% and it reaches 60% in lactating ewes and in growing lambs. The optimal calcium/phosphorus ratio is 1:1 or 2:1, but larger ratios (up to 7:1) do not determine any problems. The content of calcium in ewe milk is 0.18-0.20% on average (Table 2). In milk calcium and inorganic phosphate are present in excess of their solubility and as a result of their interactions with casein - are not precipitated as calcium phosphate. Calcium phosphate in casein micelles, which is associated with casein, is called colloidal calcium phosphate or micellar calcium phosphate. Casein micelles are the carriers of calcium phosphate and colloidal calcium phosphate plays an important role in maintaining the structure of casein micelles (Takayoshi, 1992). The allowance of calcium can vary depending on the category of animal and the physiologic condition; with respect to the maintenance phase, during the flushing period the allowance is higher and increases slightly during the first 15 weeks of gestation (Table 5). In the subsequent period of gestation the requirements of the element increase (Braithwaite, 1983a) depending on the distance from the delivery and the estimable litter weight at lambing (Table 6). The requirements of calcium for milk production increase (Braithwaite, 1983a; INRA, 1988; NRC, 1985) as lactation advances and they are in rela-
Table 6. Daily requirements of Ca and P in late pregnancy according to the ewes live weight and to the litter weight.

| Ewes live weight (kg) | Litter weight (kg) | Ca (g) | P (g) |
|----------------------|--------------------|--------|-------|
| **6-5 weeks before lambing** | | | |
| 55  | 4  | 5.7  | 3.2  |
| 55  | 5  | 6.2  | 3.3  |
| 55  | 7  | 7.2  | 3.6  |
| 60  | 5  | 6.4  | 3.6  |
| 60  | 6  | 6.9  | 3.7  |
| 60  | 7  | 7.4  | 3.8  |
| 60  | 8  | 7.9  | 3.9  |
| 70  | 5  | 7.0  | 4.1  |
| 70  | 7  | 8.0  | 4.4  |
| 70  | 9  | 9.0  | 4.7  |
| 70  | 11 | 10.0 | 4.9  |
| **4-3 weeks before lambing** | | | |
| 55  | 4  | 6.9  | 3.5  |
| 55  | 5  | 7.7  | 3.7  |
| 55  | 7  | 9.1  | 4.1  |
| 60  | 5  | 7.9  | 4.0  |
| 60  | 6  | 8.6  | 4.2  |
| 60  | 7  | 9.3  | 4.4  |
| 60  | 8  | 10.0 | 4.6  |
| 70  | 5  | 8.5  | 4.5  |
| 70  | 7  | 10.1 | 4.9  |
| 70  | 9  | 11.7 | 5.3  |
| 70  | 11 | 13.3 | 5.7  |
| **2-1 weeks before lambing** | | | |
| 55  | 4  | 9.0  | 4.0  |
| 55  | 5  | 10.3 | 4.4  |
| 55  | 7  | 13.0 | 5.0  |
| 60  | 5  | 10.5 | 4.6  |
| 60  | 6  | 11.8 | 4.9  |
| 60  | 7  | 13.2 | 5.3  |
| 60  | 8  | 14.5 | 5.7  |
| 70  | 5  | 11.1 | 5.2  |
| 70  | 7  | 13.8 | 5.8  |
| 70  | 9  | 16.5 | 6.5  |
| 70  | 11 | 19.1 | 7.1  |
tion to the weight gain of lambs as well as the fat
and protein content of milk (Tables 7 and 8). The
calcium requirements of growing replacement
lambs in relation to the main factors of variation
(live weight, weight gain, gestation, lactation, and
sex) are reported in the Tables 9-11
(Braithwaite,1983a, 1983b; INRA, 1988; NRC,
1985; Pond, 1983).

Phosphorus

This mineral is of vital importance in the
energy metabolism; in fact, it participates in the
formation of sugar-phosphates and adenosine di-
and tri- phosphates. It is a component of phospho-
proteins, nucleic acids and phospholipids. The
content of phosphorus in the animal body is lower
than that of calcium (Table 1). The relationship
between phosphorus and calcium in the inorganic
matter of bone tissue have been already
described. About 80% of the total phosphorus of
the organism is localised in the skeleton along
with calcium. In many feeds, especially in cereal
grains, the element is in the form of undigestible
phytates. In ruminants, because of the presence of
bacterial phytase in the rumen, this form of phos-
phorus can be efficiently utilised (ARC, 1980;
Field et al., 1982; Field, 1983; INRA, 1978, 1988;
NRC, 1975, 1985; Suttle, 1983b). The content of
this element in ewe milk is on average 0.14-0.15%
(Table 2). In milk this element is in part present
as calcium phosphate in casein micelles, as
described for calcium. The adsorption of phospho-
rus in the intestine is 60% in adult animals at
maintenance level and in the first 15 weeks of
gestation, 70% in the subsequent period of gesta-
tion, in lactating ewes and in growing animals
(NRC, 1985). The phosphorus requirements in the
different categories of animals (Tables 5-11)
change together with those of calcium (ARC, 1980;
Braithwaite,1984a, 1984b; Field et al., 1982; Field,
1983; INRA, 1978, 1988; NRC, 1975, 1985; Suttle,
1983b).

Potassium

Potassium is fundamental (along with sodium,
chlorine and bicarbonate ions) in the osmotic reg-
ulation of body fluids and in the acid-base balance
in the organism. It is the main intracellular cation
and plays a role of primary importance in nerve
and muscle excitability (Campbell et al.,1965;
INRA, 1988; NRC, 1985; Suttle, 1983b). Vegetable
foods always contain large amounts of potassium,
consequently potassium deficiency is rare in her-
ivores (Calhoun et al. 1983). The content of potas-
sium in ewe milk (NRC, 1985) is on average 0.15%
(Table 2).

Sodium

Sodium is the main extra-cellular cation; most
of it is present in the soft tissues, body fluids and
haematic plasma. It participates in the mainte-
nance the acid-base balance and in osmotic regu-
lation. It plays a fundamental role in the absorp-
tion of sugars and amino-acids from the intestine
and in the transmission of nerve impulses (ARC,
1980; INRA, 1978, 1988; NRC, 1975, 1985; Suttle,
1983b). Much of this element is ingested in the
form of sodium chloride. This latter is commonly
added to the concentrates (1%), but it is possible to
offer it in blocks left available for free choice lick-
ing. The content of sodium in ewe milk is on aver-
age 0.04% (Table 2). This value can increase
together with chlorine in the case of mastitis.

Chlorine

In associations with sodium and potassium,
chlorine is essential in acid-base balance and
osmotic regulation. Chlorine is fundamental in
gastric secretion, where it is in the form of
hydrochloric acid and as chloride salts (ARC, 1980;
INRA, 1978, 1988; NRC, 1975, 1985; Suttle,
1983b). The content of the element in ewe milk
(NRC, 1985) is on average 0.075% (Table 2). The
supplementation of chlorine is associated with
that of sodium.

Sulphur

In the animal organism most of it is in the sul-
phur-containing amino acids (cysteine and methio-
nine), but it is also present in the vitamins thi-
amin and biotin, in insulin and coenzyme A (ARC,
1980; INRA, 1978, 1988; NRC, 1975, 1985; Suttle,
1983b). The inorganic form of sulphur is present in
the animal body only in a small amount, although
sulphates are found in limited quantities in the
blood. Wool is rich in sulphur-containing amino
acids (particularly in cysteine) and the sulphur content reaches about 4%. The content of sulphur in ewe milk is on average 0.05% (Table 2). When the diet for ruminant animals contains high levels of non protein nitrogen, the addition of sulphur to the rations may be beneficial (Bray et al., 1969). Aiming to avoid, in these cases, the limiting factor for the ruminal synthesis of cystine, cysteine and methionine, the addition of sulphate to the ration is opportune (1.5-2 g/kg D.M. elemental sulphur or sodium sulphate).

Magnesium
About 60-70% of the total magnesium of the organism is localised in the skeleton, where it is closely associated with calcium and phosphorus; the remainder is found in the soft tissues and body fluids. It is fundamental for many enzyme systems and is the most common enzyme activator. It plays an important role in activating phosphate transferases, decarboxylases and acyl transferases. Moreover, it is essential for many functions: transmission of nerve impulse, contraction of muscles, synthesis of protein, fat and nucleic acids, utilization of glucose, trans-methylation. Magnesium is a co-factor in many reactions and participates as a moderator in the neuro-muscular excitation. In adult animals only a very small part (2%) of magnesium can be mobilised from bone; therefore a dietary deficiency of magnesium cannot be countered by mobilisation from bone reserves (Chicco et al, 1973b). The suggested minimum magnesium requirements are 0.12, 0.15 and 0.18% DM for growing lambs, for ewes in late pregnancy, and for ewes in early lactation, respectively (NRC, 1975, 1985; INRA, 1988). The administration of magnesium oxide (about 7 g head/d in the concentrate) can prevent the risk of hypomagnesaemic tetany in lactating ewes. (Chicco et al., 1973a; Amos et al., 1975; NRC, 1985). The content of magnesium in ewe milk is on average 0.016% (Table 2).

Trace elements
Iron
Most iron is combined with proteins; it participates in the composition of haemoglobin, myoglobin, cytochromes, catalases, peroxidases. In the haematic plasma it is carried as a complex with transferrin. A form of storage of iron is represented by ferritin, a protein that carries up to 20% of the element and is localised mainly in the spleen, liver, kidney, bone marrow and intestine walls. Haemosiderin is a similar storage compound containing up to 30-35% of the element. About 65-70% of iron in the animal body is combined with haemoglobin and myoglobin (Underwood, 1977). Most of feeds for ruminants are good sources of iron and its deficiency is not common in ruminants under normal conditions (INRA, 1978, 1988; NRC, 1985). Milk has a rather poor content of this element (Table 2), but newborn animals have reserves which cover their requirements until they are able to utilise solid feeds (Lawlor et al. 1965).

Copper
Copper is essential for the synthesis of haemoglobin; it is present in some other plasma proteins that are involved in the mobilisation and transfer of iron (ceruloplasmin). A deficiency of copper, therefore, reduces the adsorption of iron. Copper is a component of some other proteins in blood such as erythrocuprein, which plays a role in oxygen metabolism in erythrocytes. The element is involved in several enzyme systems, in the synthesis of the elastin, collagen and myelin sheath of the nerve fibres. It is also a component of cytochrome oxidase. Copper is important for the maintenance of the integrity and for the normal development of the central nervous system (Underwood, 1977). It is involved in the synthesis of cutaneous pigments and it is important for crimp, tensile strength, elasticity and affinity for dyes of wool (NRC, 1985). The adsorption of copper is limited when the diet contains high levels of molybdenum and in the presence of sulphur (Suttle, 1983a). In this case a chain reaction leads to the formation of insoluble copper thiomolybdate (CuMoS4) limiting the availability of dietary copper for absorption (Wiener, 1979). The content of copper in ewe milk (Table 2) is on average 0.05-0.15 mg/l (NRC, 1985). A prolonged ingestion of copper exceeding nutritional requirements (5-7 ppm DM) leads to an accumulation of the element in the tissues, especially in the liver. Chronic cop-
per poisoning is, therefore, rather frequent in ovines (Buck et al., 1969; NRC, 1980) and occurs when the diet contains 15-20 ppm DM of the element and low levels of molybdenum even under natural conditions because the maximum tolerable level is very low (Table 3).

**Cobalt**
Cobalt is utilised by rumen microorganisms for the synthesis of vitamin B12 of which cobalt is an essential component (Underwood, 1977). Owing to body reserves of vitamin B12 in the liver and kidneys, symptoms of cobalt deficiency may appear after some months from the beginning of the deficiency. Vitamin B12 is involved in the metabolism of propionic acid into succinic acid even at the ruminal level; therefore, the rumen microorganisms need cobalt. In particular, vitamin B12 is necessary for the conversion of methylmalonyl coenzyme A into succinyl coenzyme A. Moreover, cobalt seems to have other functions in the animal body as an activating ion in some enzyme reactions. The normal requirements (Table 1) in ruminants are covered when the diet contains 0.1-0.2 ppm DM of the element (INRA, 1978, 1988; NRC, 1985).

**Iodine**
A very small amount of iodine is present in the animal body and most of it (70-80%) is localised in the thyroid gland (Underwood, 1977). The major role of iodine is supposed to be the contribution to the synthesis of thyroid hormones (triiodothyronine and tetraiodothyronine). The normal requirements of iodine in ruminants are covered when the diet contains 0.1-0.2 ppm DM of the element (INRA, 1978, 1988; NRC, 1985).

**Manganese**
The content of manganese in the animal body is extremely limited; it is more concentrated in the bones, liver, kidneys, pancreas and pituitary gland. It is an important enzyme activator (phosphate transferases, arginases and decarboxylases). Manganese participates in the production of mucopolysaccharides and therefore in the formation of several connective tissues, particularly the bone. It is required for coordination of movements and to keep balance, preventing ataxia in lambs. It is necessary for the normal functionality of the reproductive apparatus in both the male and female (Underwood, 1977). The manganese (Table 3) requirement of ruminants is 40-50 ppm DM of the ration with a good tolerance limit (INRA, 1978, 1988; NRC, 1980, 1985). The requirements can increase when the levels of calcium and phosphorus in the diet are high (NRC, 1985). The content of manganese in ewe milk (NRC, 1985) is on average 0.06 mg/l (Table 2).

**Zinc**
Zinc has the tendency to accumulate in bone tissue rather than in the liver (as many other trace elements), but it is found in every tissue and reaches rather high levels in skin, hair and wool. Zinc plays a role in the formation of several enzymes: carbonic anhydrase, thymidine kinase, alkaline phosphatase, lactate dehydrogenase and pancreatic carboxypeptidase (Underwood, 1977). The element is an activator of several enzyme systems and enters in the composition of insulin. Zinc requirements (Table 3) are 20-33 ppm DM of the ration (Apgar et al, 1979; Pond, 1983; Suttle, 1983b).

**Selenium**
In the 1950s it was demonstrated that most ovine myopathies can be prevented by adding selenium or vitamin E to the diet (Allaway et al., 1966; Muth, 1970). The element is a component of glutathione peroxidase, which catalyses the removal of hydrogen peroxide (Underwood, 1977). Molybdenum deficiency is not observed in animals under normal feeding conditions (Ellis et al. 1958; Suttle, 1983c).

**Molybdenum**
Molybdenum is a component of several fundamental enzymes in animals: xanthine oxidase, aldehyde oxidase and sulphite oxidase (Underwood, 1977). Molybdenum deficiency is not observed in animals under normal feeding conditions (Ellis et al. 1958; Suttle, 1983c). Selenium requirements (Table 3) are 0.1-0.2 ppm DM of diet (INRA, 1978, 1988; NRC, 1983, 1985).
Aluminium
It is an element that is present in ewe milk (NRC, 1985) on average 1.70 mg/l (Table 2). The role of aluminium in the animal organism, like that of some other trace elements, is not completely clear and its deficiency is not observed in animals under normal feeding conditions.

Conclusions
Nearly 40 minerals, classified as either major or trace elements, are essential to the normal vital functions of animals, performing numerous and heterogeneous functions. However, the deficiency of many mineral trace elements can be

| Daily requirements of Ca and P in milking sheep in relation to the daily gain of lambs, to the production of milk and to the distance from lambing. |
|-----------------|------------|------------|------------|------------|------------|
| Daily gain of lambs (g) | 150 | 250 | 350 | 450 | 550 |
| Up to 3 weeks after lambing: |
| Milk production (kg/d) | 0.90 | 1.40 | 1.90 | 2.60 | 3.00 |
| Ca (g) | 5.4 | 8.4 | 11.4 | 15.6 | 18.0 |
| P | 2.3 | 3.5 | 4.8 | 6.5 | 7.5 |
| 4 to 6 weeks after lambing: |
| Milk production (kg/d) | 0.75 | 1.15 | 1.60 | 2.25 | 2.60 |
| Ca (g) | 4.5 | 6.9 | 9.6 | 13.5 | 15.6 |
| P | 1.9 | 2.9 | 4.0 | 5.6 | 6.5 |
| 7 to 10 weeks after lambing: |
| Milk production (kg/d) | 0.50 | 0.8 | 1.05 | 1.45 | 1.65 |
| Ca (g) | 3.0 | 4.8 | 6.3 | 8.7 | 9.9 |
| P | 1.3 | 2.0 | 2.6 | 3.6 | 4.1 |
| 11 to 14 weeks after lambing: |
| Milk production (kg/d) | 0.30 | 0.40 | 0.60 | 0.80 | 0.90 |
| Ca (g) | 1.8 | 2.4 | 3.6 | 4.8 | 4.8 |
| P | 0.8 | 1.0 | 1.5 | 2.0 | 2.3 |
### Table 8. Requirements of Ca and P for milk production of ewes in relation to the stage of lactation and to the content of fat and of protein in milk.

| Stage of lactation (months) | Fat content (g/l) | Protein content (g/l) | Ca (g/kg of milk) | P (g/kg of milk) |
|-----------------------------|-------------------|-----------------------|-------------------|-----------------|
| 1-4                         | 58-75             | 49-60                 | 6.4               | 2.5             |
| 5-6                         | 80-90             | 62                    | 7.0               | 2.8             |

### Table 9. Daily requirements of Ca and P in ewe lambs in relation to the live weight, daily weight variation, period of gestation, and first 6-8 weeks of lactation with single lamb and twins suckling and weaning at 8 weeks.

| Live weight (kg) | Daily weight variation (g) | Ca (g) | P (g) |
|------------------|----------------------------|--------|-------|
| Maintenance beginning gestation period |                         |        |       |
| 30               |                            | 3.5    | 2.2   |
| 40               |                            | 4.4    | 2.5   |
| First 15 weeks of gestation – non lactating |                  |        |       |
| 40               | 160                        | 5.5    | 3.0   |
| 50               | 135                        | 5.2    | 3.1   |
| 60               | 135                        | 5.5    | 3.4   |
| Last 4 weeks of gestation (100-120% lambing rate prevision) | | | |
| 40               | 180                        | 6.4    | 3.1   |
| 50               | 160                        | 6.3    | 3.4   |
| 60               | 160                        | 6.6    | 3.8   |
| Last 4 weeks of gestation (130-175% lambing rate prevision) | | | |
| 40               | 225                        | 7.4    | 3.5   |
| 50               | 225                        | 7.8    | 3.8   |
| 60               | 225                        | 8.1    | 4.3   |
| First 6-8 weeks of lactation |                  |        |       |
| suckling single lamb |                      |        |       |
| 40               | -50                        | 6.0    | 4.3   |
| 50               | -50                        | 6.5    | 4.7   |
| 60               | -50                        | 6.8    | 5.1   |
| First 6-8 weeks of lactation |                  |        |       |
| suckling twins |                      |        |       |
| 40               | -100                       | 8.4    | 5.6   |
| 50               | -100                       | 8.7    | 6.0   |
| 60               | -100                       | 9.0    | 6.4   |
Table 10. Daily requirements of Ca and P in growing male and female replacement lambs in relation to the live weight and daily gain.

| Live weight (kg) | Daily gain (g) | Ca (g) | P (g) |
|-----------------|----------------|--------|-------|
| 10              | 200            | 4.0    | 1.9   |
| 10              | 250            | 4.9    | 2.2   |
| 15              | 150            | 4.2    | 1.7   |
| 15              | 200            | 5.3    | 2.1   |
| 15              | 250            | 6.4    | 2.5   |
| 15              | 300            | 7.5    | 2.9   |
| 20              | 150            | 4.6    | 1.9   |
| 20              | 200            | 5.7    | 2.3   |
| 20              | 250            | 6.8    | 2.7   |
| 20              | 300            | 8.0    | 3.0   |
| 25              | 150            | 5.2    | 2.2   |
| 25              | 200            | 6.4    | 2.6   |
| 25              | 250            | 7.6    | 3.0   |
| 25              | 300            | 8.9    | 3.3   |
| 25              | 350            | 10.3   | 3.7   |
| 30              | 150            | 5.8    | 2.4   |
| 30              | 200            | 7.1    | 2.8   |
| 30              | 250            | 8.5    | 3.2   |
| 30              | 300            | 9.7    | 3.6   |
| 30              | 350            | 11.1   | 4.0   |
| 30              | 400            | 12.6   | 4.4   |
| 35              | 150            | 6.5    | 2.8   |
| 35              | 200            | 8.0    | 3.2   |
| 35              | 250            | 9.5    | 3.6   |
| 35              | 300            | 10.9   | 4.0   |
| 35              | 350            | 12.4   | 4.4   |
| 35              | 400            | 13.9   | 4.8   |
| 35              | 450            | 15.4   | 5.2   |
| 40              | 200            | 9.0    | 3.5   |
| 40              | 250            | 10.5   | 3.9   |
| 40              | 300            | 12.0   | 4.4   |
| 40              | 350            | 13.6   | 4.8   |
| 40              | 400            | 15.3   | 5.2   |
| 40              | 450            | 16.8   | 5.6   |
obtained only under experimental conditions, because these minerals are required in minute quantities and are widely distributed in foods. Moreover, some elements, although essential, can become toxic when ingested in excessive quantities. The mineral requirements of ovinæ in different physiological situations are not always completely clear. In fact, studies regarding mineral requirements of sheep very often refer to breeds specialised in meat production. In dairy sheep, however, these requirements can be different, especially during the milking period, which is much longer in dairy sheep. Moreover, the content of minerals in milk can change as the lactation advances.

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**Table 11.** Daily requirements of Ca and P in growing male and female replacement lambs in relation to the live weight, daily gain and sex.

| Live weight (kg) | Daily gain (g) | Ca (g) | P (g) |
|-----------------|---------------|-------|------|
| Female replacement lambs: | | | |
| 30 | 227 | 6.4 | 2.6 |
| 40 | 182 | 5.9 | 2.6 |
| 50 | 120 | 4.8 | 2.4 |
| Male replacement lambs: | | | |
| 40 | 330 | 7.8 | 3.7 |
| 60 | 320 | 8.4 | 4.2 |
| 80 | 290 | 8.5 | 4.6 |
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